CREWES

2017 Annual Meeting

devon

Quantifying Footprint

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Contents

Take-away points

- Grid correlation is a method to objectively measure the footprint on seismic time (or depth) slices.
- It is useful to decide if footprint suppression is required.
- Also useful to compare the performance of competing footprint suppression algorithms.
- CREWES Matlab software to do this is readily available.

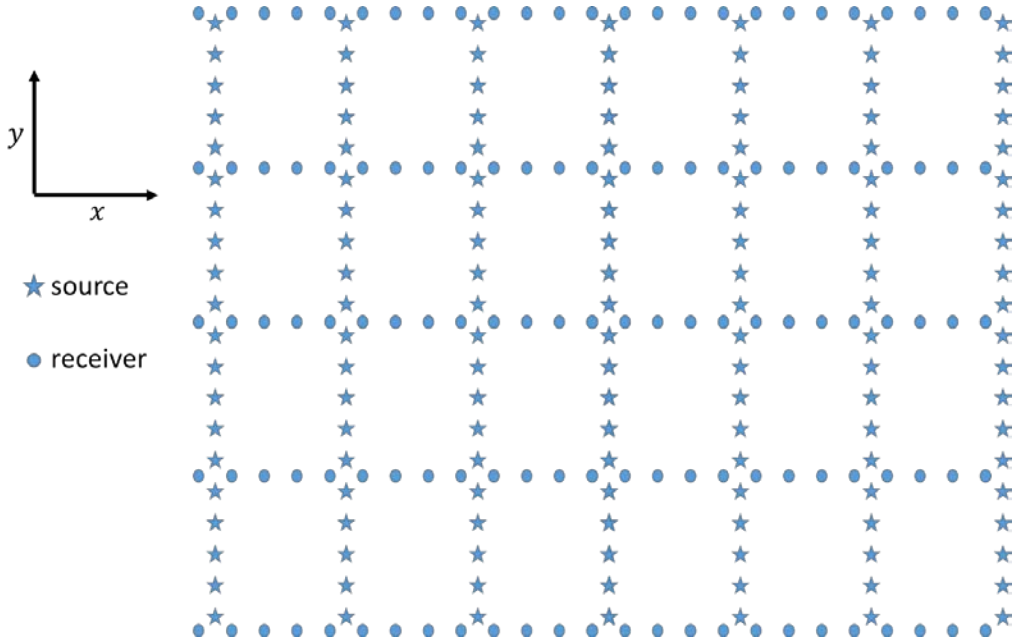
seisplotsvd_sep.m … Interactive SVD separation tool (GUI)
seisplotsvd_foot.m … Interactive footprint suppression tool (GUI)
ccfoot.m … Numerical computation of grid correlations

Grid Correlation Method

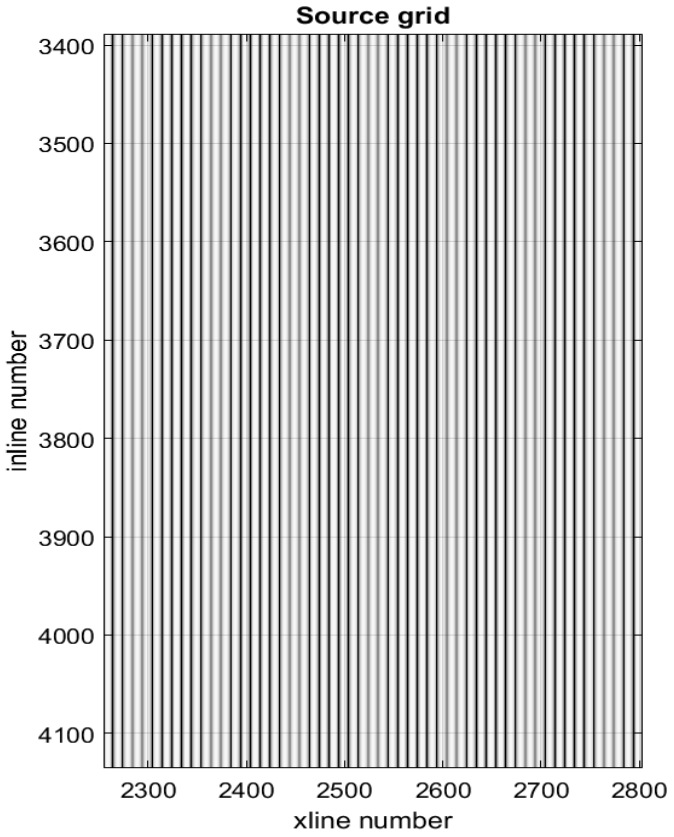
1. Construct numerical representations of source and receiver grids.
2. Crosscorrelate these grids with the absolute value of the time slice. For each gird examine lags orthogonal to the line direction.
3. Footprint is indicated by periodicity in the crosscorrelations.

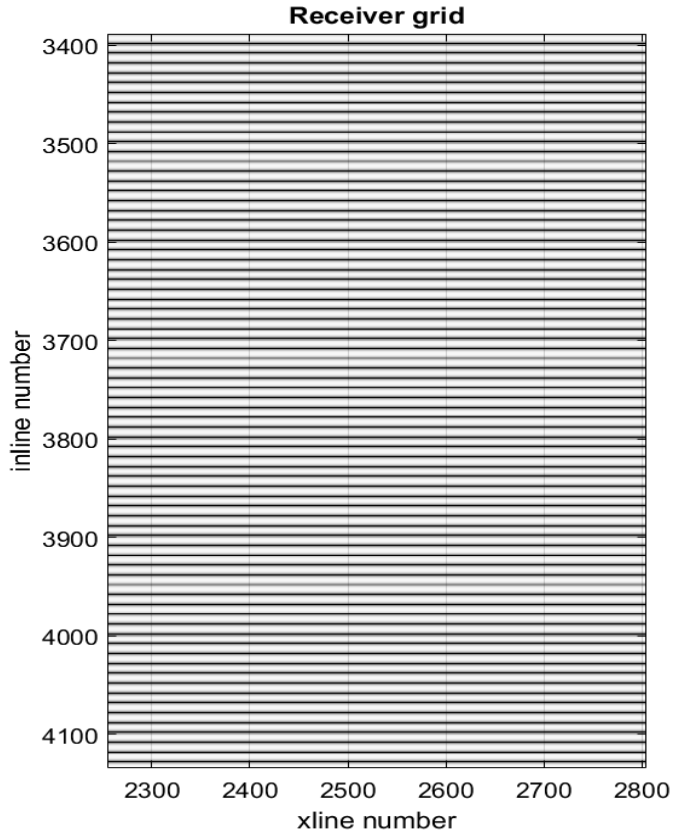
Orthogonal acquisition grids

Orthogonal Plan



Numerical grid models for an actual survey

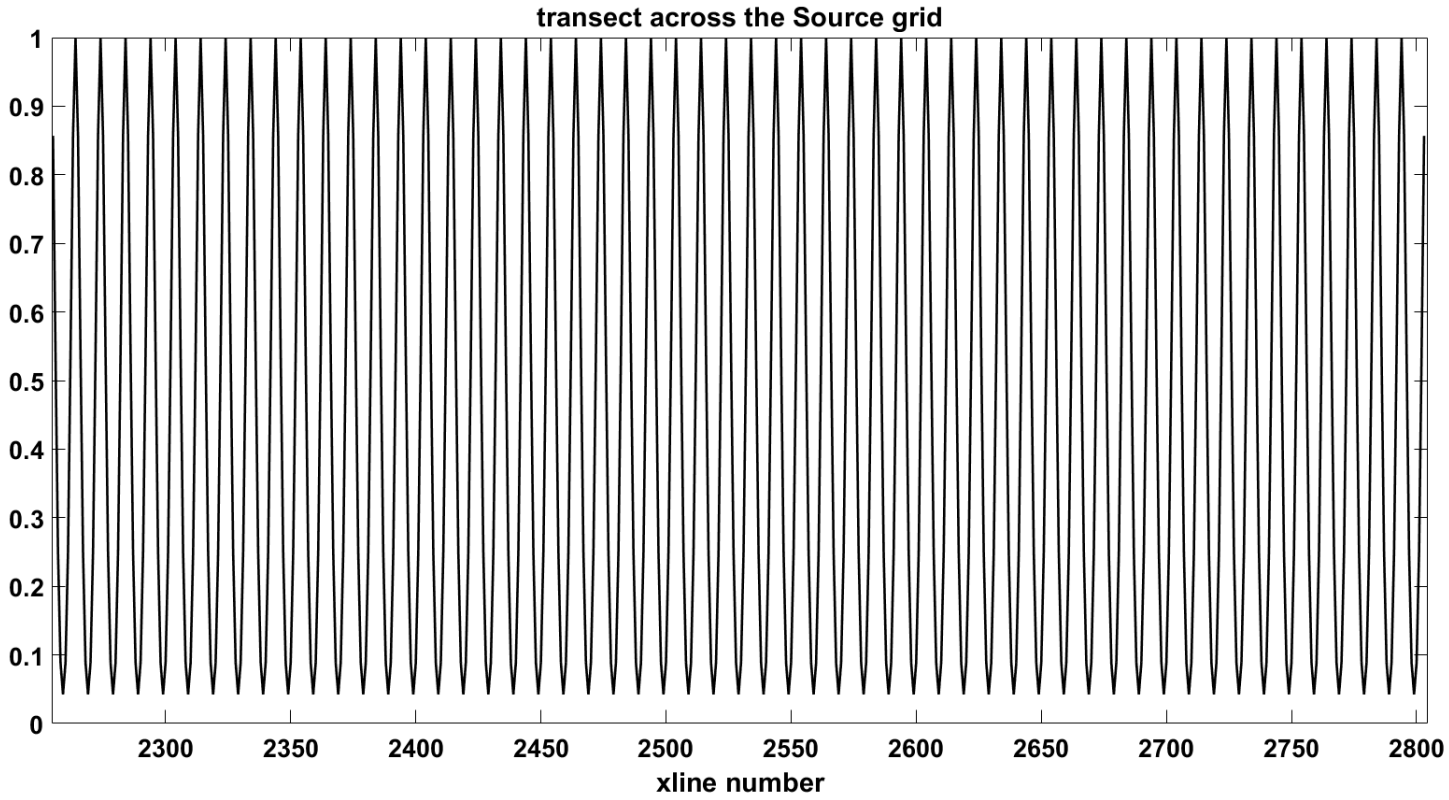




Source grid transect

Construction method:

1. Start with two blank grids the same size as the time slice.
2. Place a 1 at every source location in the source grid and similarly for the receiver grid.
3. Apply a gentle, isotropic, wavenumber filter to slightly soften the 1/0 transitions.



It does not matter if you use the actual source and receiver locations. What matters is that you get the proper spacing between lines.

