Where is the radar data?

Groningen monastery - Spring 2018

Diego Domenzain

Long story short

In order to find a velocity model from the observed radagrams, first the common offset gathers were analyzed, then a section of seemingly flat subsurface layers was isolated (near $25m$), and then the shot gather near this region was further analyzed.

Raw data is assumed time corrected from the radar system and dewowed.

Common offset gathers

The radar system source was a $250\ MHz$ Ricker wavelet which when coupled to the ground gives a signal of roughly $(0.07, 0.26)\,GHz$.

The processing workflow for the COG's is,

1. bandpass the data in the time-frequency interval $(0.26, 0.46)\,GHz$, (which is *not* supposed to be entirely from the radar system),
2. low-bandpass the data in the space-frequency domain, (this "un-sharpens" the image and stacks coherent lateral events),
3. normalize data.

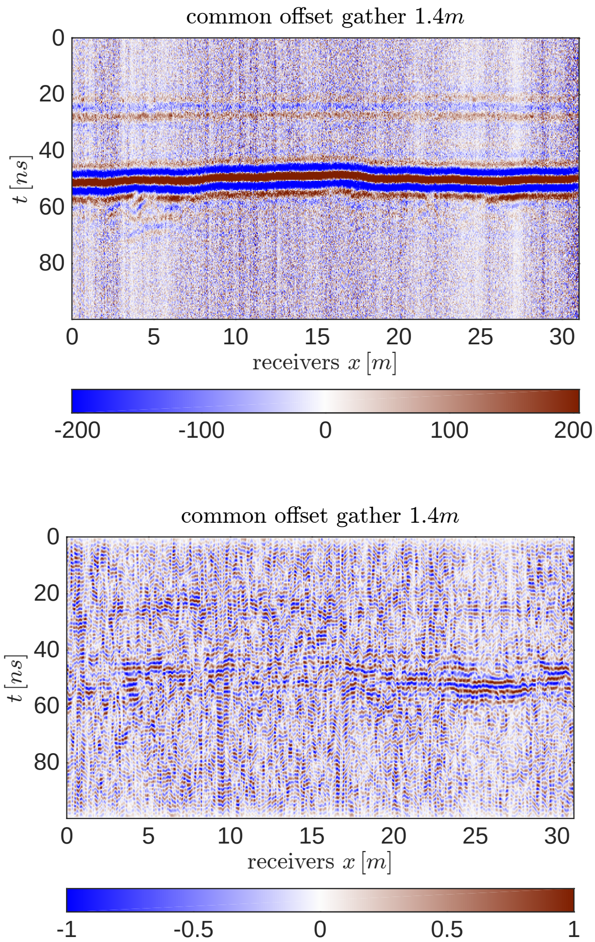

Figure 1: $1.4m$ common offset gather before and after processing. The radar system source was a $250\ MHz$ Ricker wavelet.

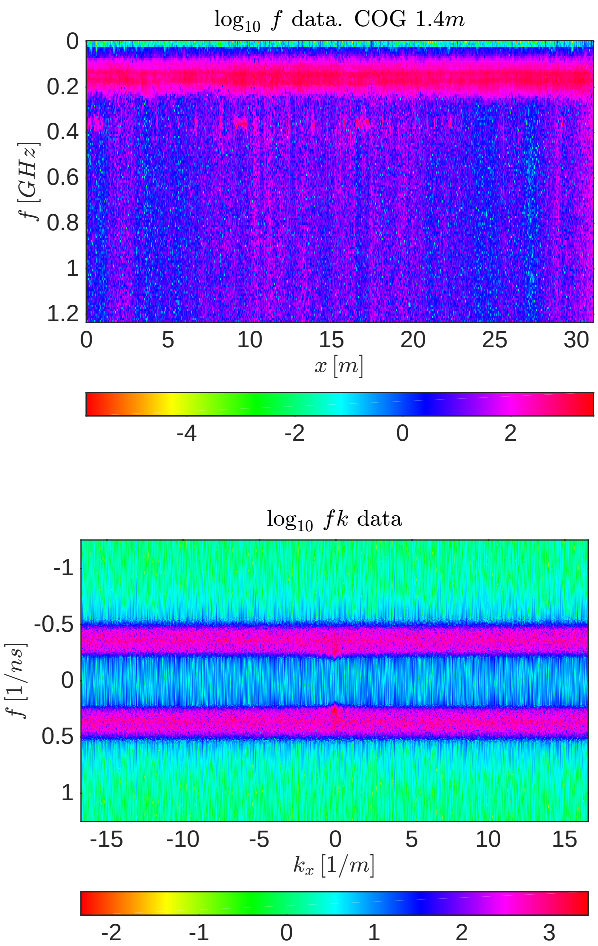

Figure 2: $1.4m$ common offset gather **top:** power spectra and **bottom:** fk domain after bandpass $(0.26, 0.46)\,GHz$.

