

Interferometry of a roadside DAS array in Fairbanks, AK

SEP 163, p. 91-102

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Nate Lindsey

Shan Dou

Jonathan Ajo-Franklin

Anna Wagner

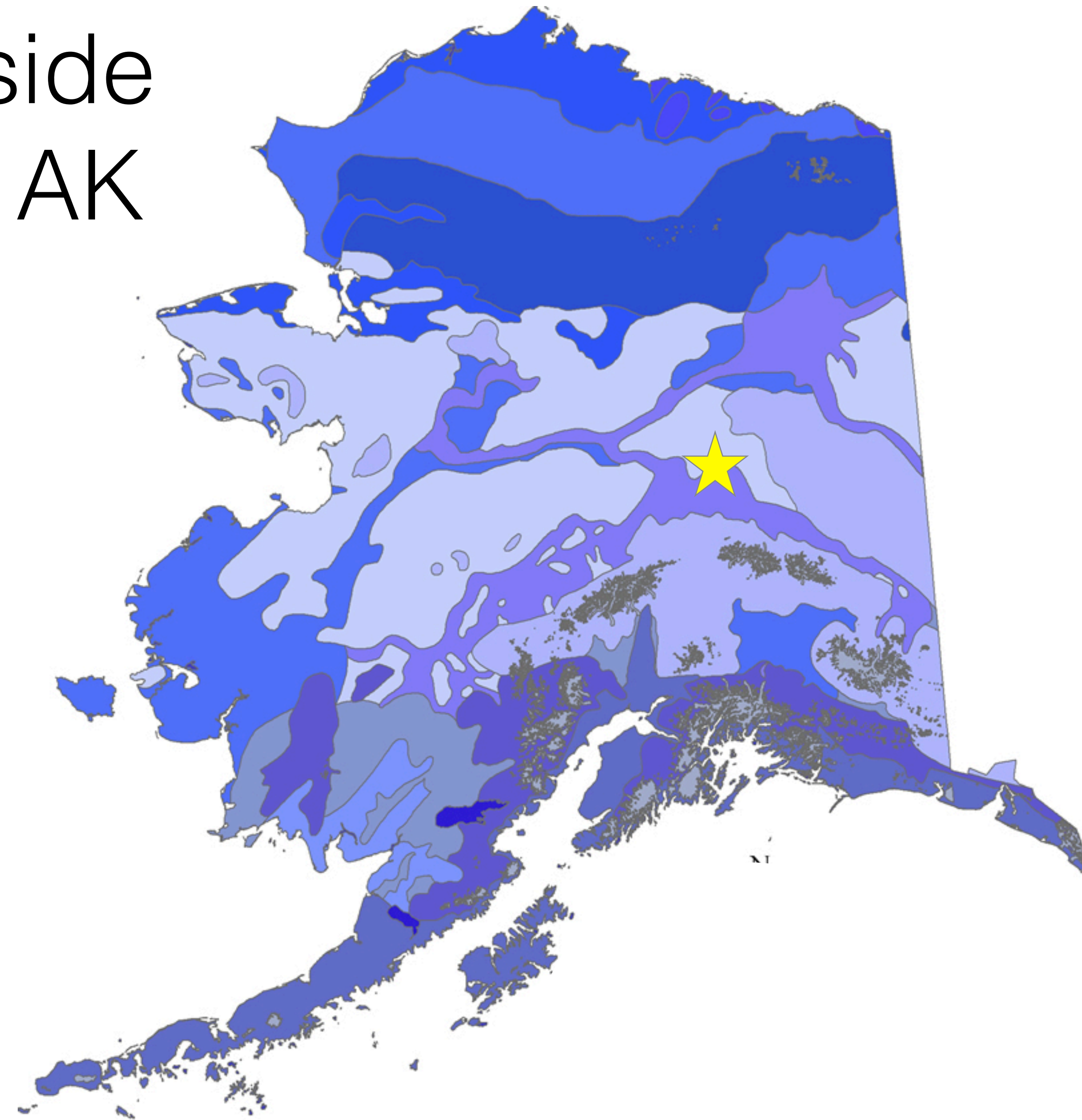
Kevin Bjella

Tom Daley

Barry Freifeld

Michelle Robertson

Craig Ulrich



Developing Smart Infrastructure for a Changing Arctic Environment Using Distributed Fiber-Optic Sensing Methods

PI: Jonathan Ajo-Franklin, LBNL

Co-PI: Anna Wagner, CRREL



"Transpolar Railway between Salekhard and Nadym" by ru:Участник:ComIntern - ru:Файл:Перегон Салехард-Надым.jpg. Licensed under GFDL via Commons