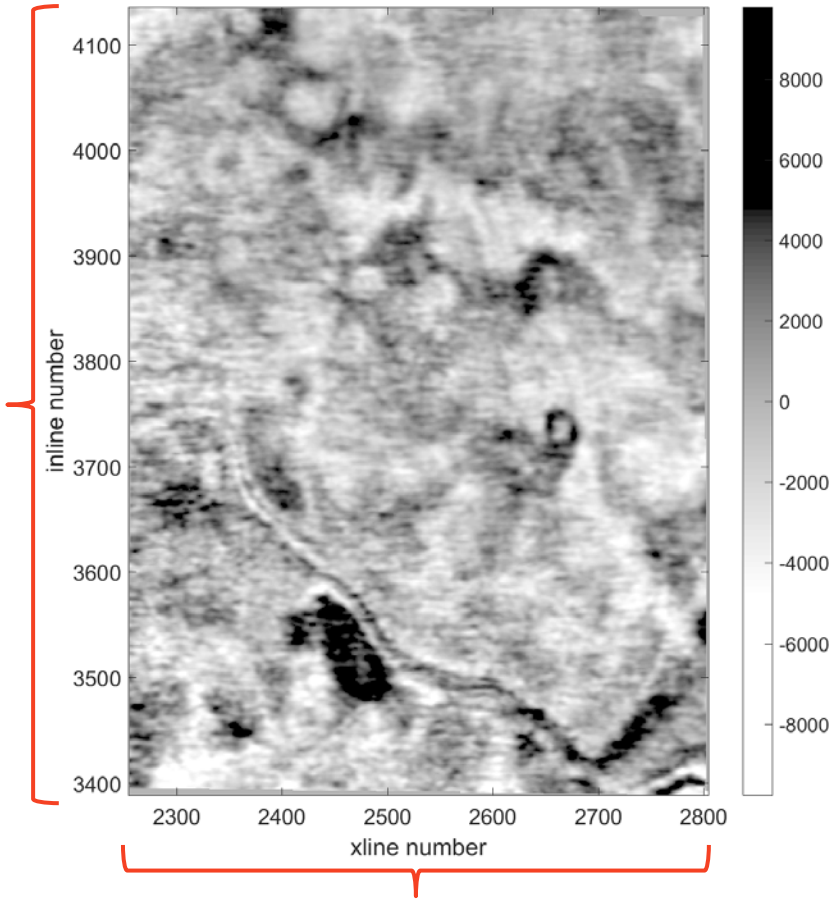
A time slice

Acquisition details:
Source and receiver line spacings: 825 ft.
Source and receiver spacing: 82.5 ft.
Image bin size 82.5x82.5 ft^2

~62000 ft.
~ 75 receiver lines

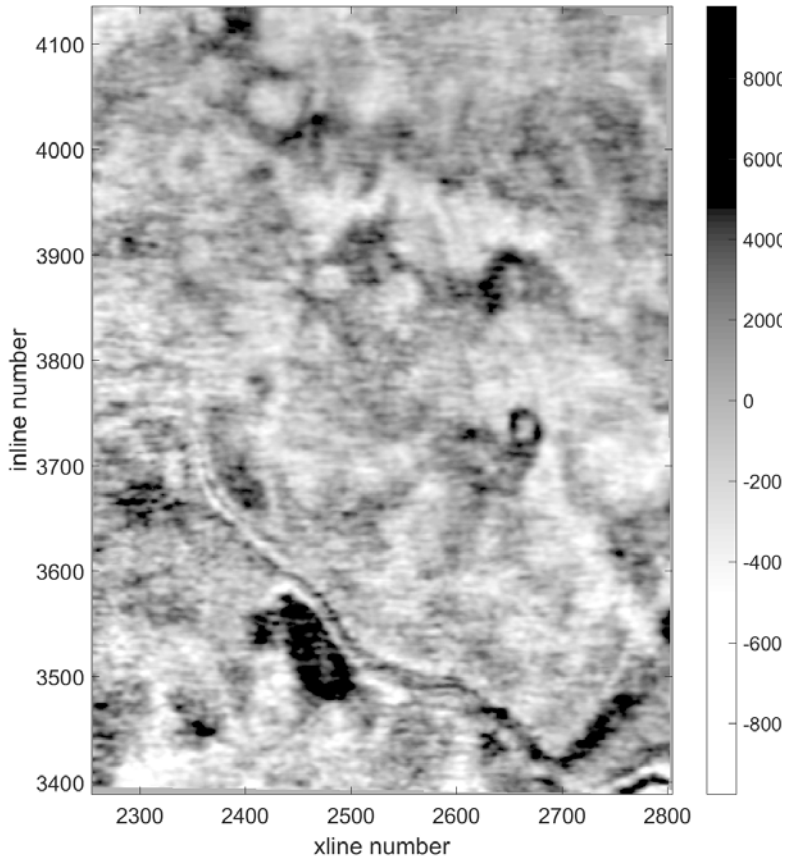
Ratio of line spacing to bin size: R=10

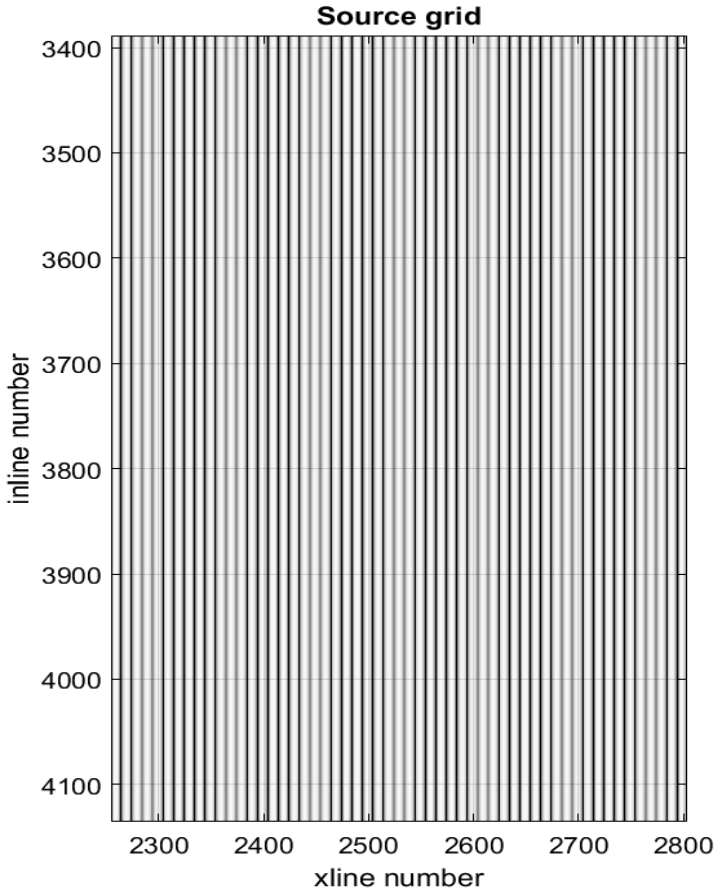
Do you see receiver footprint?
Source footprint?
Both?

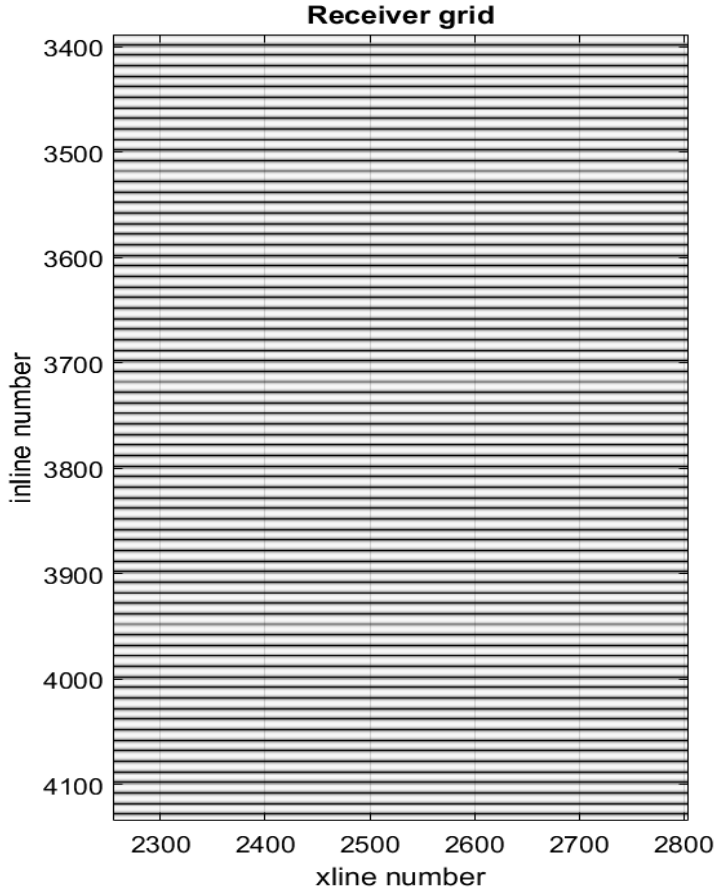


~45000 ft.
~ 55 source lines

The time slice and the acquisition grids

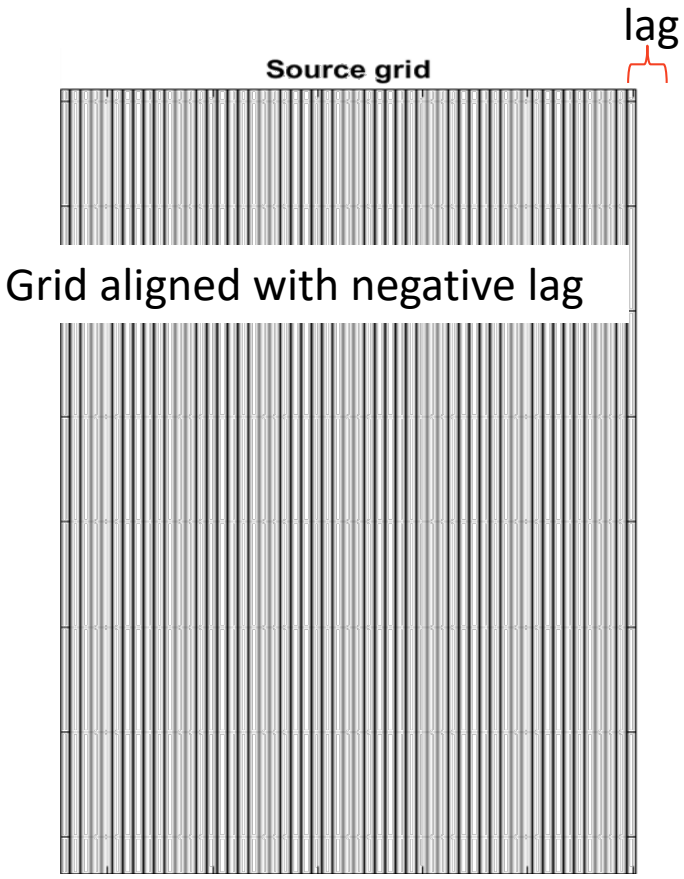






The grid correlation process

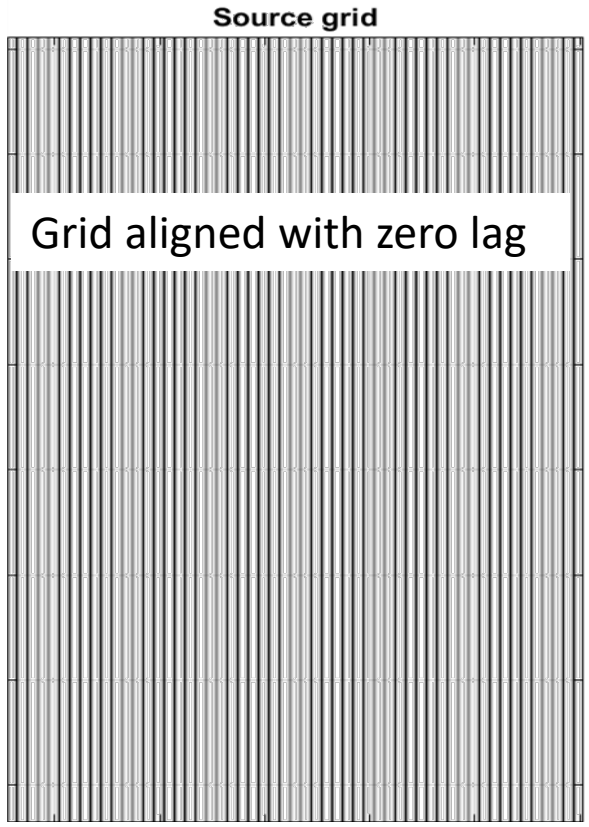
Illustrated for the source grid



1. Align grid and slice with some lag.
2. Multiply aligned samples together and sum.
3. Repeat for all desired lags
4. Normalize

Important detail #1:
It is only necessary to search lags from –R to R. Here R=10.