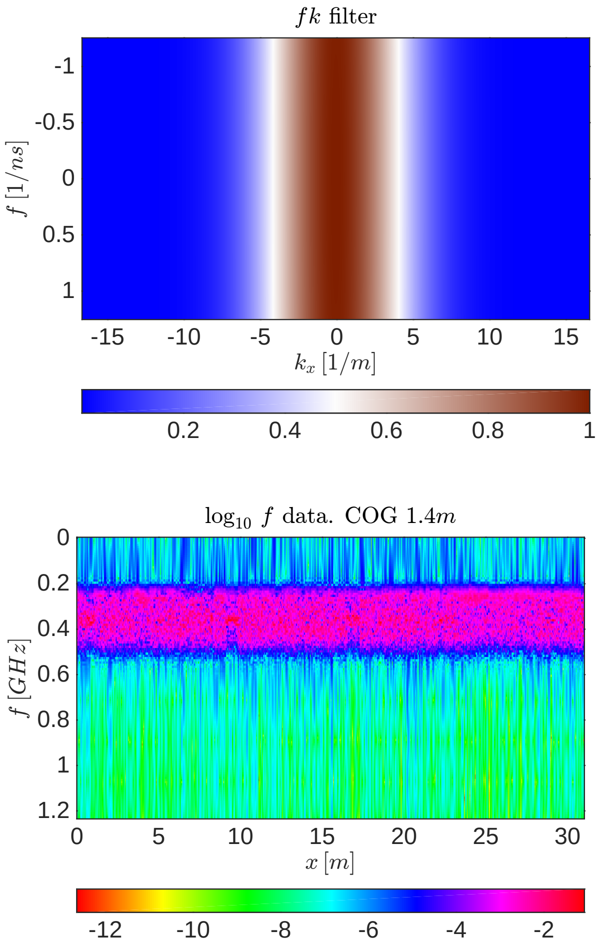

Figure 3: $1.4m$ common offset gather **top:** fk filter used and **bottom:** power spectra after fk filtering and amplitude normalization.

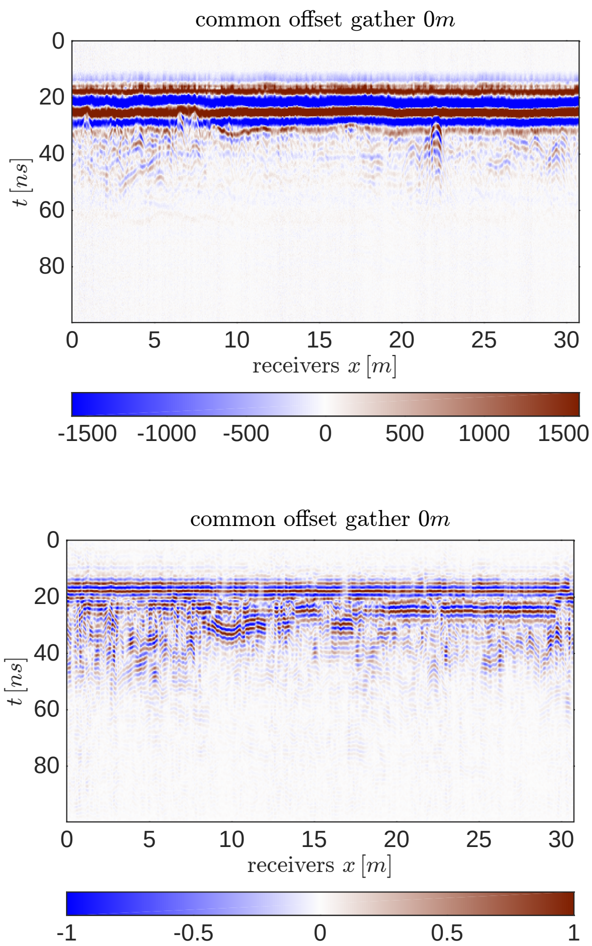

Figure 4: $0m$ common offset gather before and after processing. The radar system source was a $250\ MHz$ Ricker wavelet.