Goal: low-cost frequent monitoring of the near surface

Method: passive seismic collected by fiber optics with low-cost per sensor



Jonathan Ajo-Franklin, LBNL



Tom Daley, LBNL



Barry Freifeld, LBNL



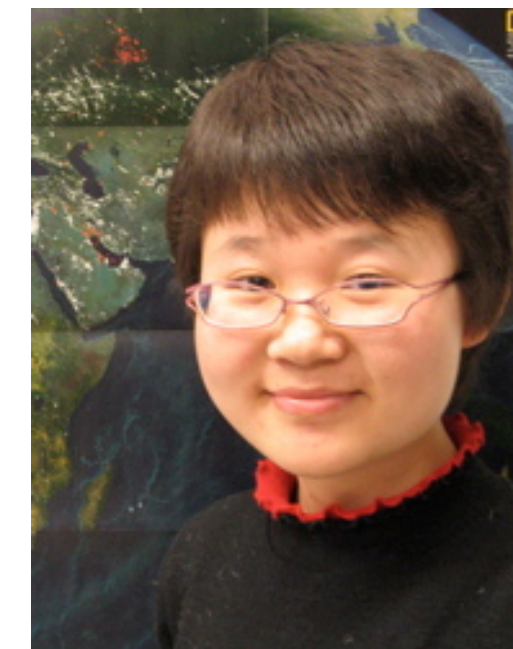
Michelle Robertson, LBNL



Craig Ulrich, LBNL



Nate Lindsey, UC Berkeley, LBNL