Important detail #2:
It is best to use the absolute value of the time slice in this process.

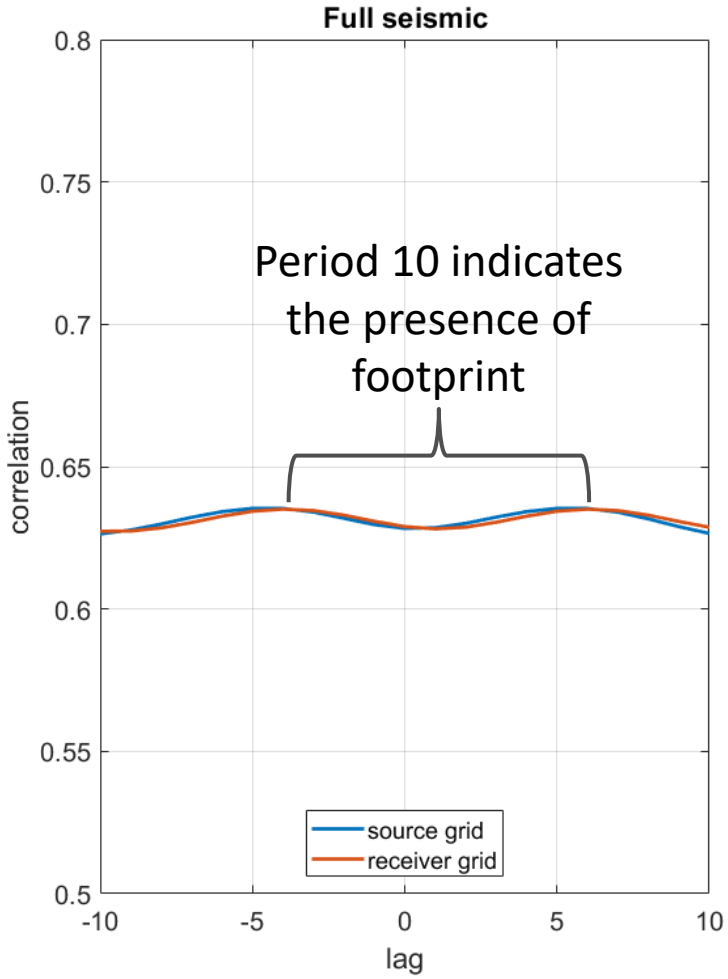


Why the absolute value?

- The time slice contains both positive and negative values and is often near zero mean.
- Footprint is largely a multiplicative process which makes positives more positive and negatives more negative.
- The correlation directly with the time slice then still tends to sum to zero.
- Using the absolute value avoids the cancellation of large positives by large negatives.

A first result

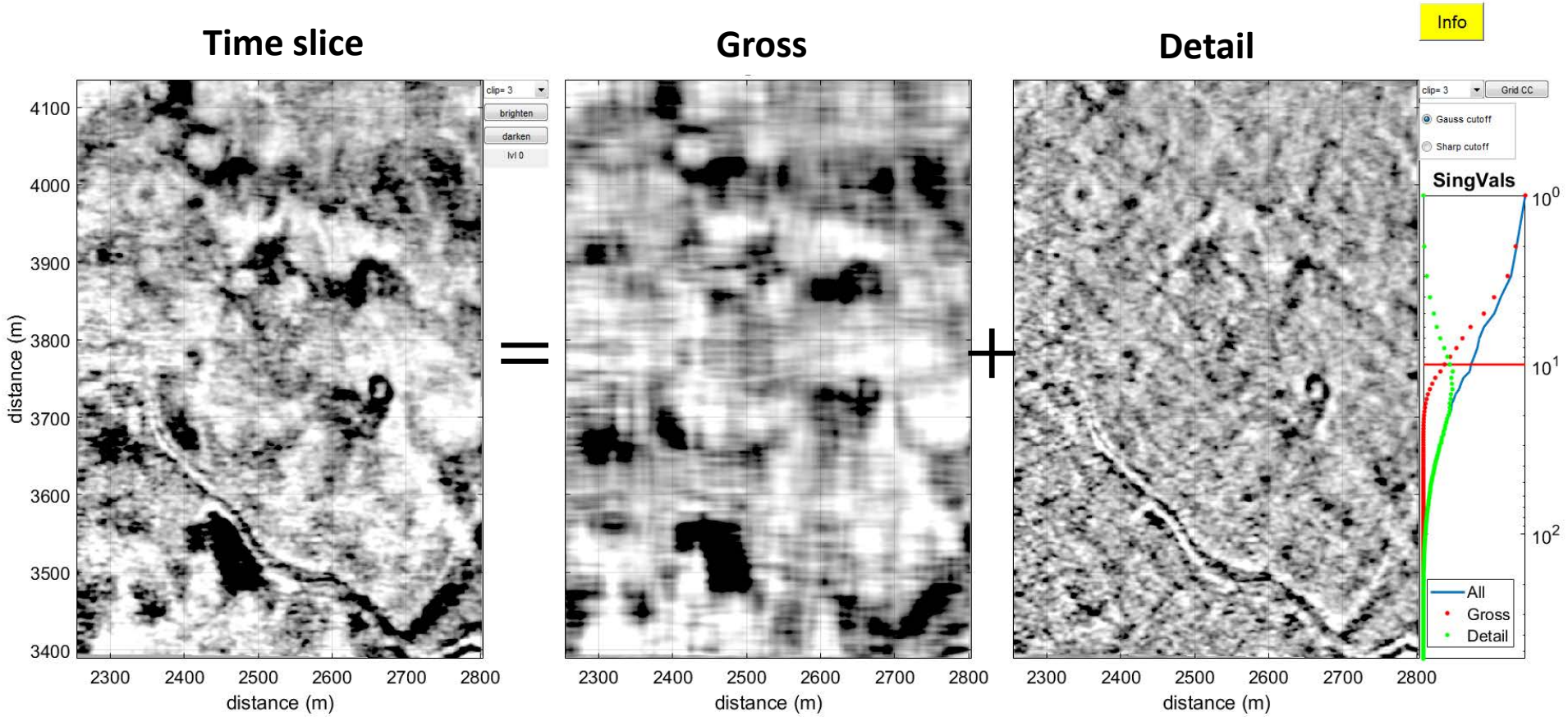
- At some lag, the grid will align with footprint artefacts, if present. The correlation will then produce a larger value.
- If this is indeed footprint, this same value should be measured again R=10 lags later.



CREWES tool: ccfoot.m

SVD Separation into Gross and Detail

SVD= Singular Value Decomposition



CREWES tool: seisplotsvd_sep.m

Singular Value Decomposition

Fact: Any matrix M can be decomposed as $M = USV^T$ where U and V^T are largely uninteresting "rotation matrices" and S is a diagonal matrix containing the non-negative "singular values".

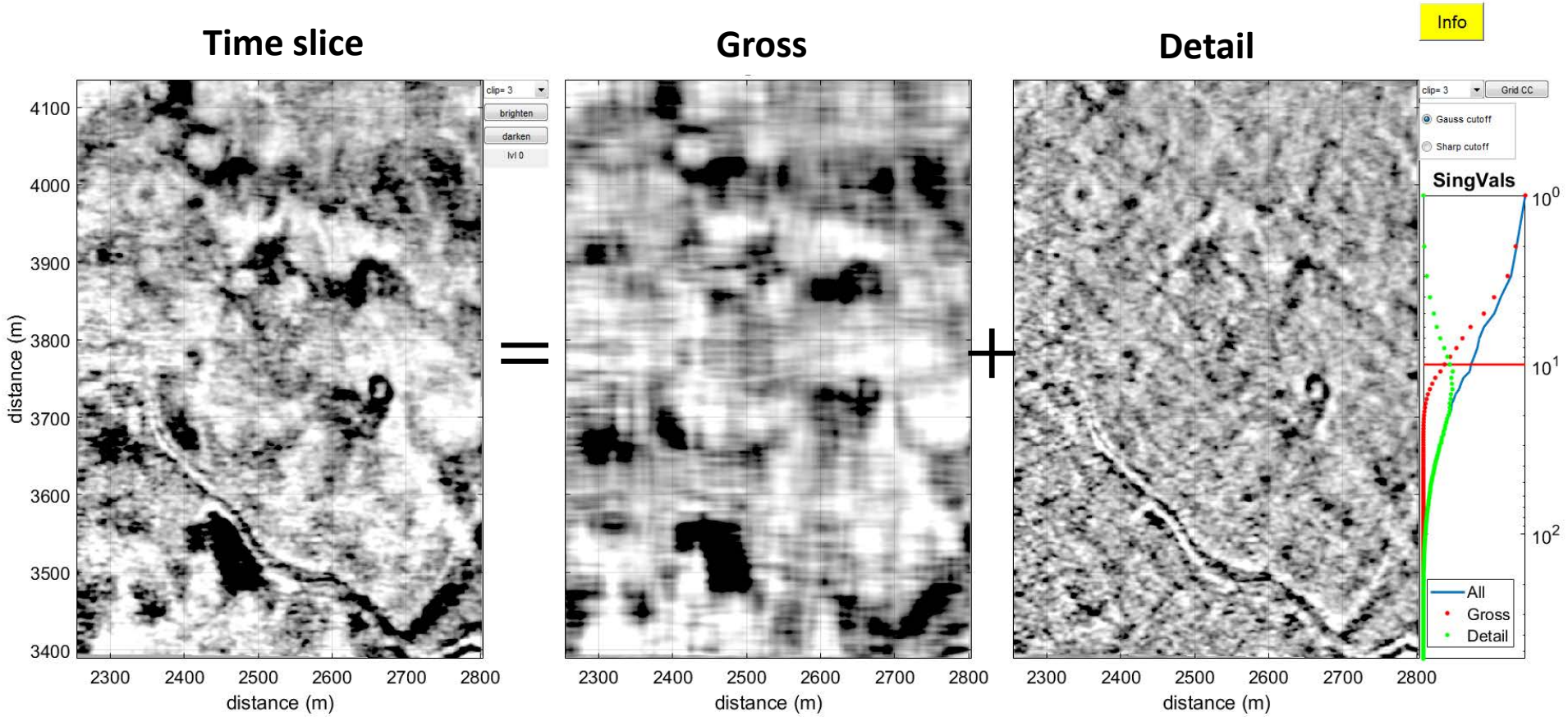
Analogy: S contains the all important "genetic" information of the matrix while U and V^T are simply the instructions for the proper assembly of these genes.

Important point: The singular values are ordered from largest to smallest and their number is the smaller of the row and column dimensions of the matrix.

Threshold filtering: A common use of SVD is to de-noise a matrix by setting all singular values less than some threshold to zero.