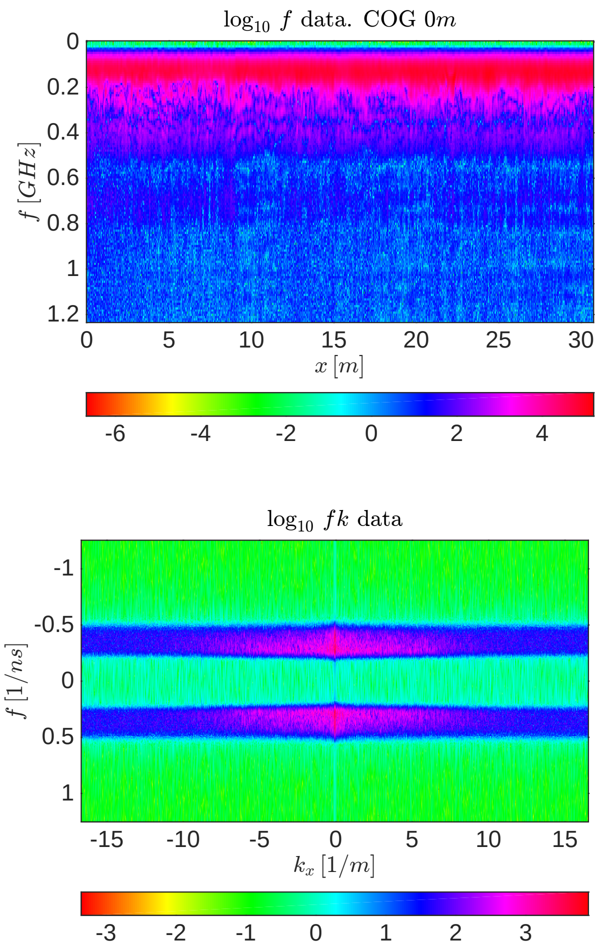

Figure 5: $0m$ common offset gather **top:** power spectra and **bottom:** fk domain after bandpass $(0.26, 0.46)\, GHz$.

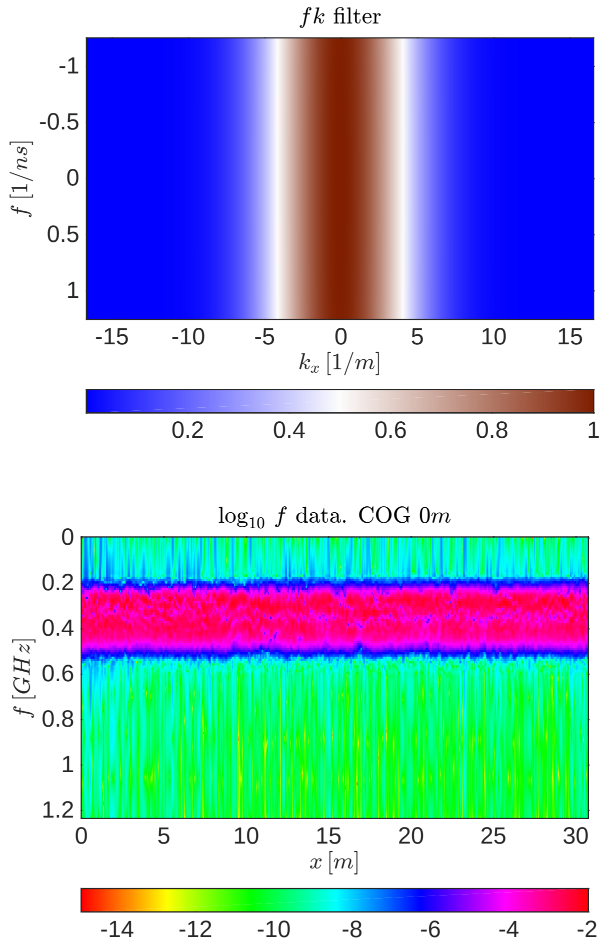

Figure 6: $0m$ common offset gather **top:** fk filter used and **bottom:** power spectra after fk filtering and amplitude normalization.

Common shot gathers

The radar system source was a $250\ MHz$ Ricker wavelet which when coupled to the ground gives a signal of roughly $(0.07, 0.26)\, GHz$.