Shan Dou, LBNL

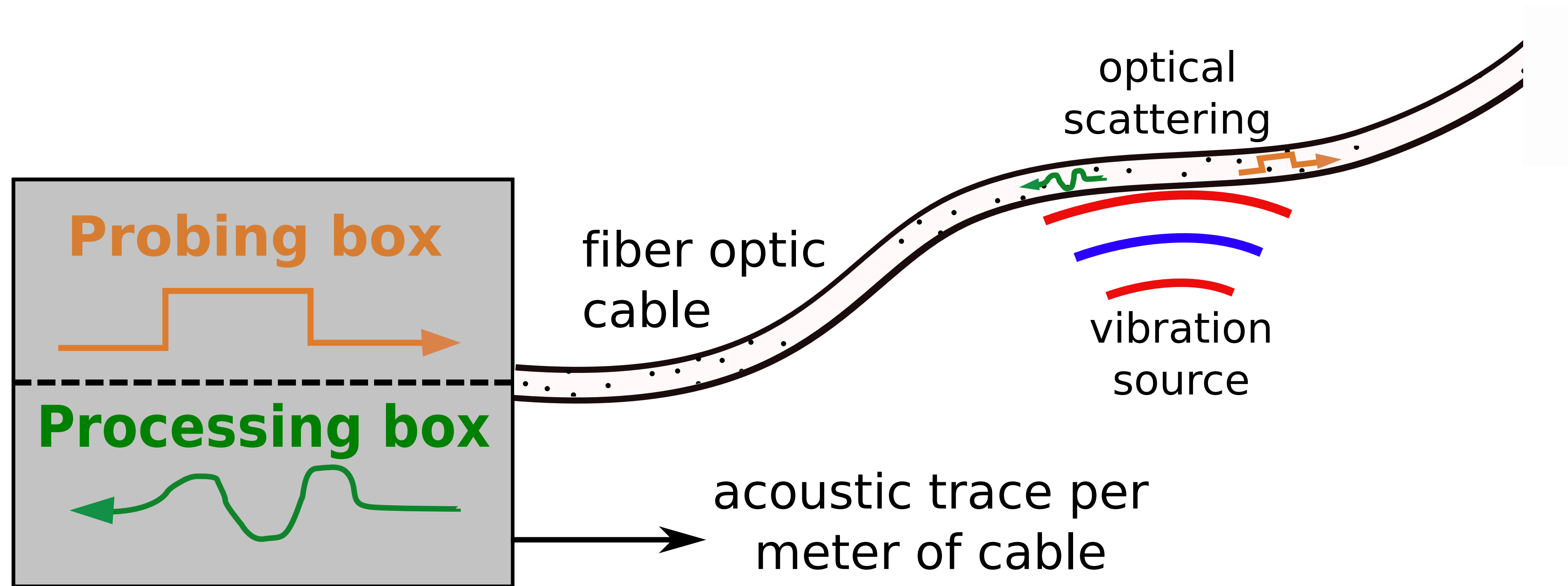


Anna Wagner
US Army Corps of Engineers
Cold Regions Research & Engineering Lab



Kevin Bjella

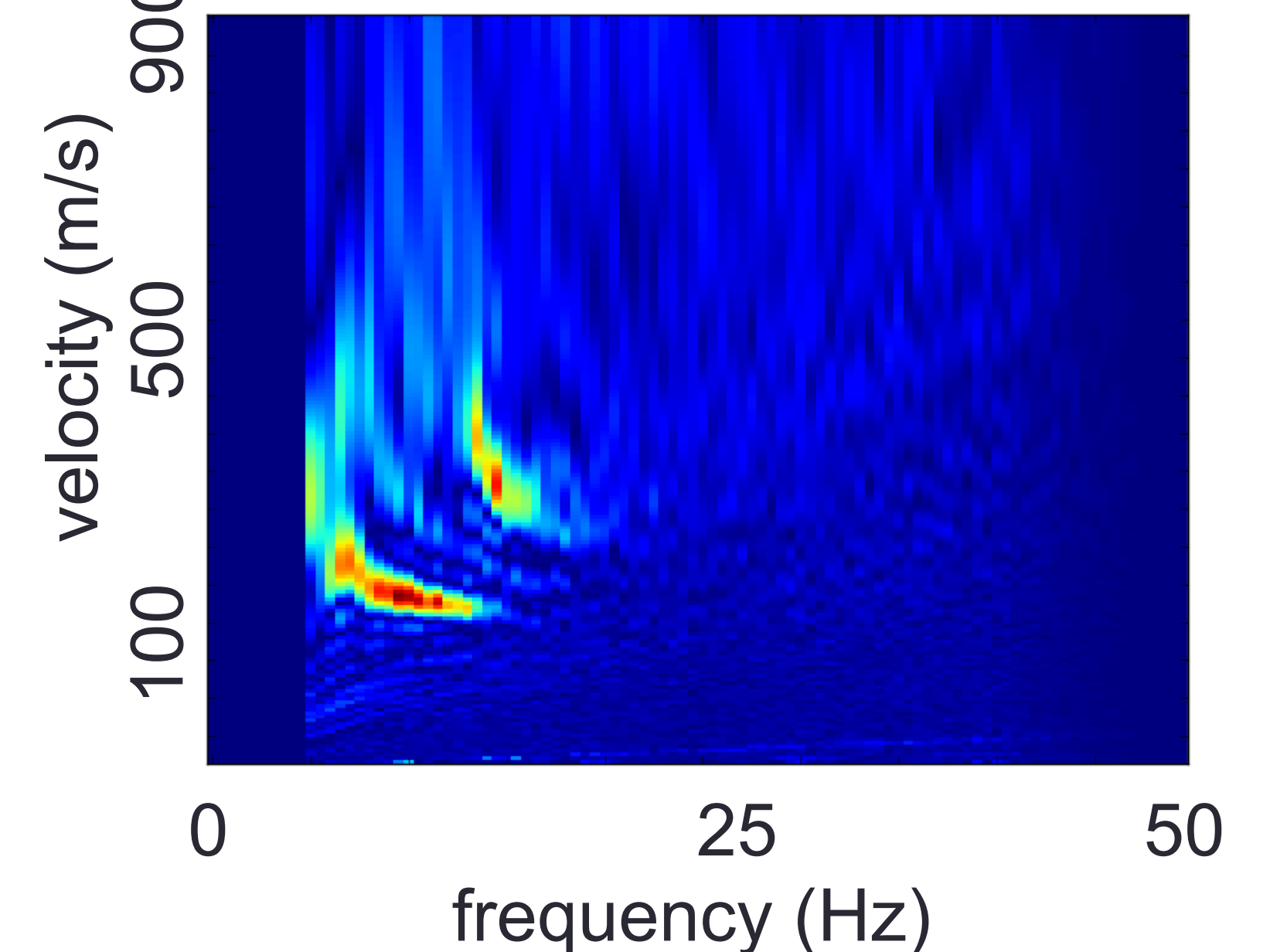
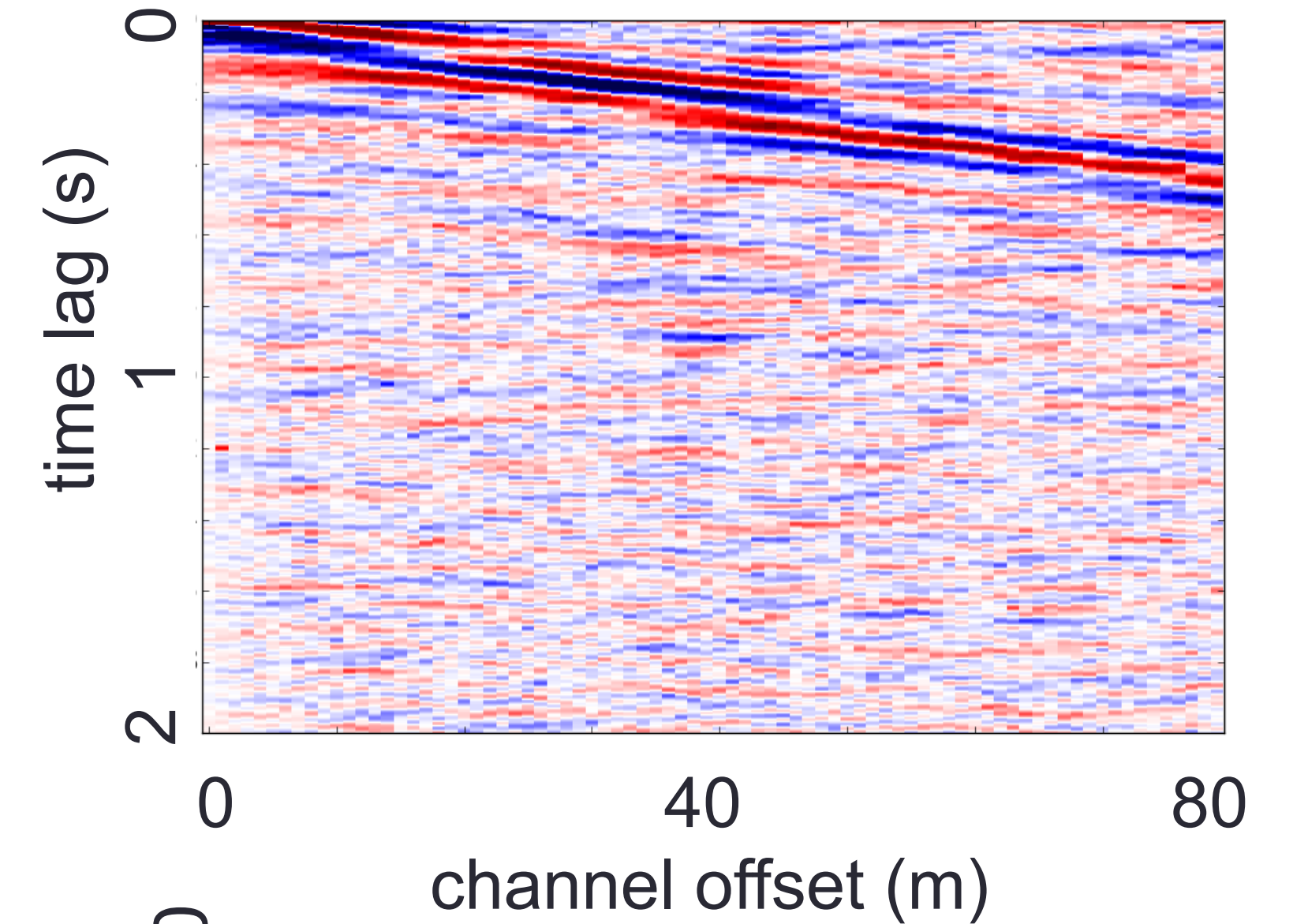
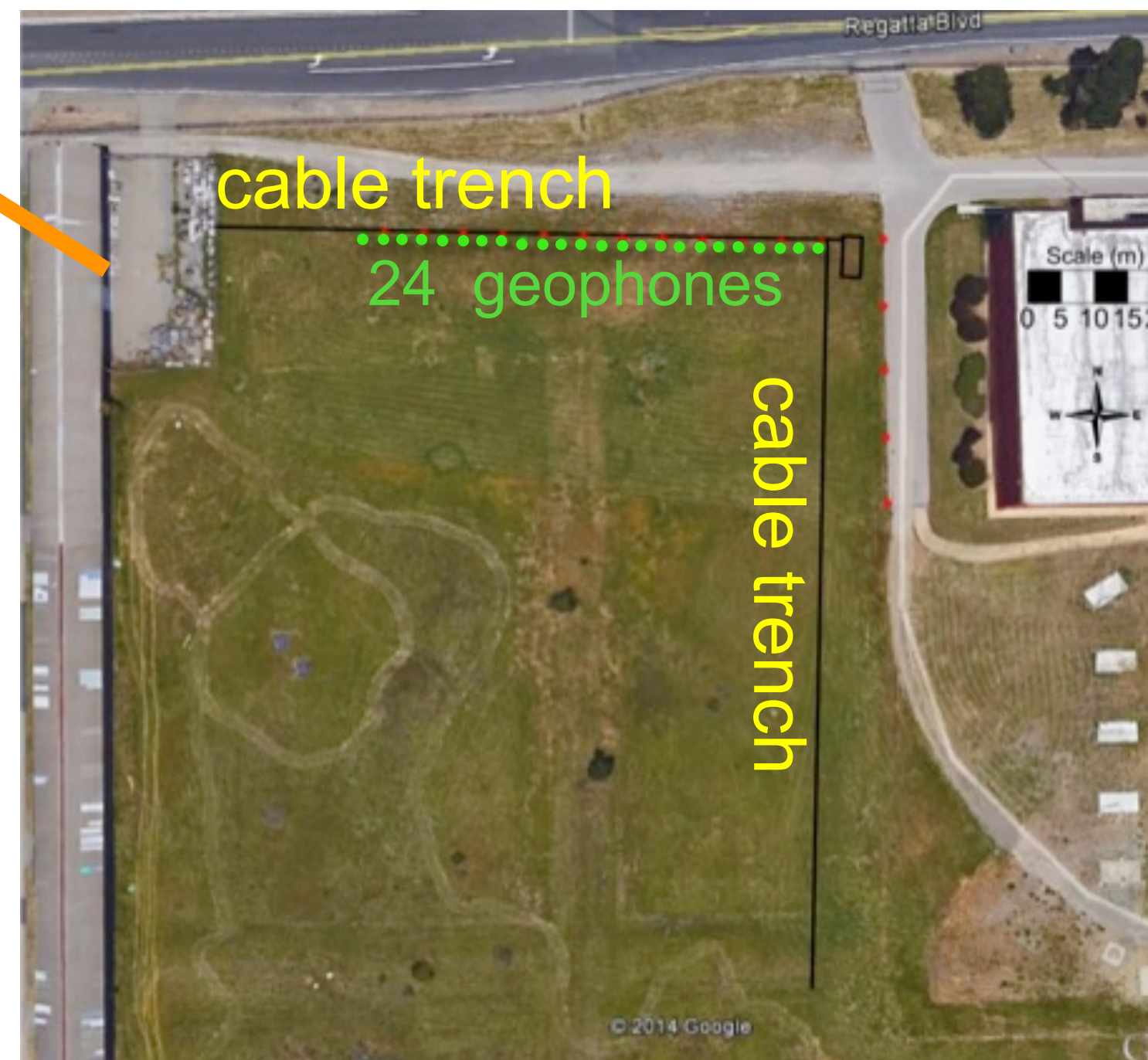
How distributed acoustic sensing (DAS) works