SVD Separation into Gross and Detail

SVD= Singular Value Decomposition



CREWES tool: seisplotsvd_sep.m

Footprint suppression by wavenumber filtering

A Gentle filter

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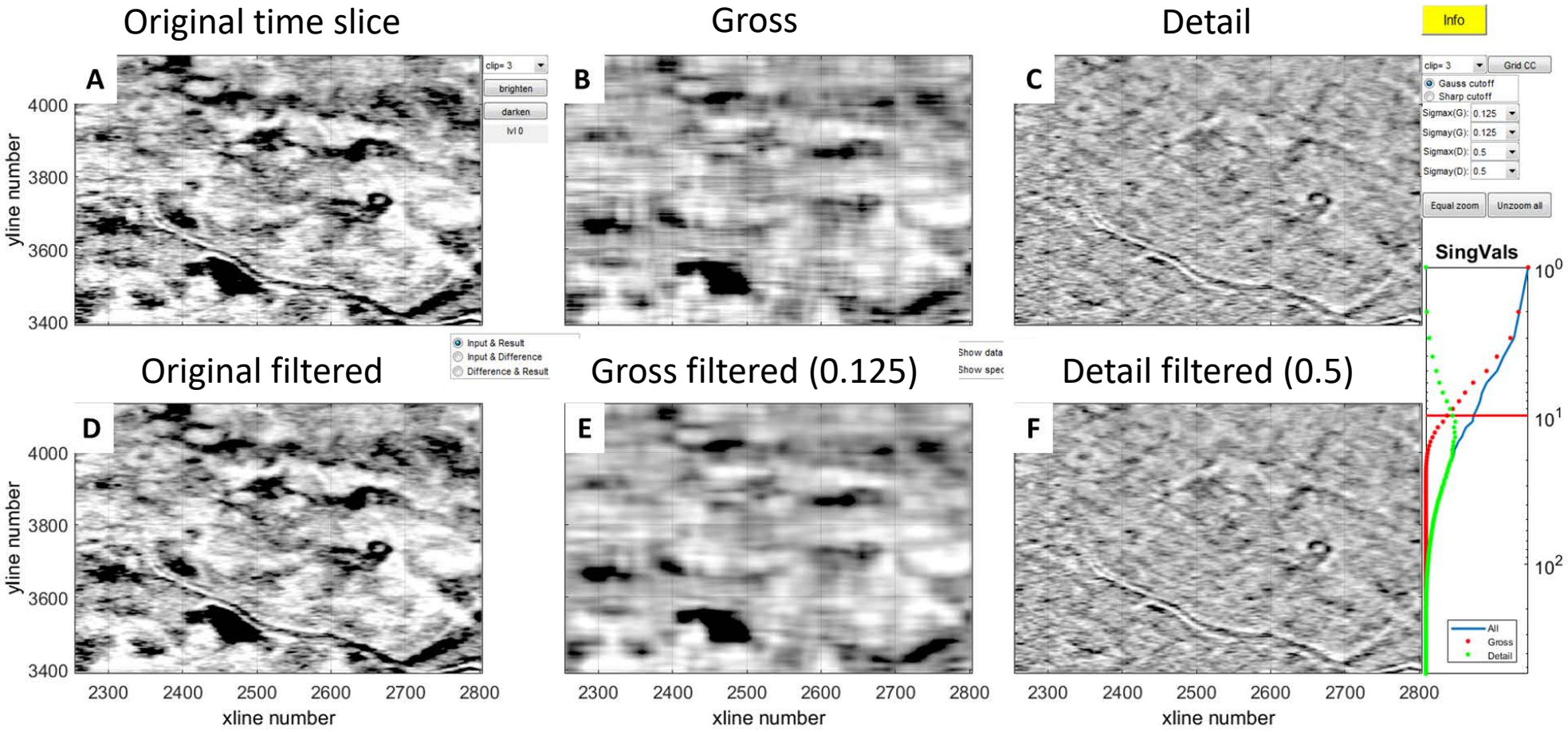
Before