The processing workflow for the CSG's is,

1. bandpass the data in the time-frequency interval $(0.07, 0.26)\, GHz$, (which *is* supposed to be entirely from the radar system),
2. throw away far offset receivers where there is no visible radar signal, (every trace after the $1m$ offset),
3. manual velocity estimation,
    - perform a Hilbert transform to plot the instantaneous phase of the data and visually hunt reflections, (it is easier to see it in such a plot than in the raw data),
    - manually fit shot-gather hyperbolic move-outs to these reflection events,
4. velocity estimation using semblance analysis,
5. dispersion analysis using short-time Fourier transform (*STFT*), and frequency-time analysis (*FTAN*).

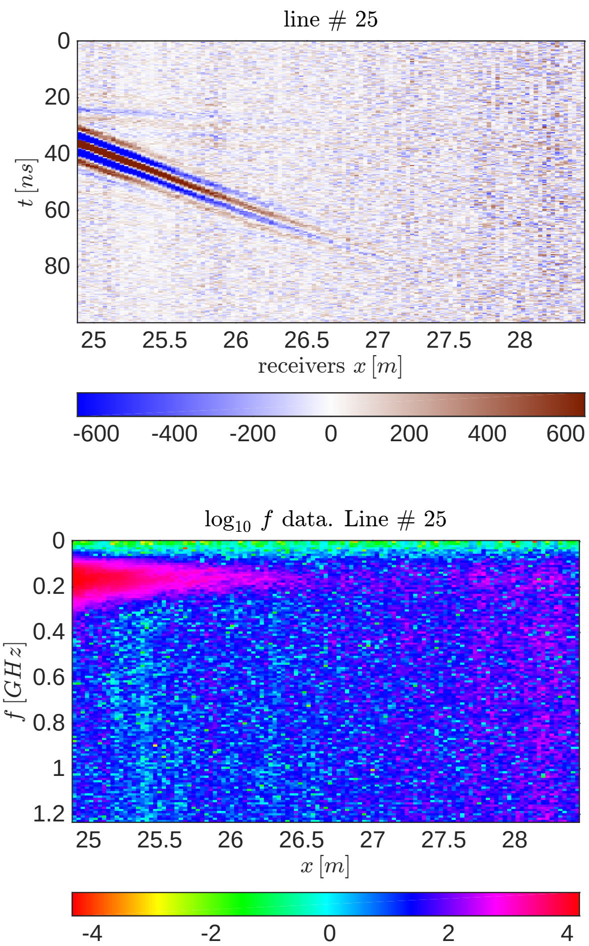

Figure 7: Line # 25. **Top:** raw data and **bottom:** power spectra. The radar system source was a $250\ MHz$ Ricker wavelet.

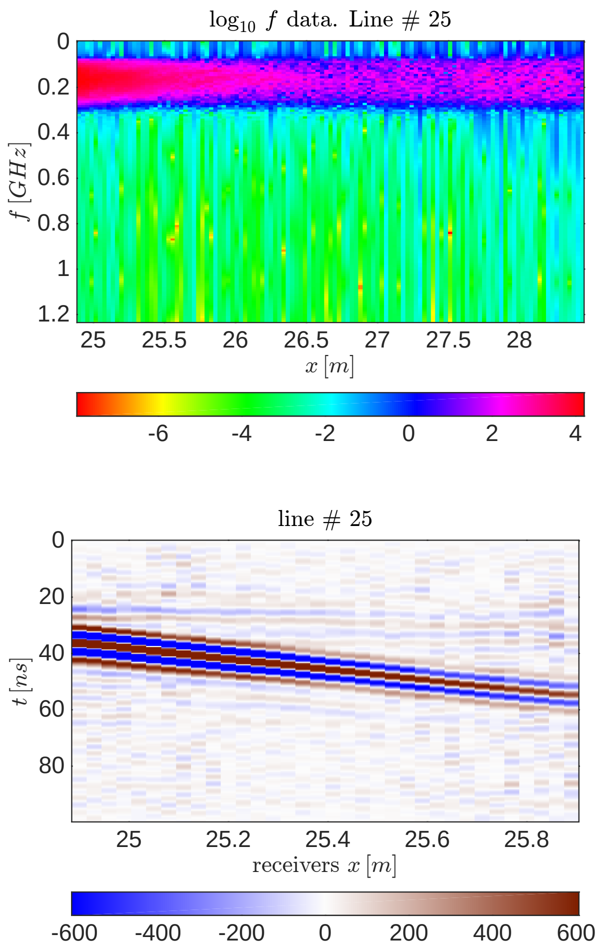

Figure 8: Line # 25. **Top:** filtered power spectra and **bottom:** filtered and amputated data.