Review of pilot test, Richmond Field Station



Small trenched array showed that we could extract coherent signal from short passive DAS recordings.



References for RFS pilot

Deployment:

JAF, NL, TD, BF, EM, MR, CU, AW, *A field test of distributed acoustic sensing for ambient noise recording*, SEG extended abstracts 2015.

DAS interferometry:

EM, JAF, SD, NL, TD, BF, MR, AW, CU, *Interferometry of ambient noise from a trenched distributed acoustic sensing array*, SEG extended abstracts 2015.

Fast dispersion images, paper in preparation:

E. Martin, *Fast dispersion curves from ambient noise*, SEP 158, 2015.



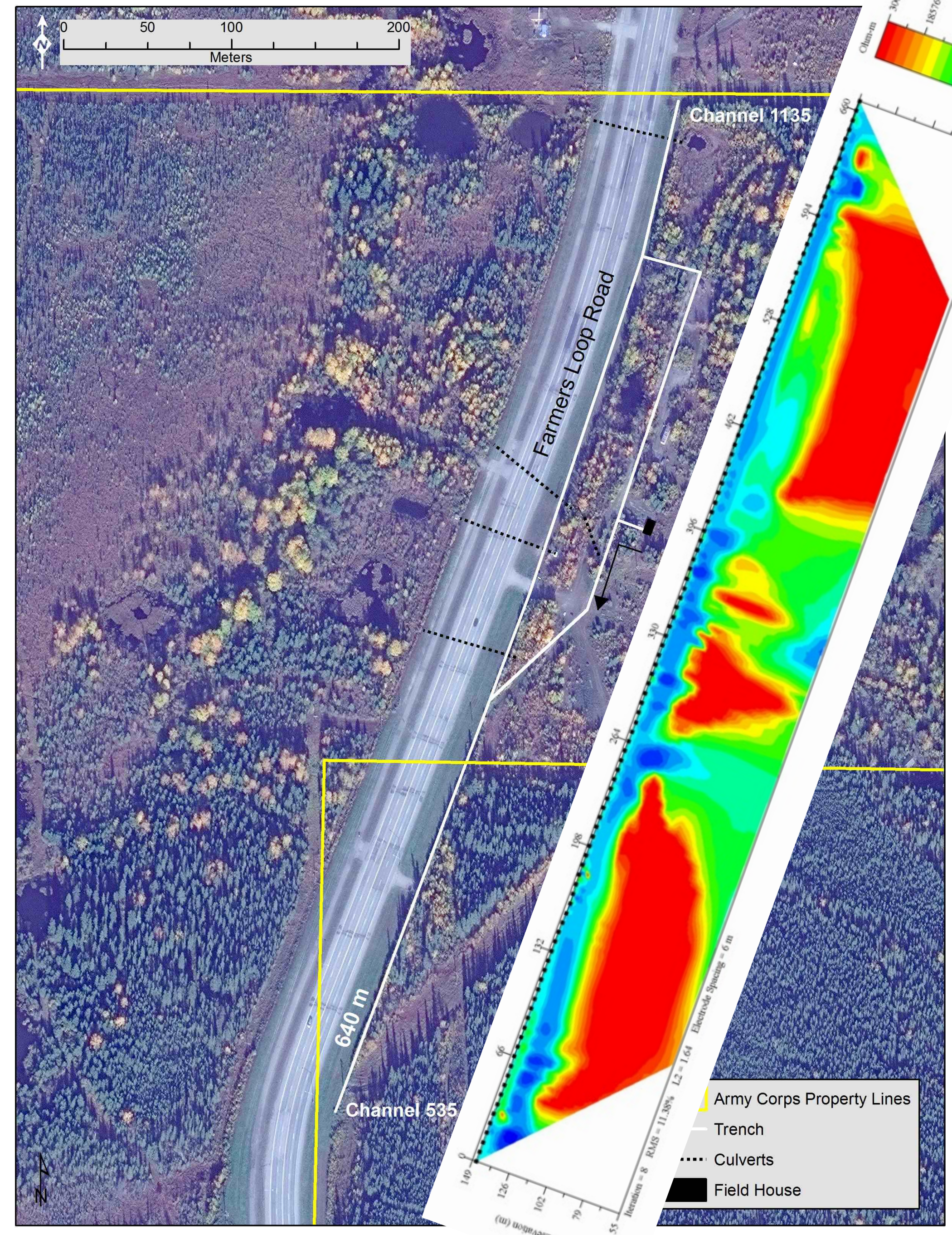
Site

patchy permafrost
 wooded area
 1 mi north of Fairbanks
 highway 400 m east

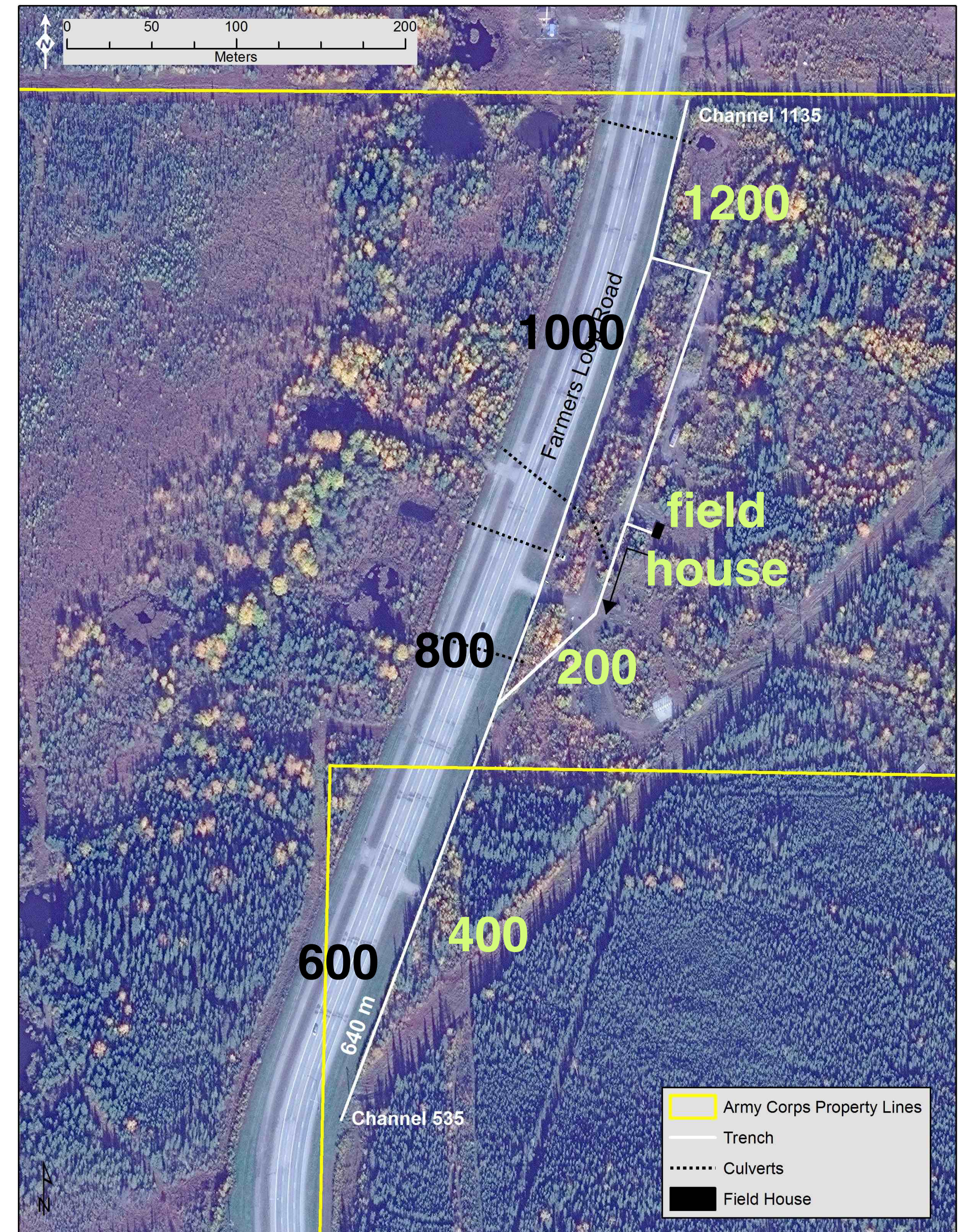
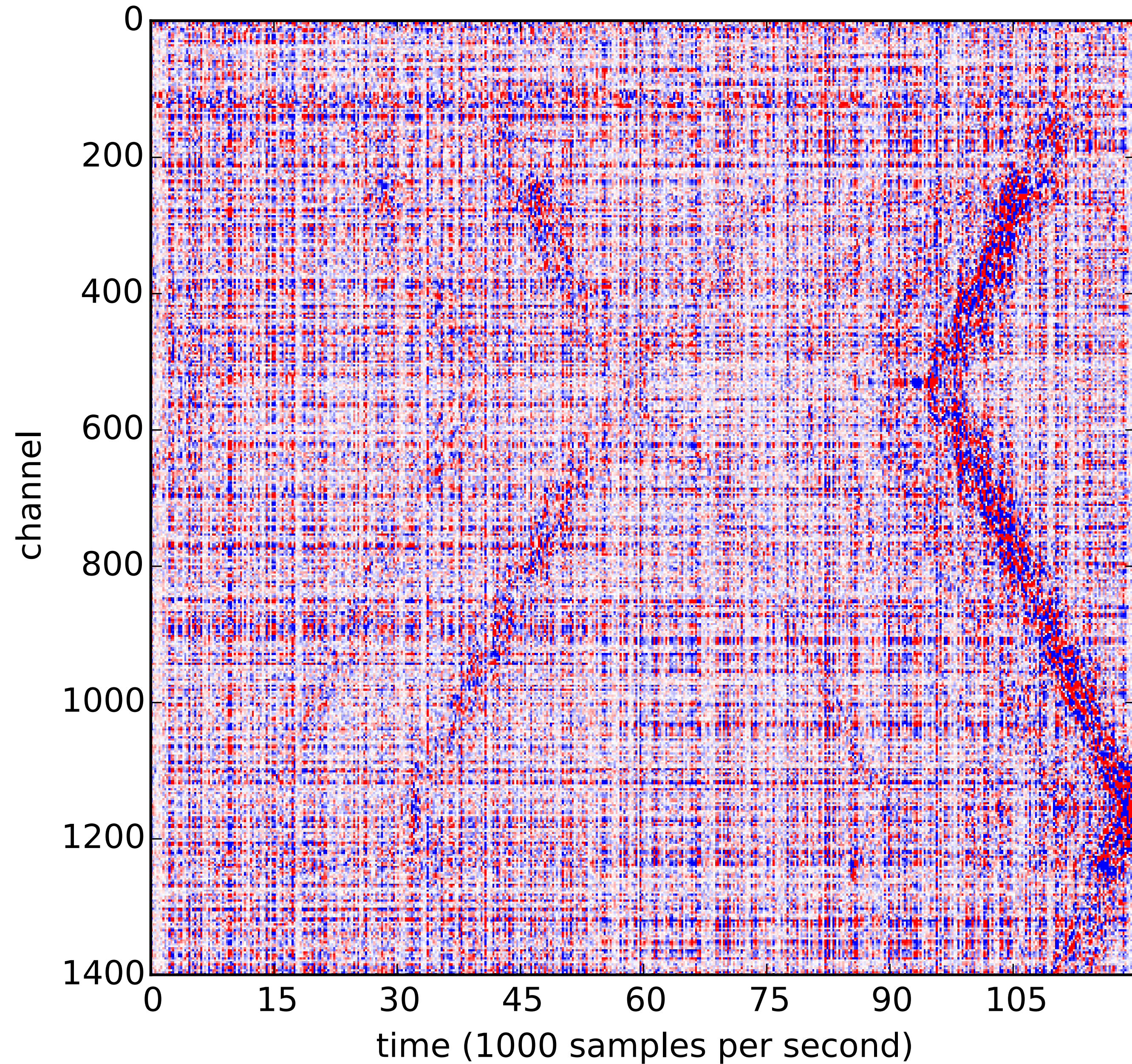
passive recording