After



CREWES tool: seisplotsvd_foot.m

Harsh

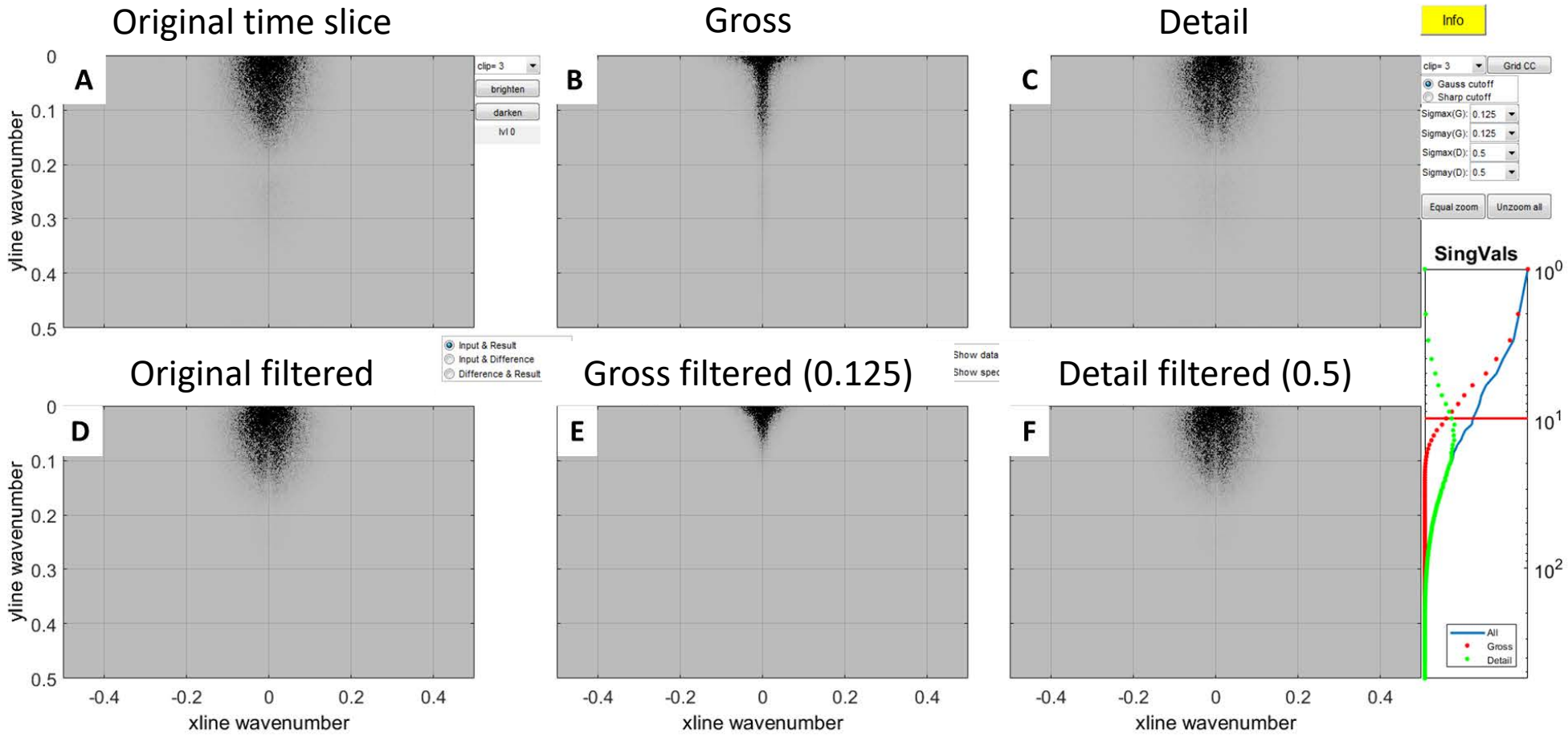
Vendor

Footprint suppression by wavenumber filtering

A Gentle filter, Wavenumber spectra

Before

After



CREWES tool: seisplotsvd_foot.m

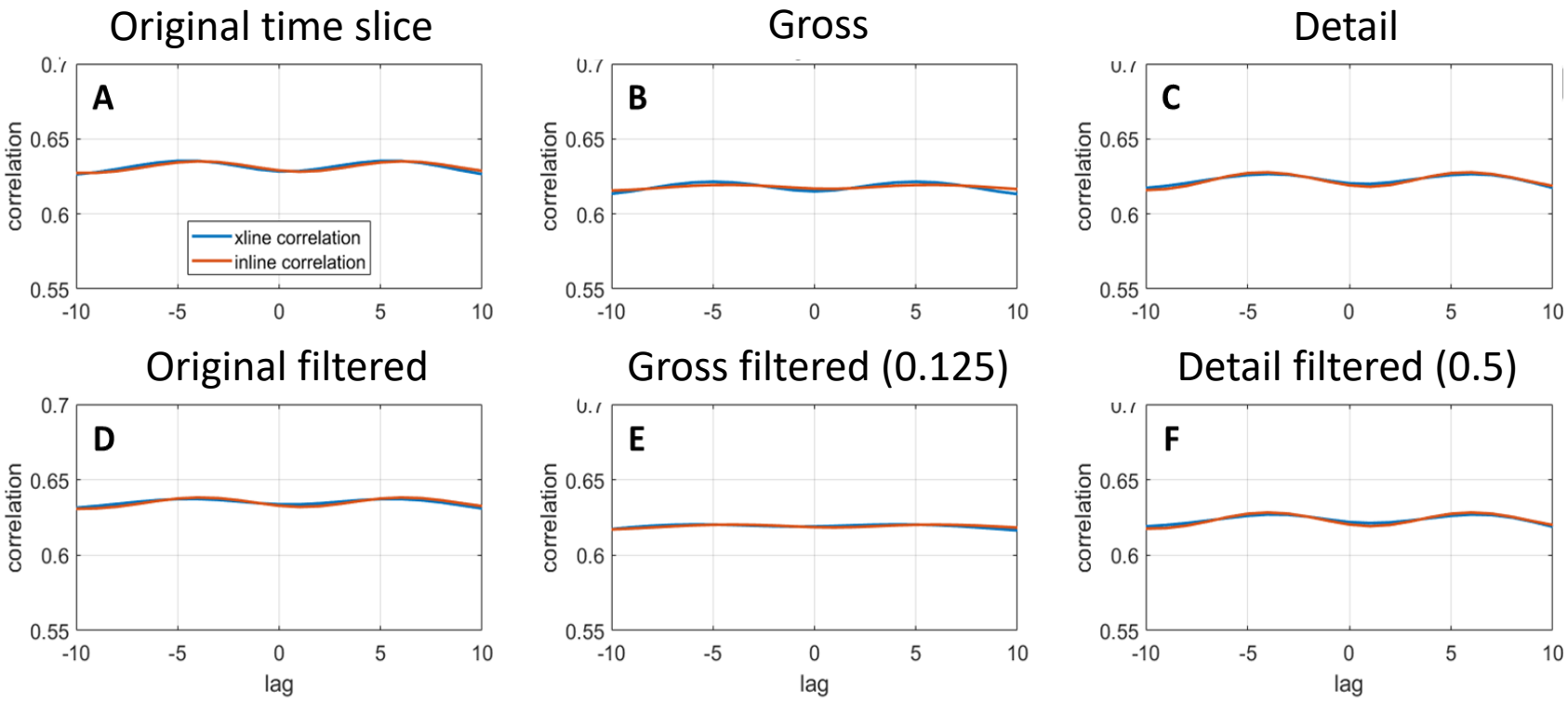
Harsh

Footprint suppression by wavenumber filtering

A Gentle filter, Grid correlations

Before

After



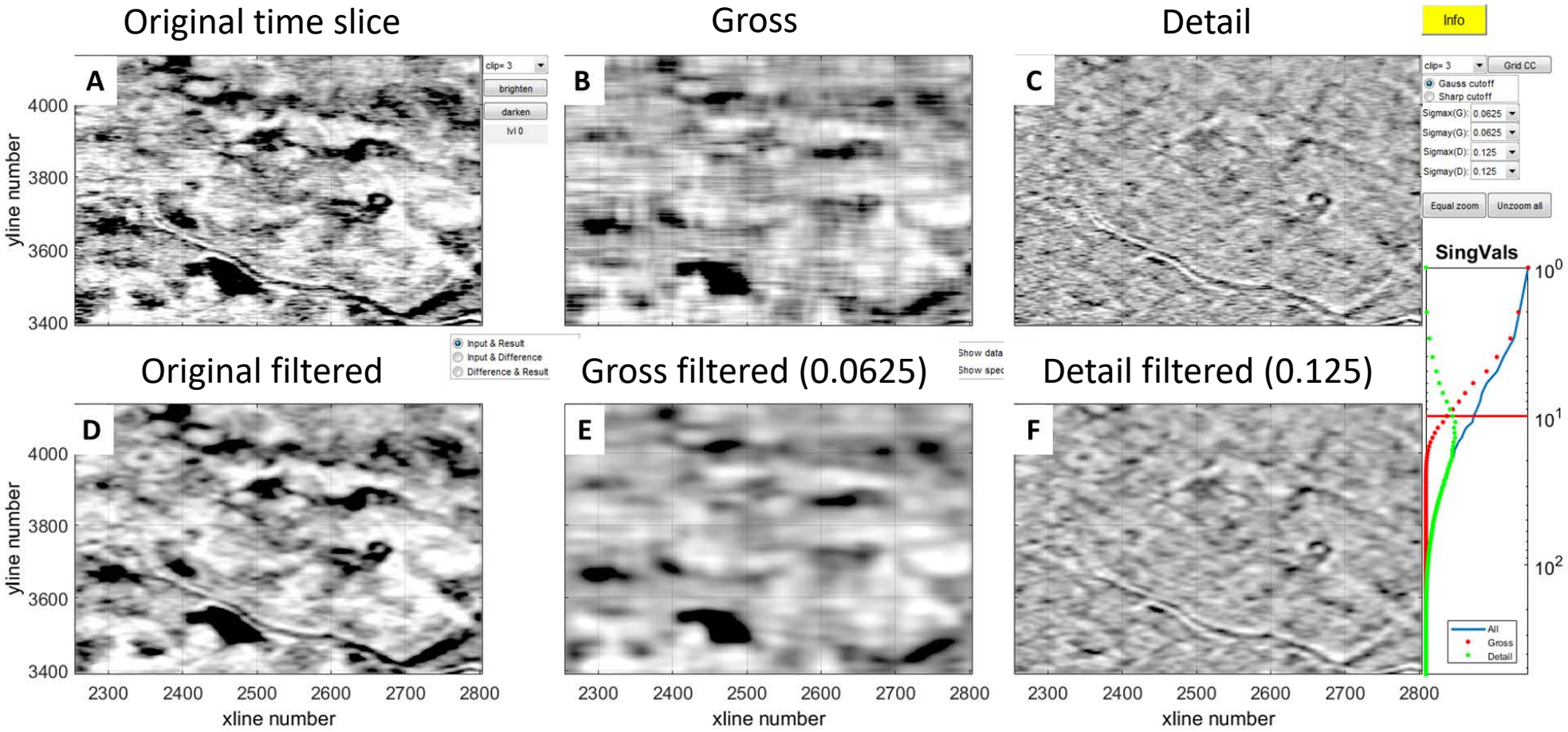
Harsh

Vendor

CREWES tool: seisplotsvd_foot.m

Footprint suppression by wavenumber filtering

A Harsh filter



Before

After

Gentle

Vendor

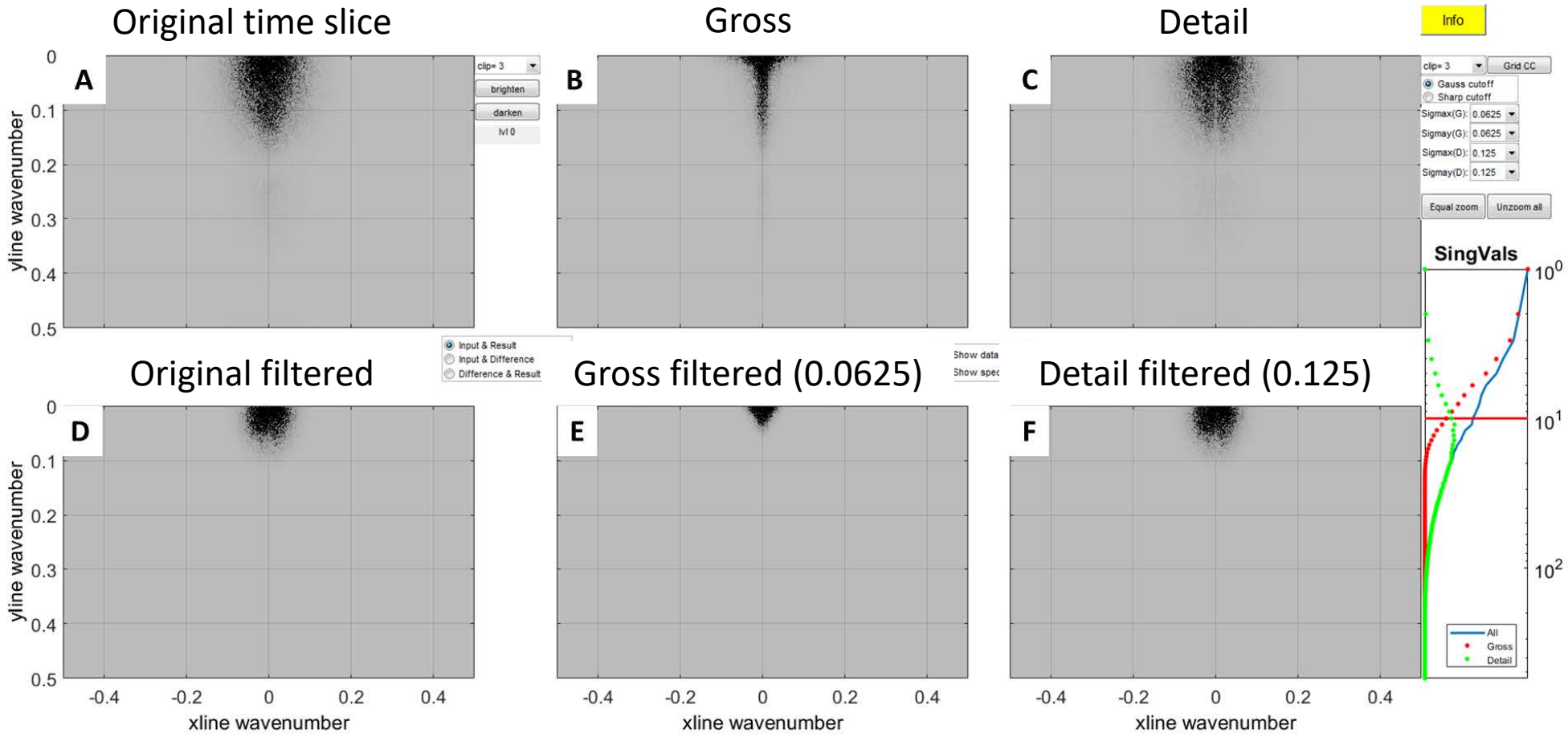
CREWES tool: seisplotsvd_foot.m

Footprint suppression by wavenumber filtering

A Harsh filter, Wavenumber spectra

Before

After