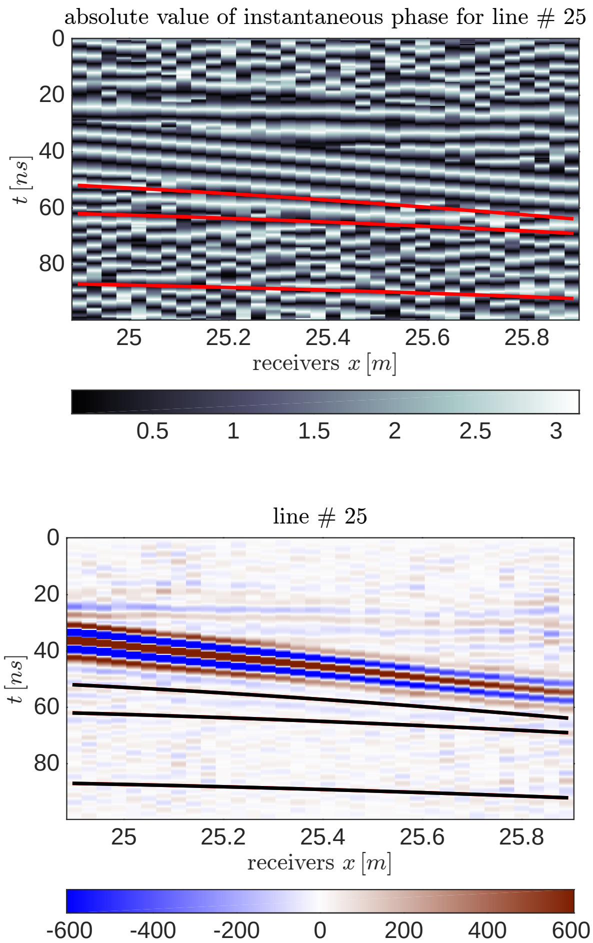

Figure 9: Line # 25. **Top:** instantaneous phase and **bottom:** data with hyperbolic events highlighted.

Assuming flat layers in depth the hyperbolic fit for a given event is (see Figure **??**),

$$t_h(\Delta sR) = 2\sqrt{\left(\frac{\Delta sR}{2v}\right)^2 + \left(\frac{z}{v}\right)^2}, \qquad z = v\sqrt{\left(\frac{t_o}{2}\right)^2 - \left(\frac{\Delta sr}{2v}\right)^2},$$
$$\Rightarrow t_h(\Delta sR) = \sqrt{\frac{\Delta sR^2 - \Delta sr^2}{v^2} + t_o^2},$$

where t_o is arrival time of reflection for the receiver closest to the source, ΔsR is source-receiver distance, v is cumulative velocity, z is cumulative distance in depth traveled to reflector and Δsr is distance from source to closest receiver.

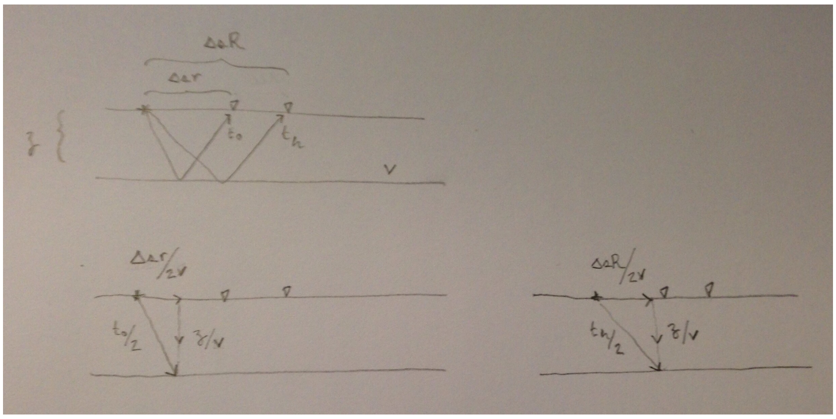

Figure 10: Hyperbolic move-out diagram. **Top:** Assumed geometry, **bottom:** Pythagorean theorem on traveled times. The time z/v is the common link between the two travel time triangles.