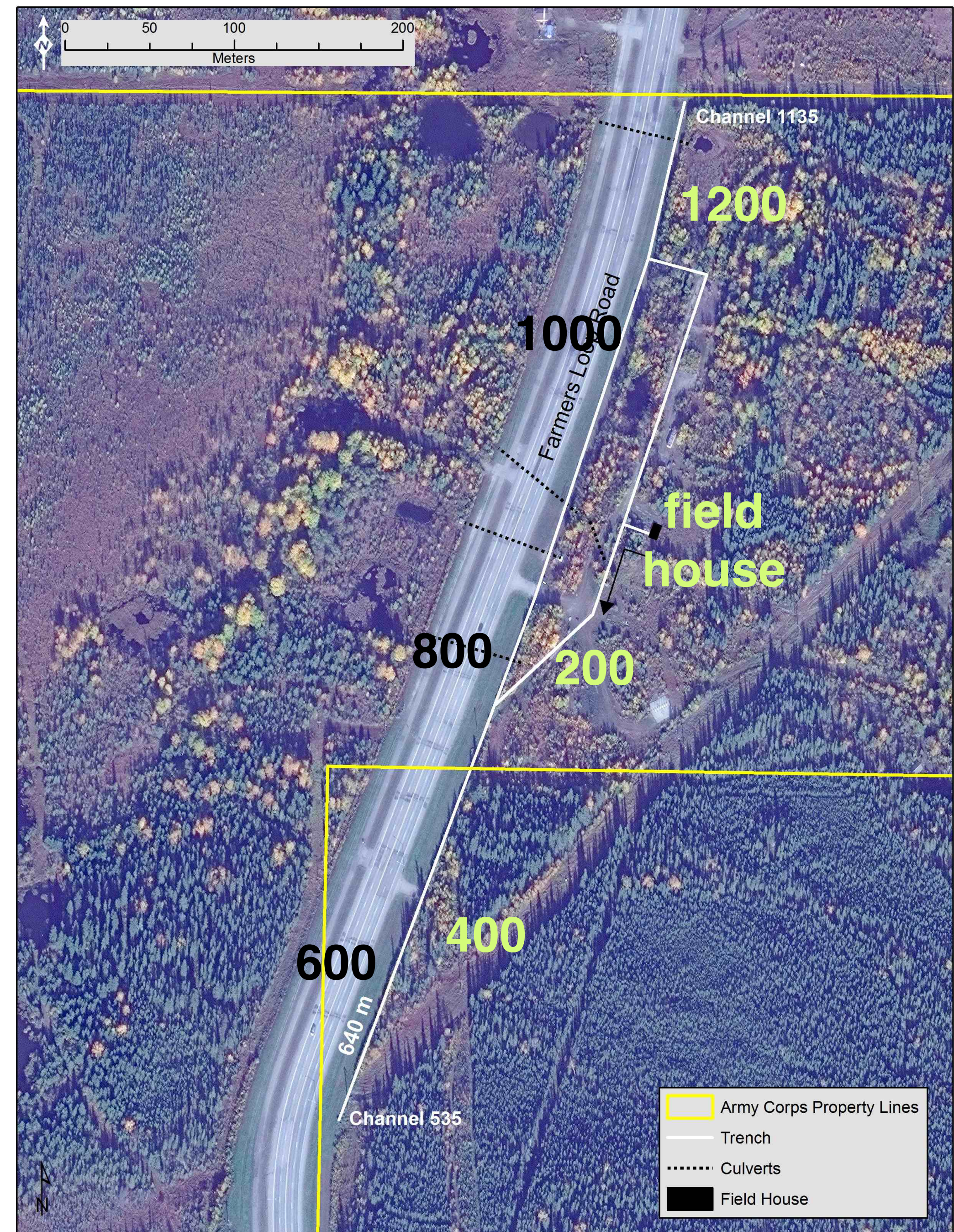
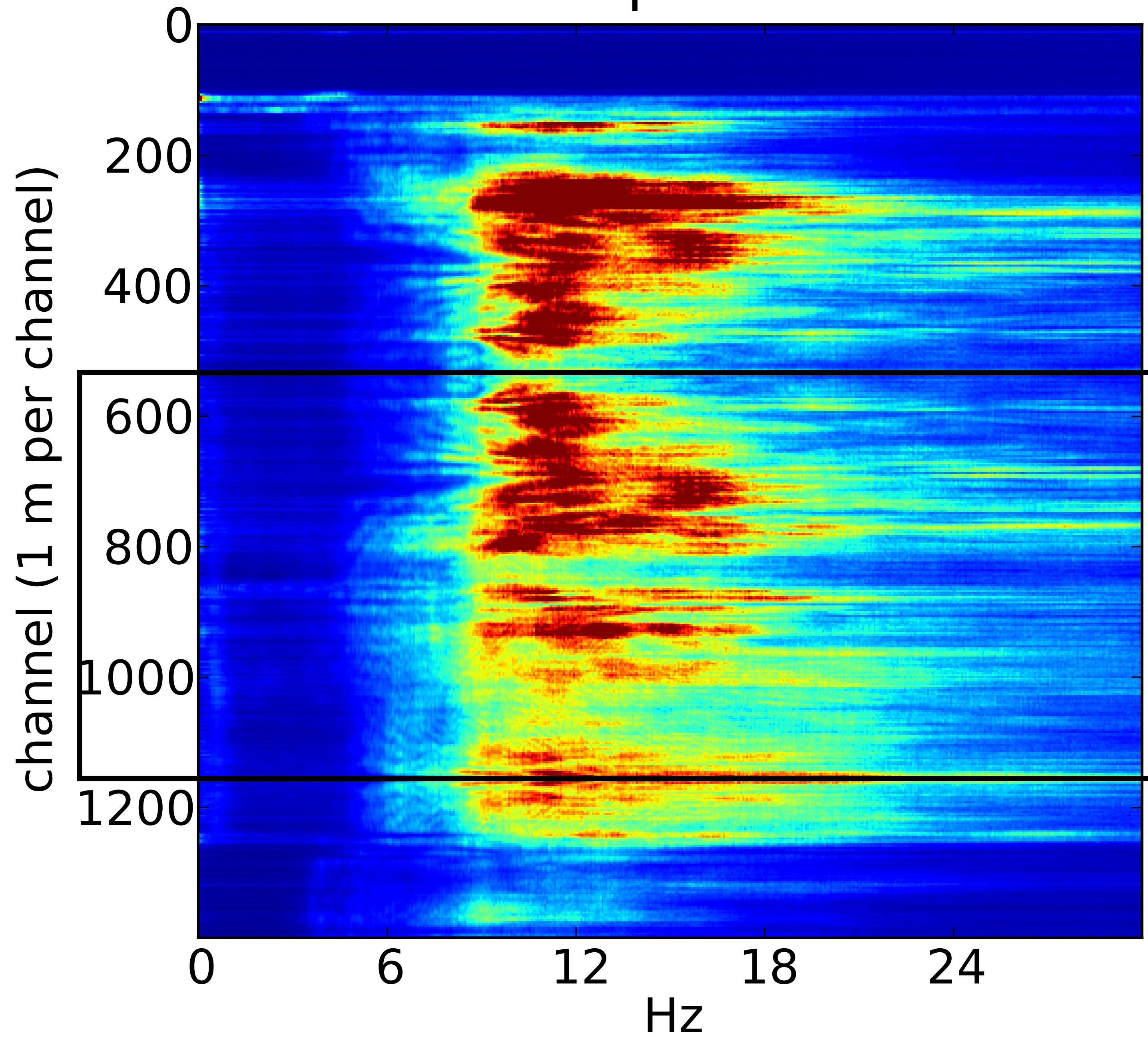
1 m channel spacing
 10 m gauge length
 1 kHz recording