CREWES tool: seisplotsvd_foot.m

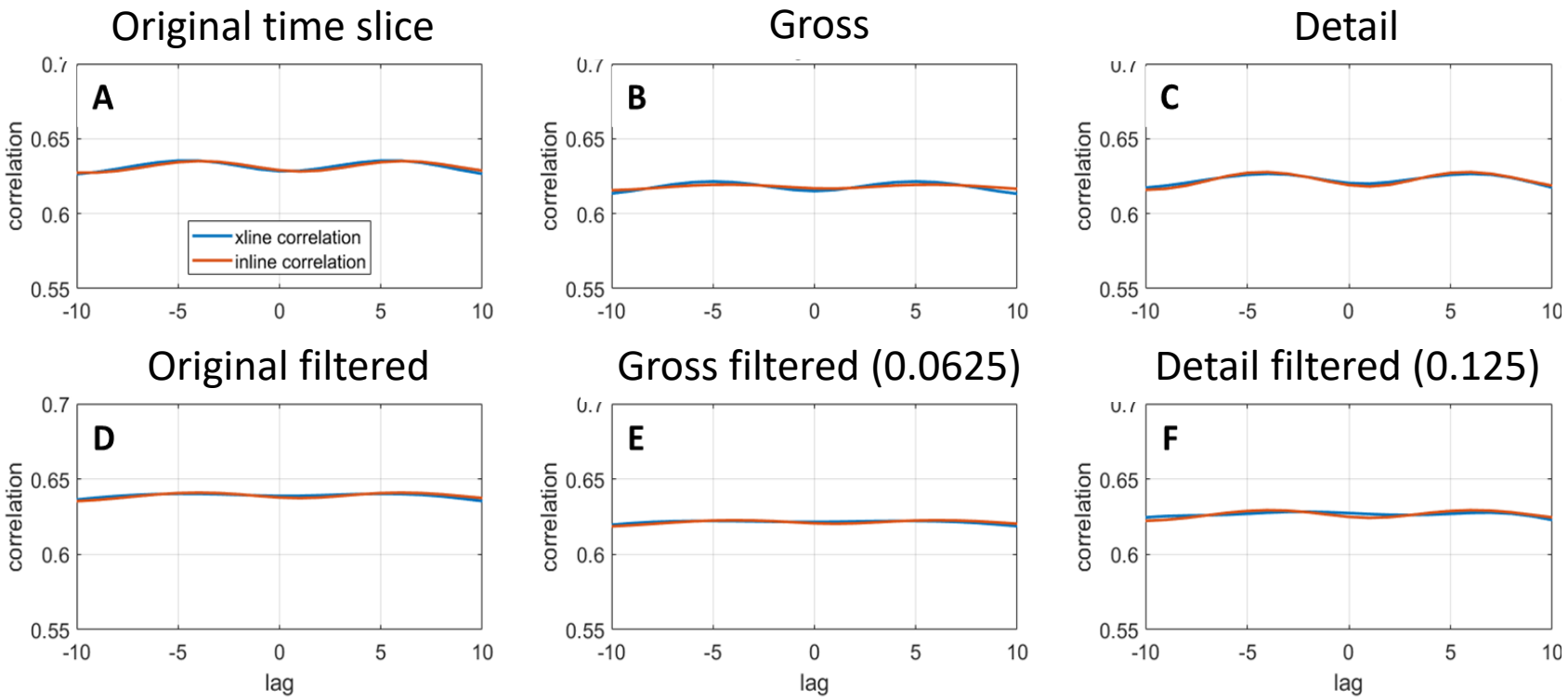
Gentle

Footprint suppression by wavenumber filtering

A HARSH filter, Grid correlations

Before

After



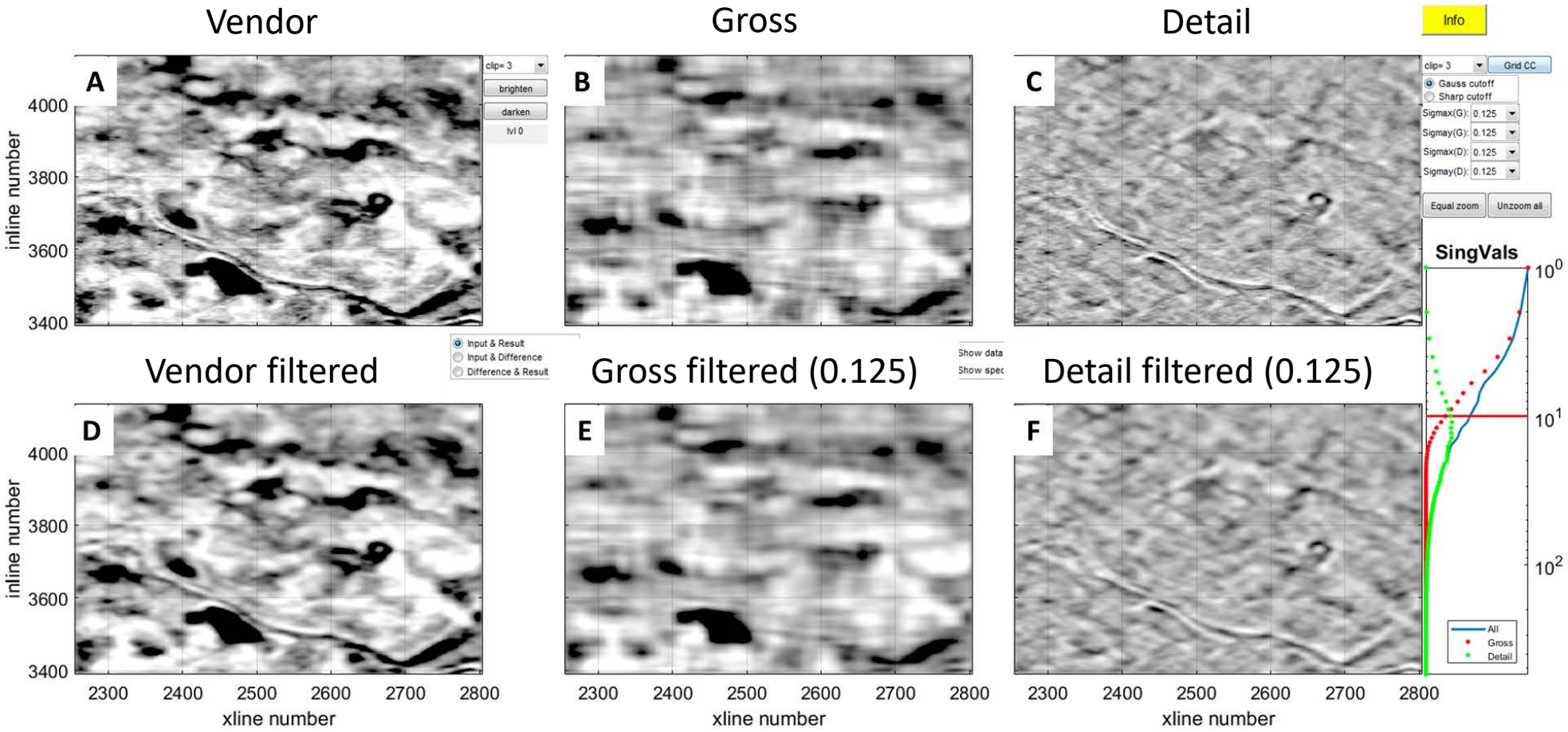
Gentle

Vendor

CREWES tool: seisplotsvd_foot.m

Footprint suppression by Geostatistical filtering

Vendor method



Gentle

Harsh

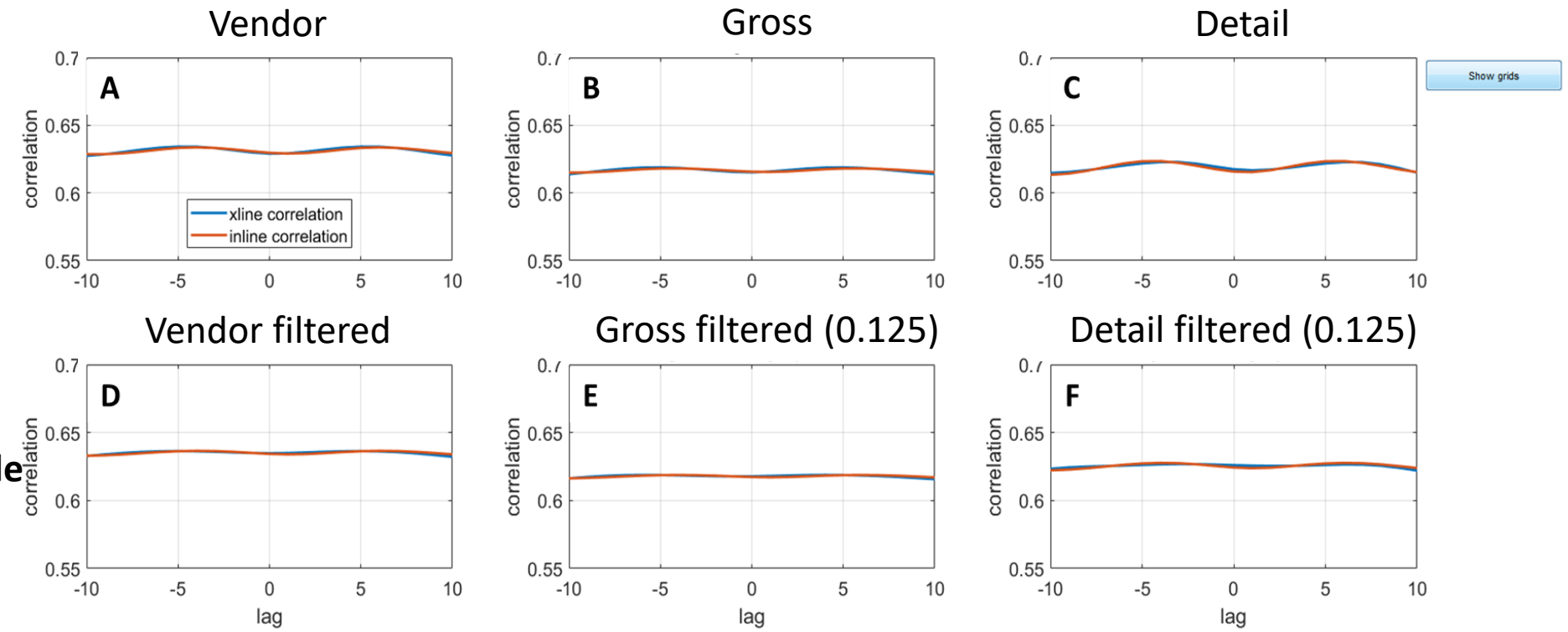
CREWES tool: seisplotsvd_foot.m

Footprint suppression by wavenumber filtering

Vendor method, Grid correlations

Vendor

Vendor+Gentle



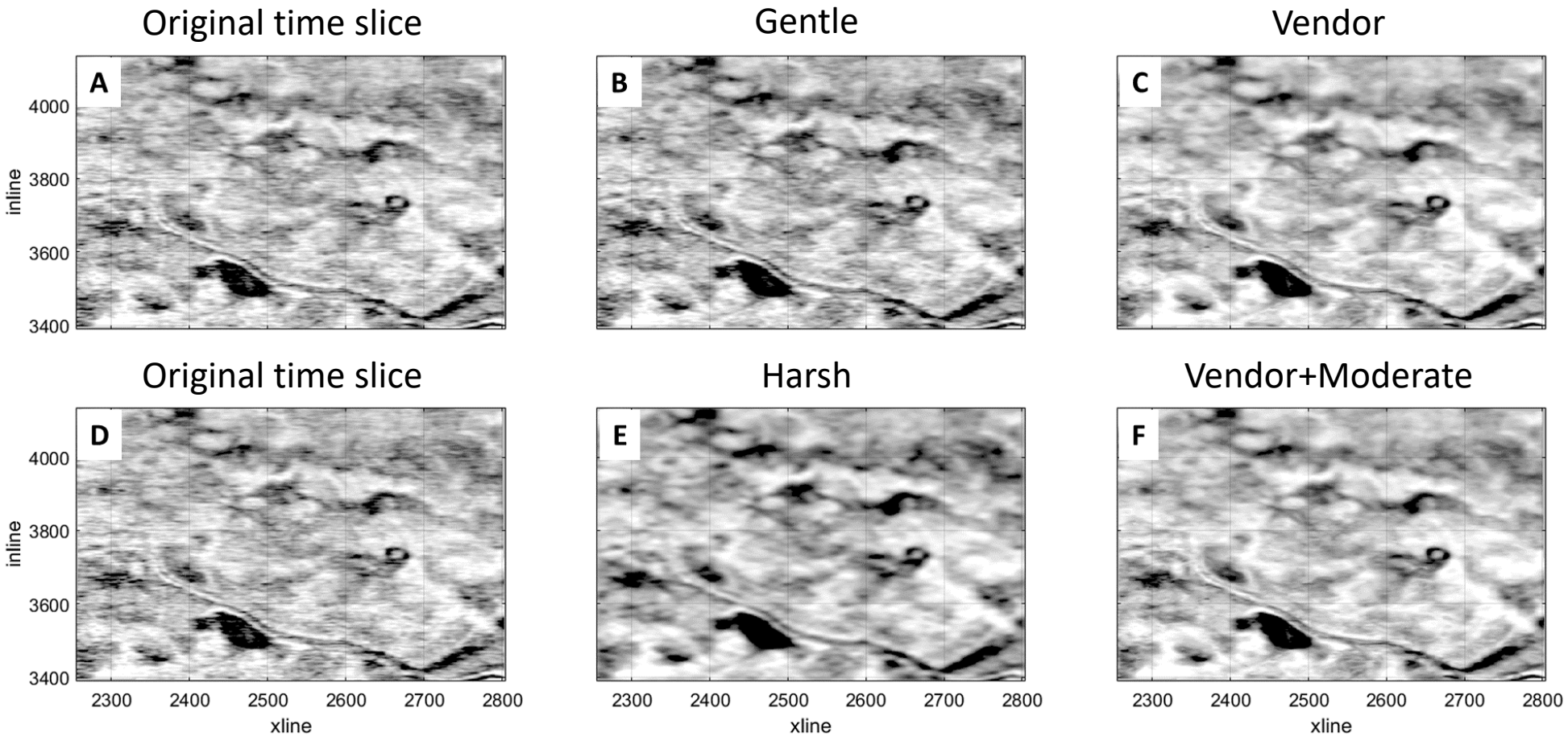
Gentle

Harsh

CREWES tool: seisplotsvd_foot.m

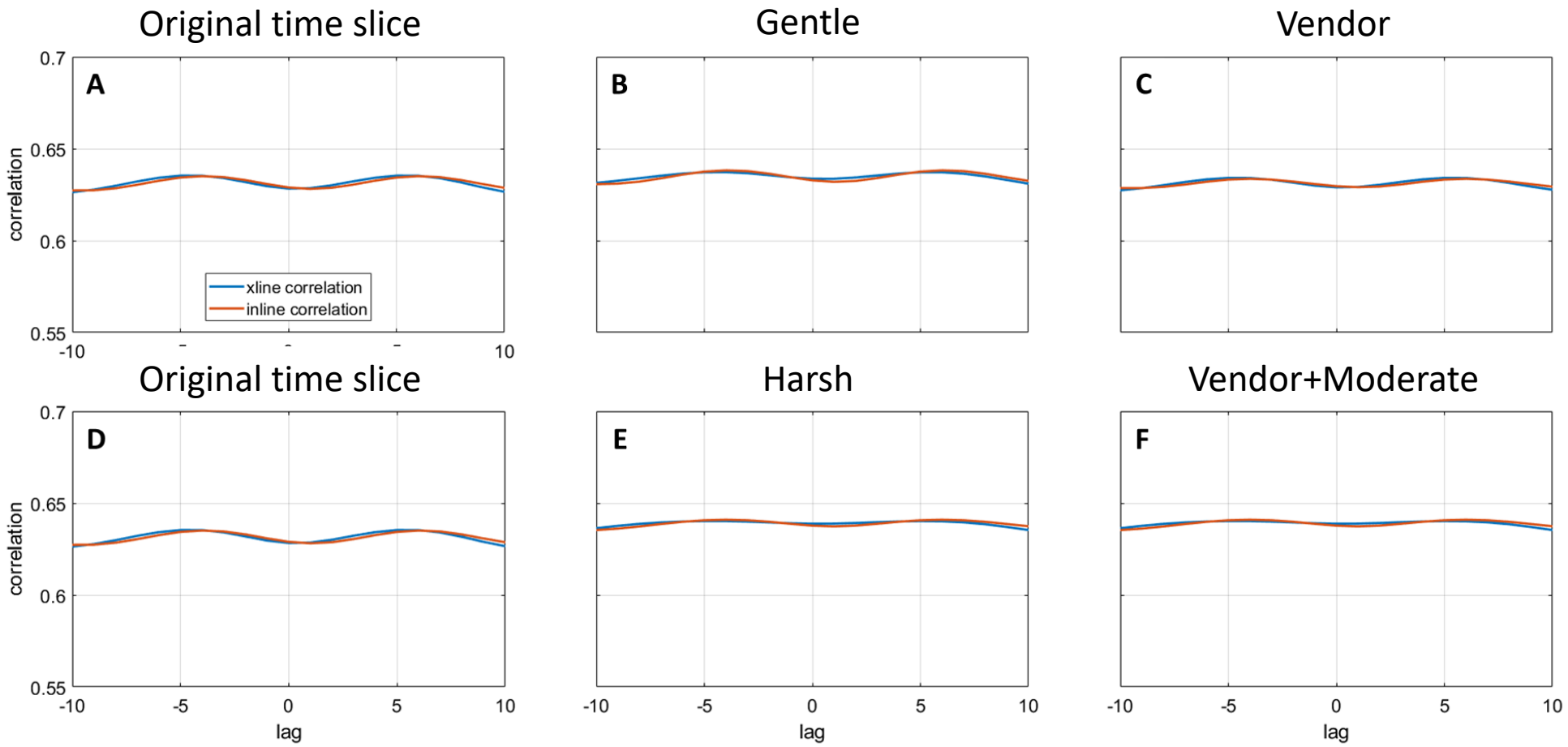
All four suppression results

Gentle, Vendor, Harsh, Vendor+Moderate