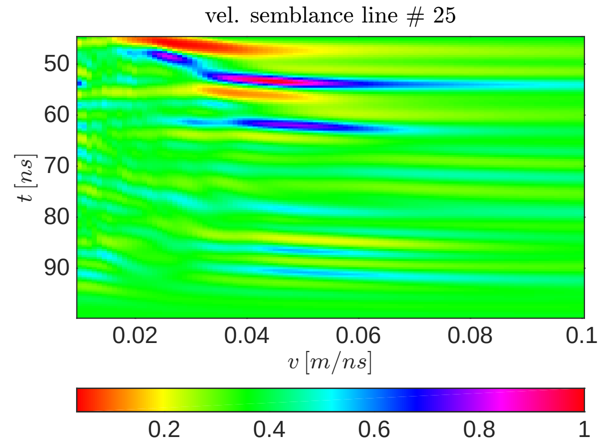

Figure 11: Velocity semblance using the shot-gather hyperbolic move-out and a weighted sum that penalizes fast velocities (flat hyperbolas). Velocities from the manual and velocity semblance procedures agree.

event #	$t_o\,[ns]$	$v\,[m/ns]$	$z\,[m]$	$\varepsilon\,[\,]$	interpretation
0	30	0.055	0.00	30	plane wave thru layer 1
1	52	0.045	1.08	45	reflection of layer 2
2	62	0.055	1.64	30	multiple of layer 1
3	87	0.055	2.35	30	multiple of layer 1

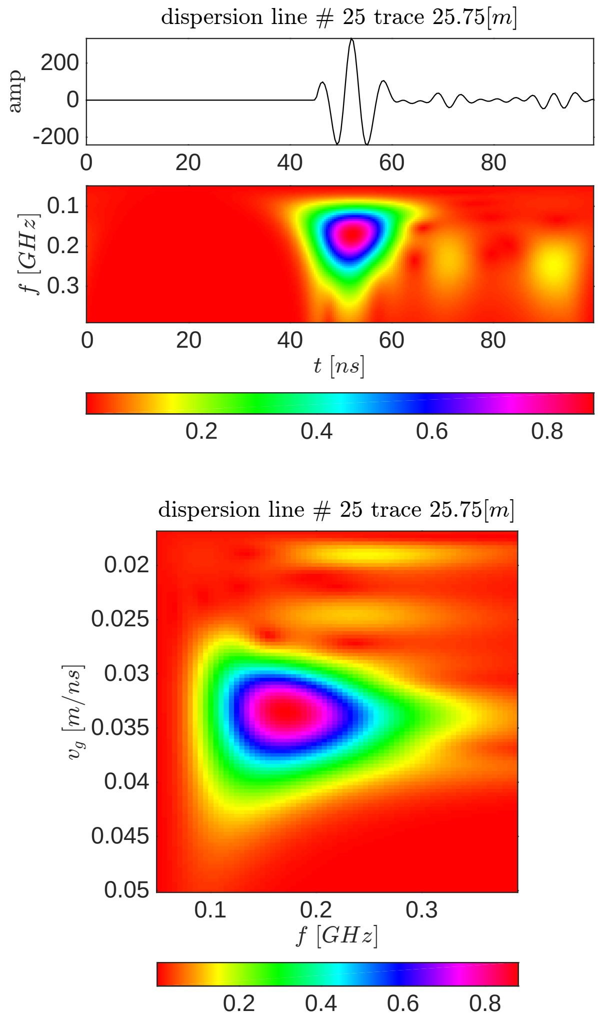

Figure 12: **Top:** STFT using FTAN as a function of (f, t). **Bottom:** dispersion using FTAN as a function of (v_g, f).

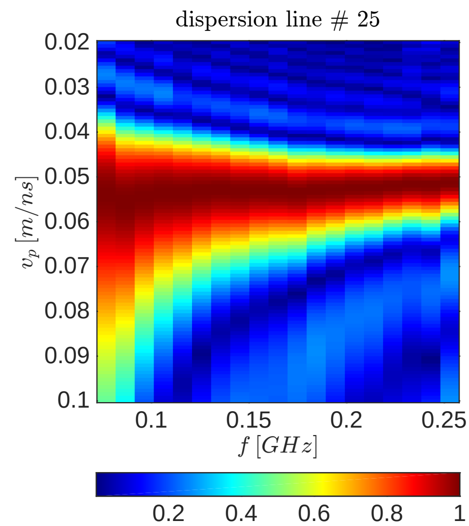

Figure 13: Phase velocity dispersion using MASW.

Once upon a wave

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