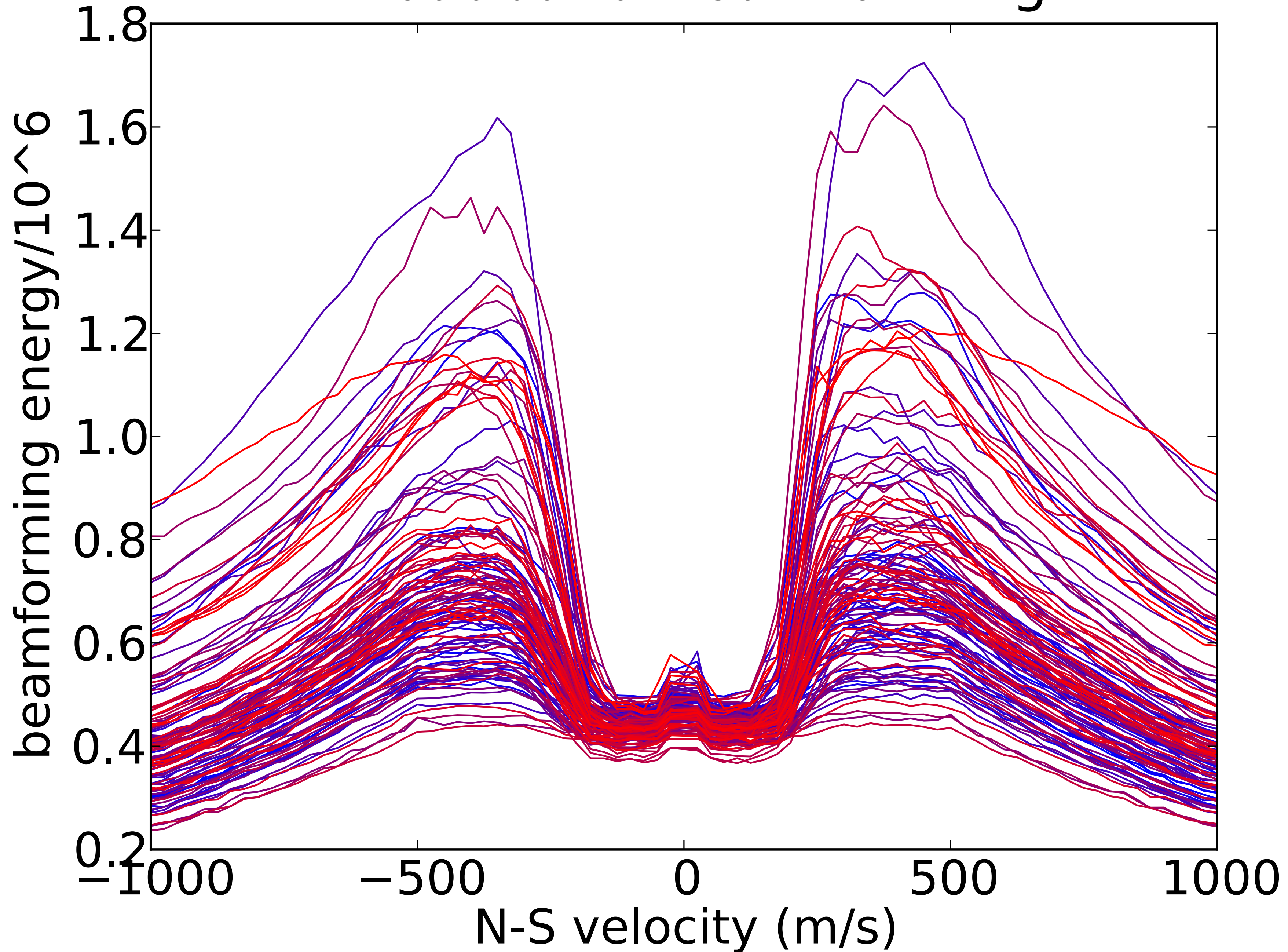
Raw data



Zoomed spectral stack

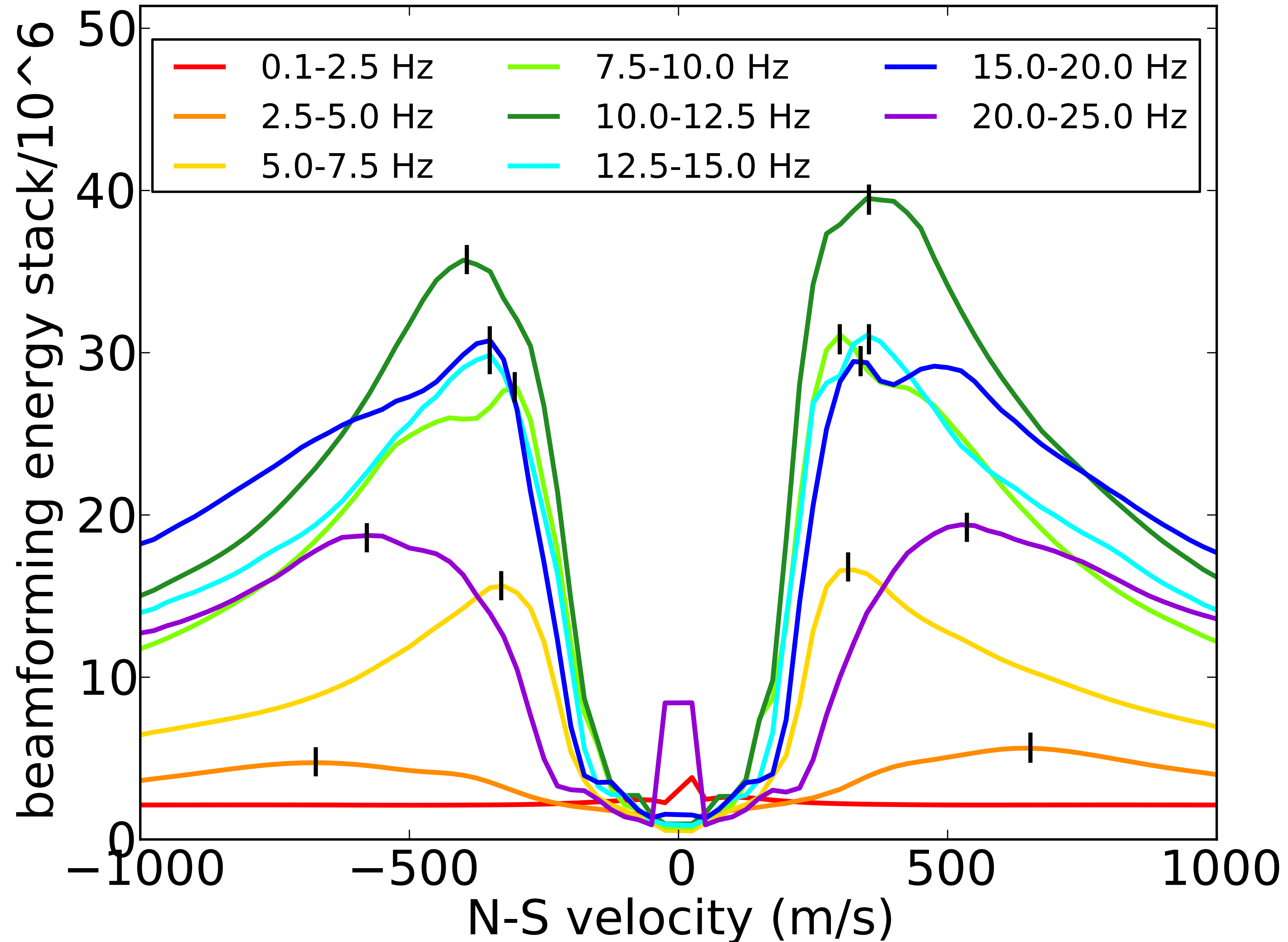


Broadband Beamforming

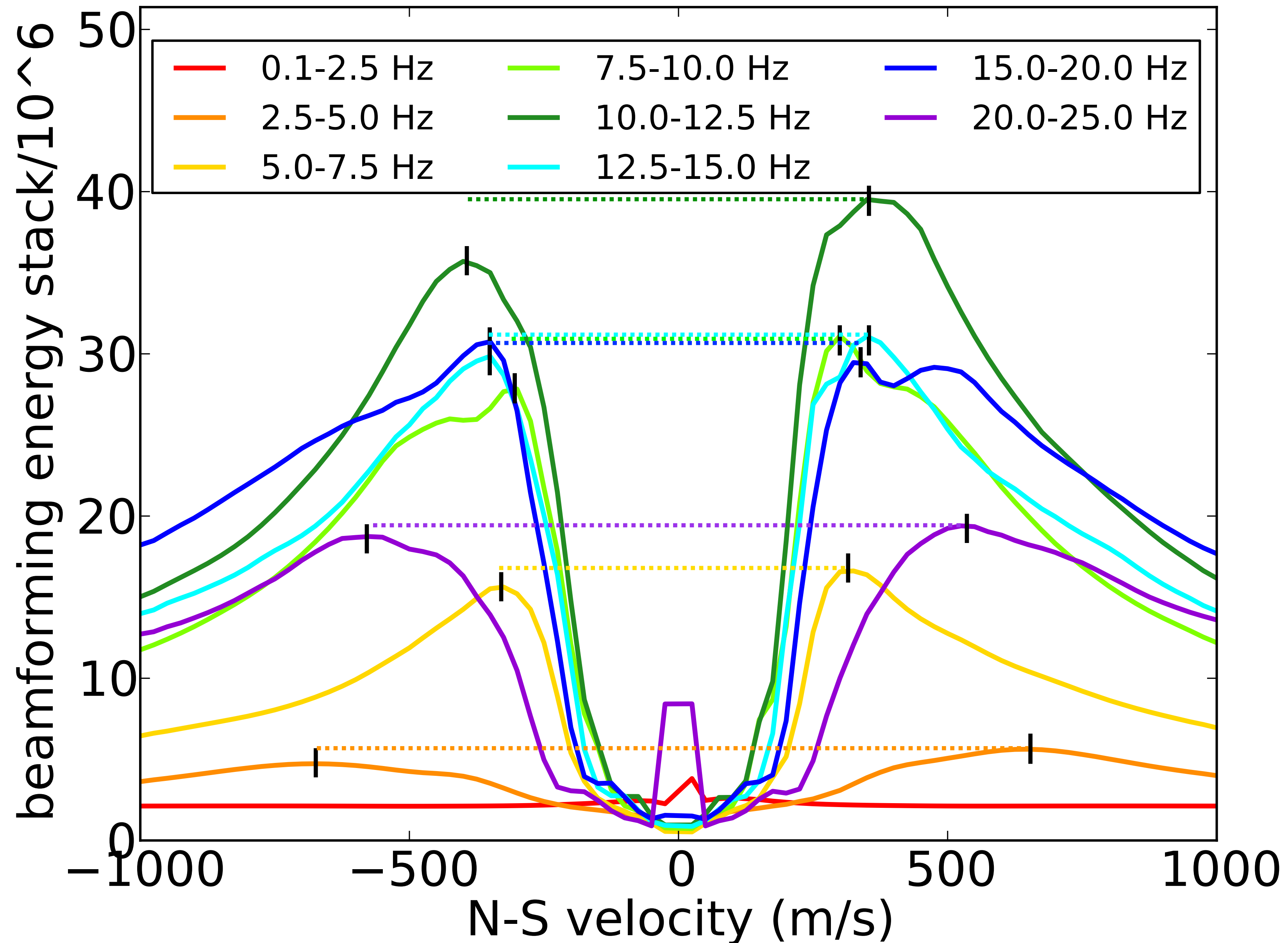