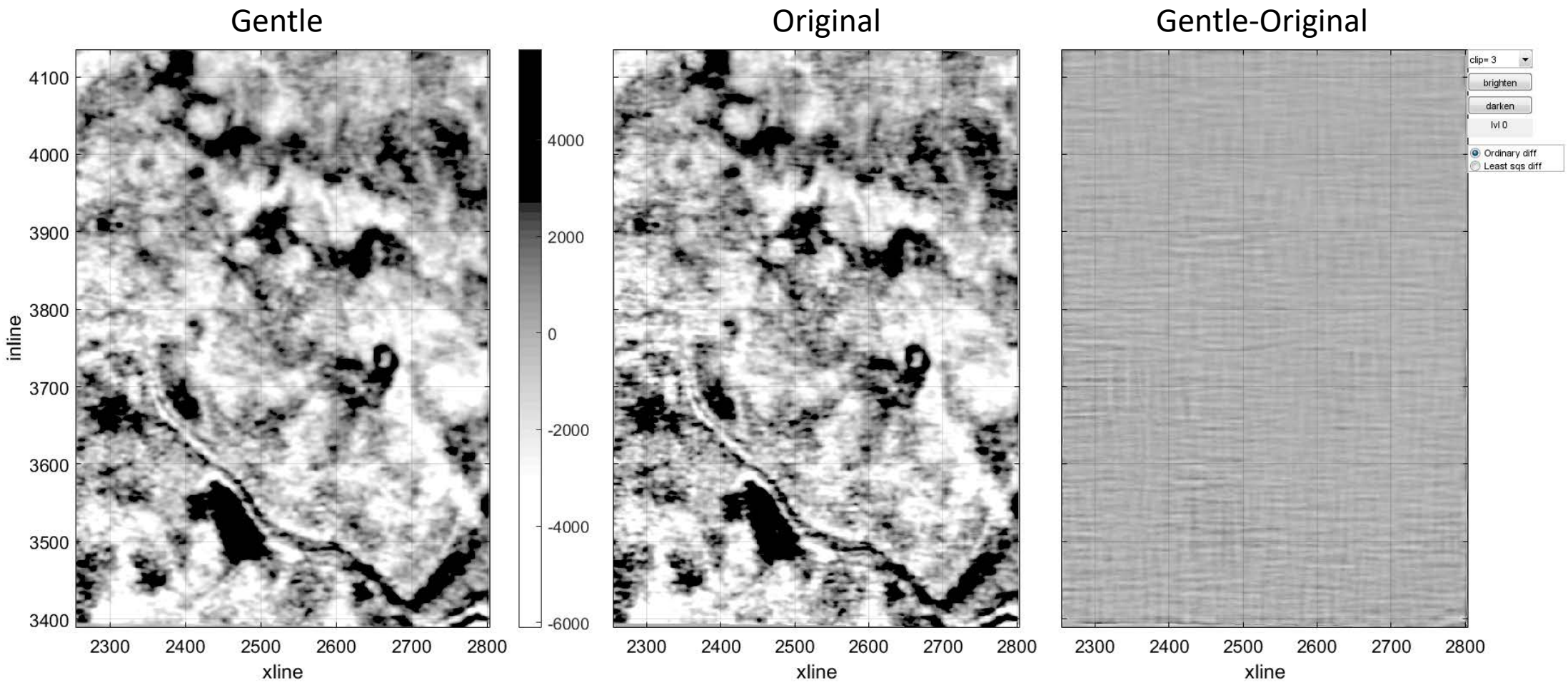
All suppression results

The grid correlations



Difference plots

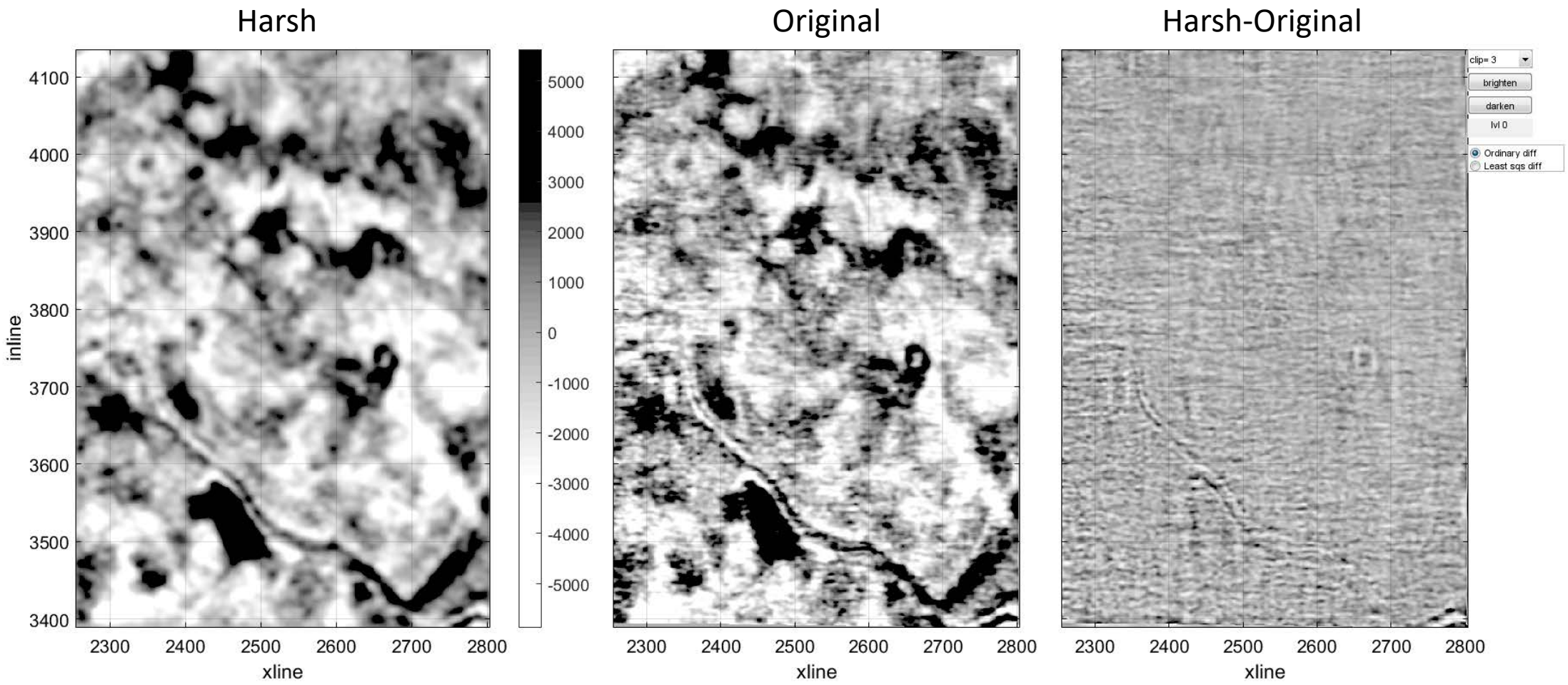
Gentle wavenumber filter - Original



CREWES tool: seisplotdiff.m

Difference plots

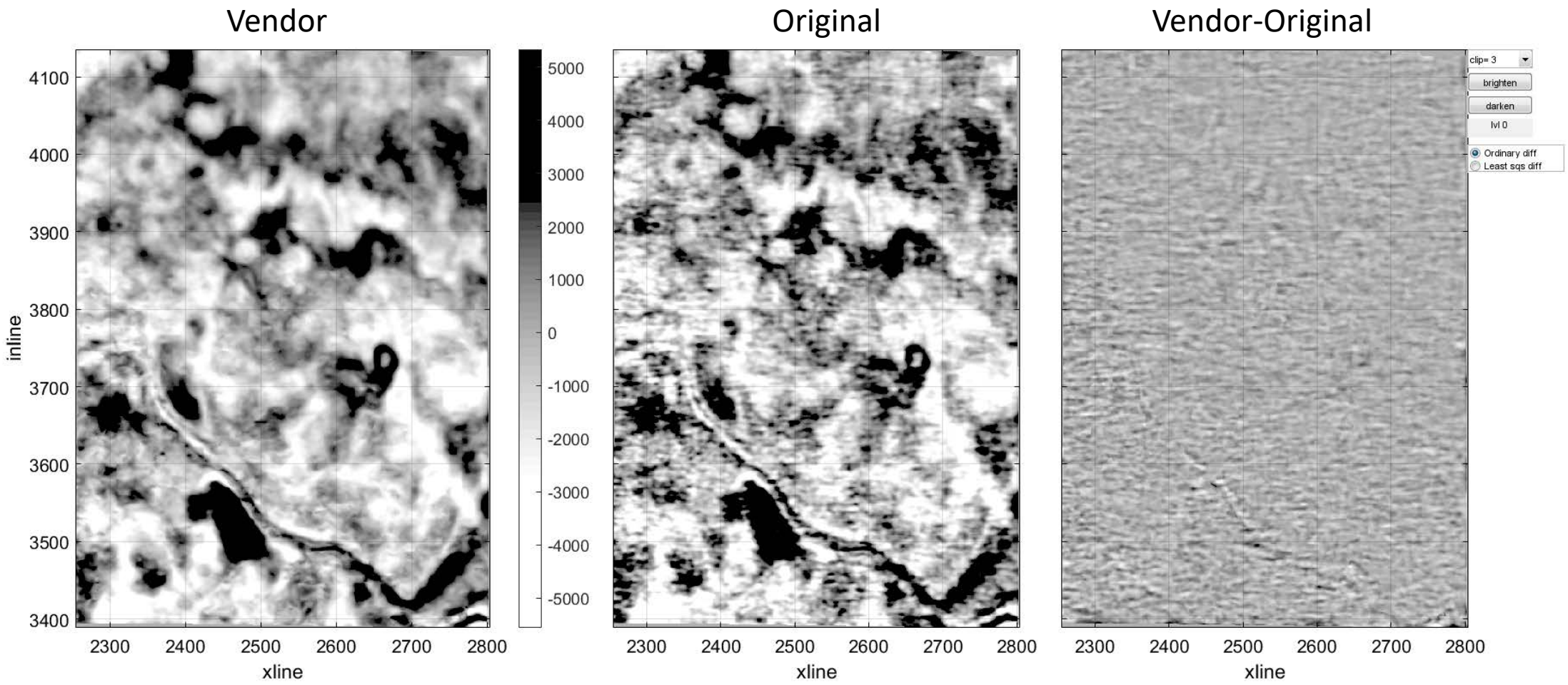
Harsh wavenumber filter - Original



CREWES tool: seisplotdiff.m

Difference plots

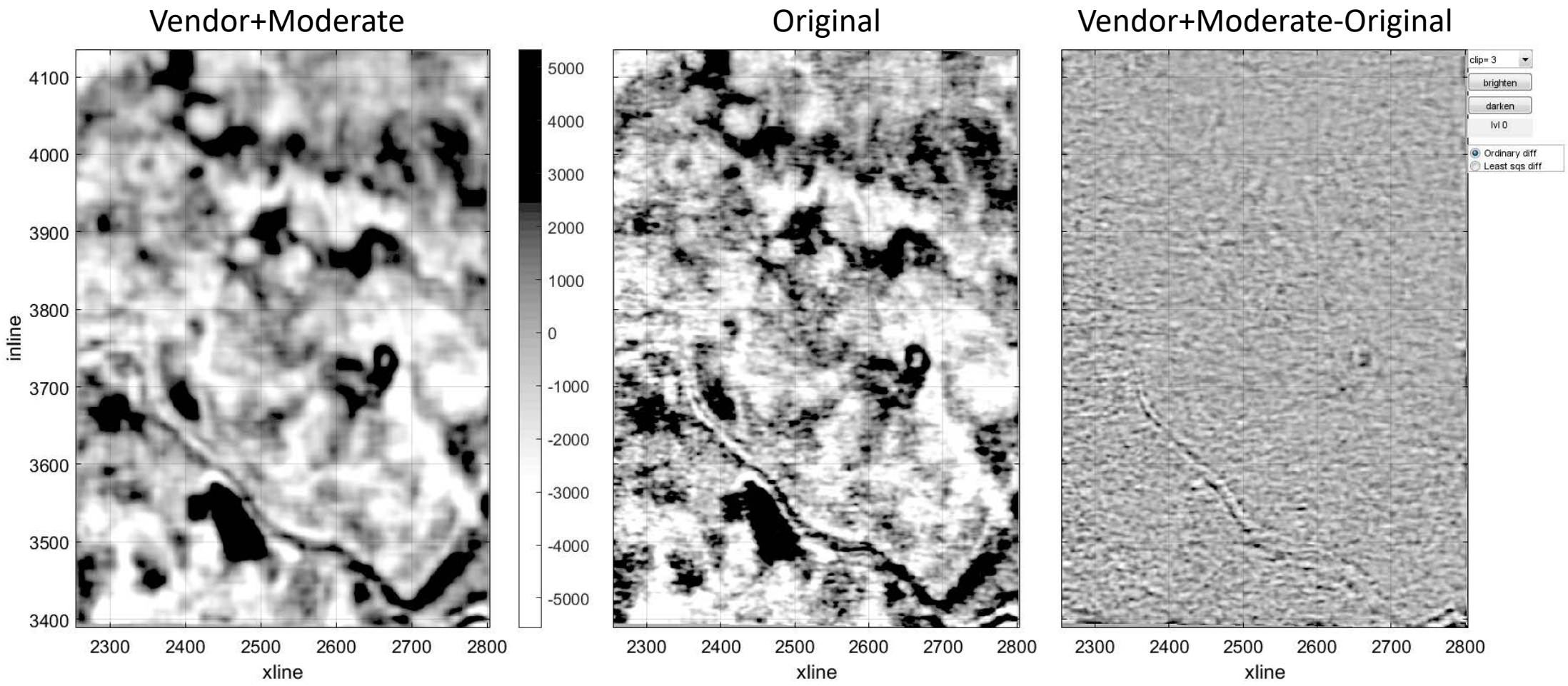
Vendor - Original



CREWES tool: seisplotdiff.m

Difference plots

Vendor+Moderate - Original



CREWES tool: seisplotdiff.m

Difference plots

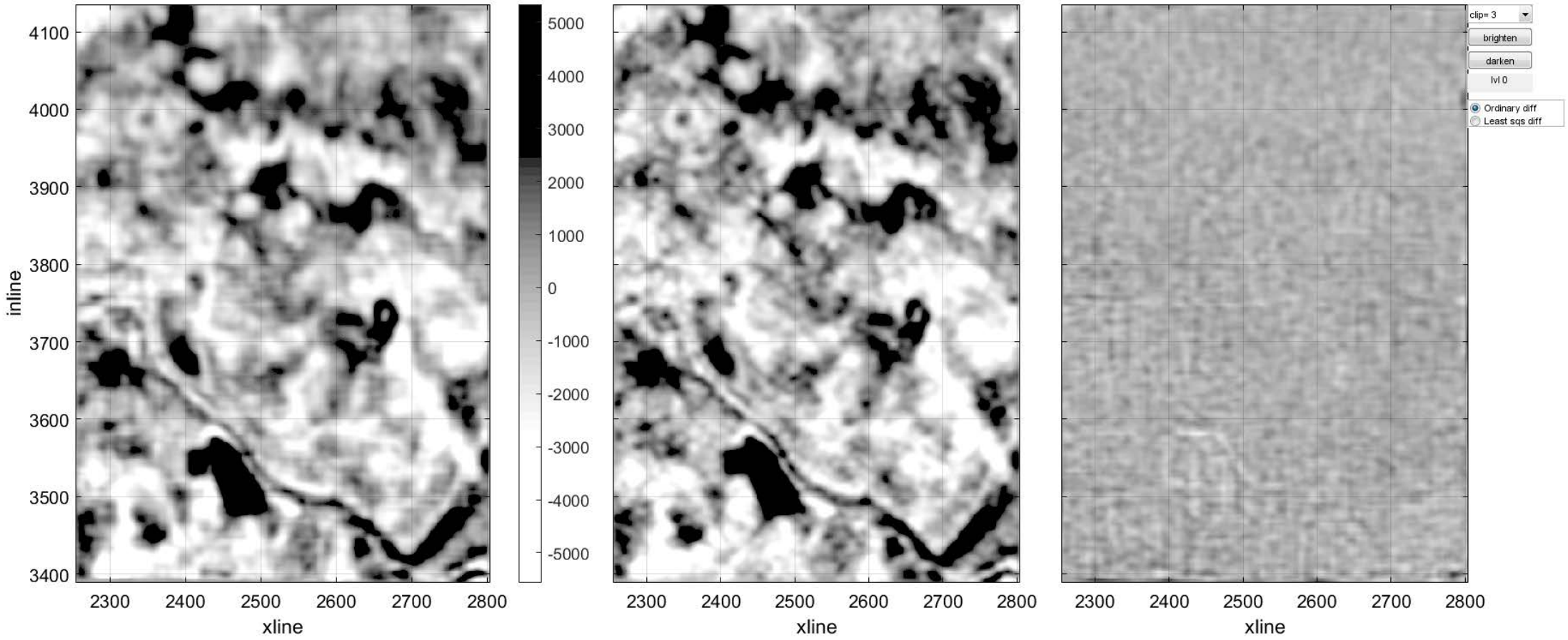
Vendor+Moderate- HARSH

These two methods have similar grid correlations

Vendor+Moderate

Harsh

Vendor+Moderate-Harsh



CREWES tool: seisplotdiff.m

Difference plots

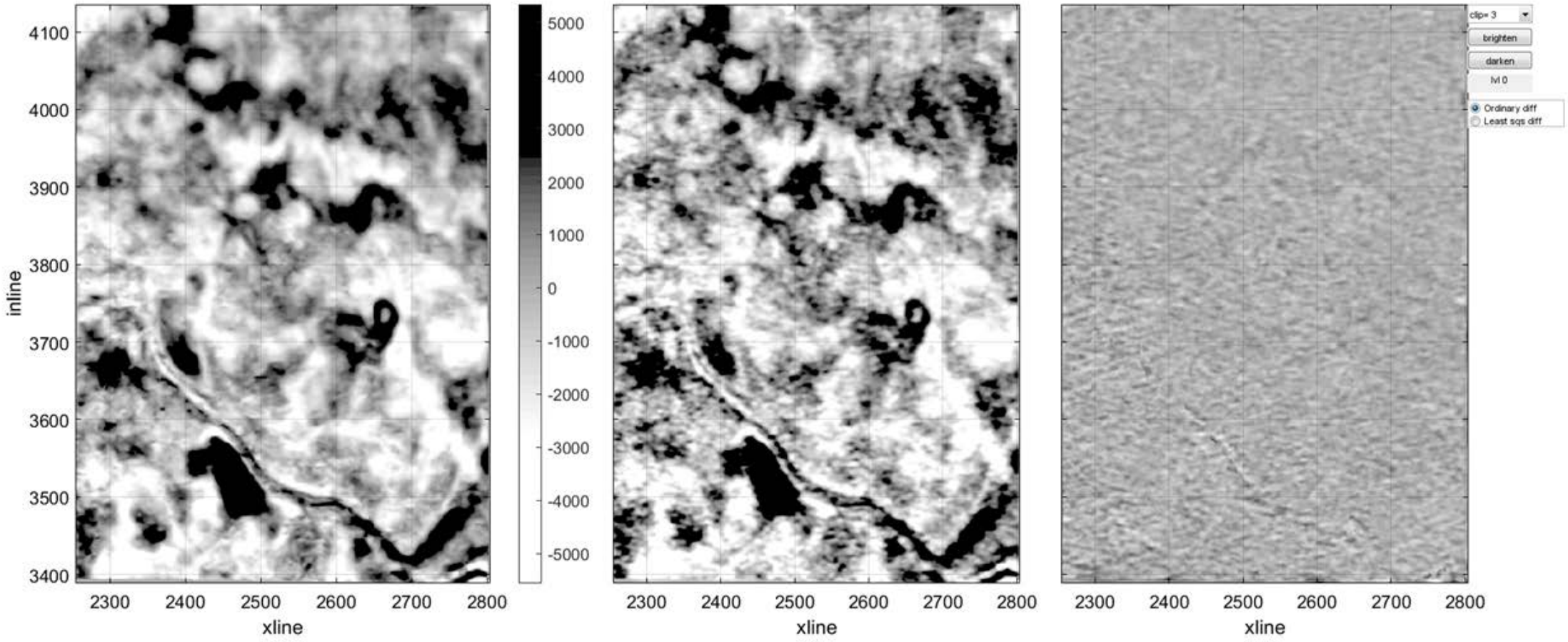
Vendor - Gentle

These two methods have similar grid correlations

Vendor

Gentle

Vendor-Gentle



CREWES tool: seisplotdiff.m

Conclusions

- Grid correlations provide an objective measure of the presence of footprint in a seismic time slice.
- Their use allows the assessment of footprint suppression methods to be less biased by visual perception.
- Neither of the two methods examined was able to completely suppress footprint without also altering the geology.

Acknowledgements

I think the sponsors of CREWES, especially Devon Canada, for their support.

Devon USA made the data available.

Colleagues at Devon provided valuable commentary and insight.

An unnamed Vendor provided the geostatistical result.