blue earlier
red later

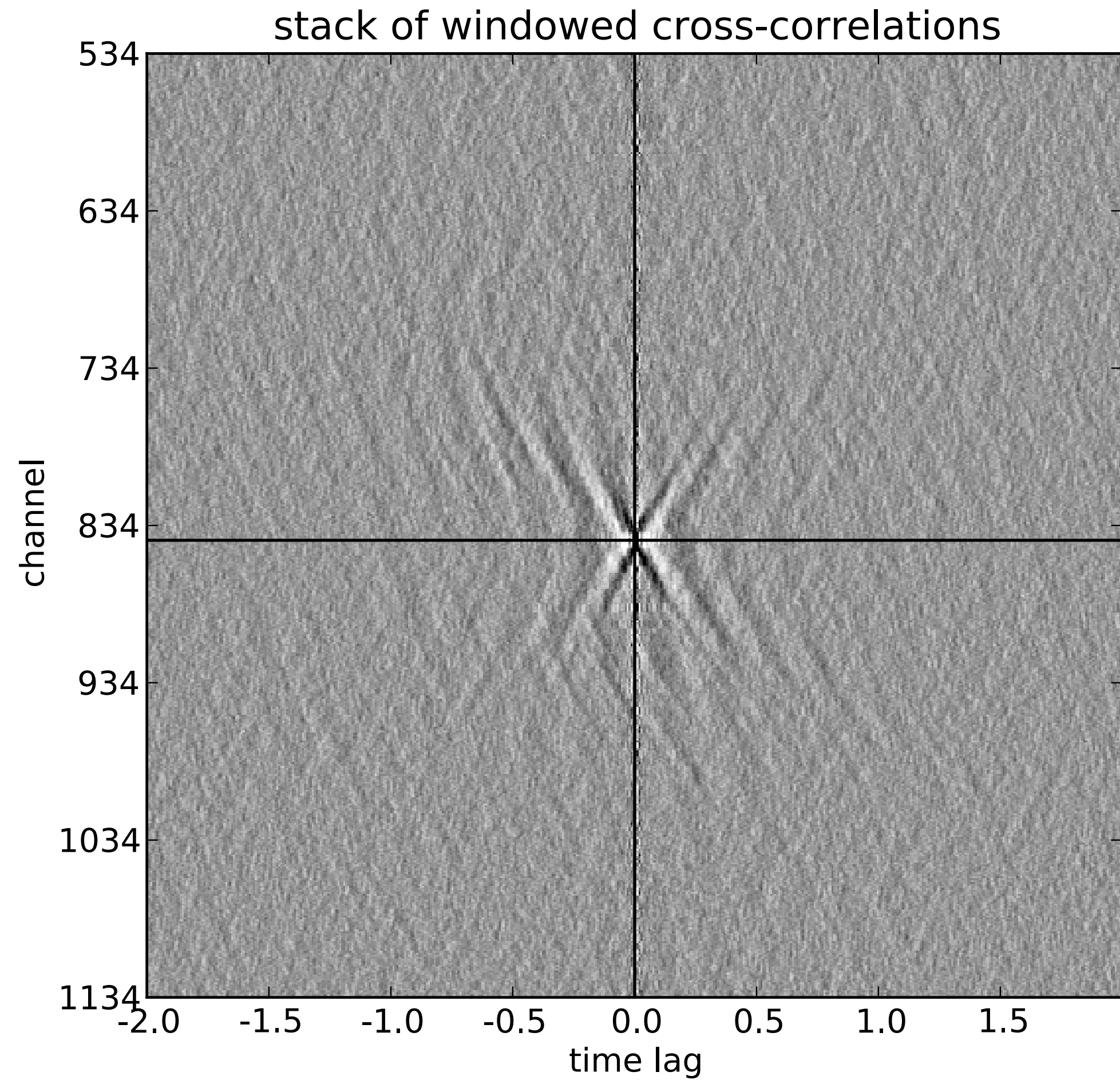
slightly more energy is coming from the south <15 Hz



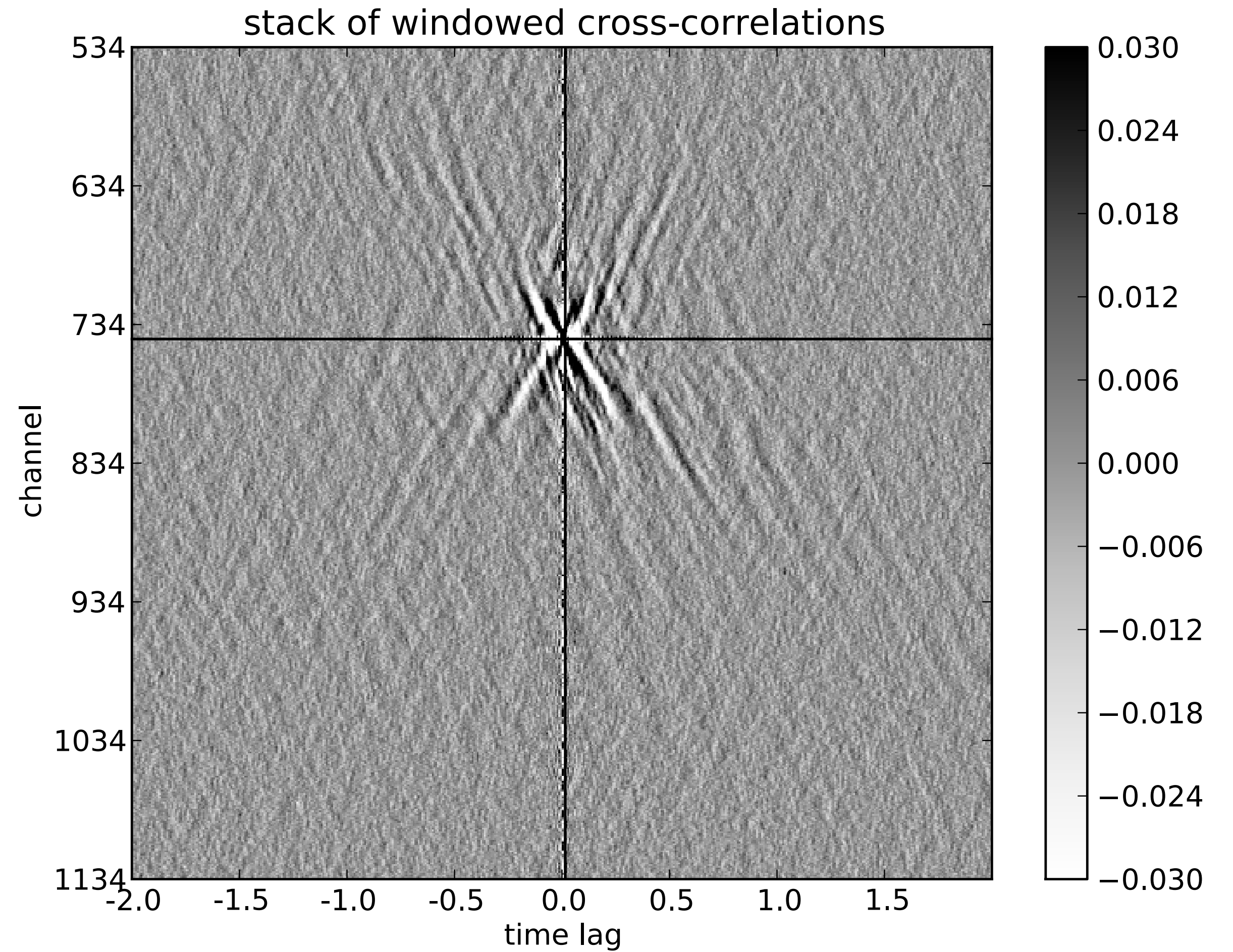
slightly more energy is coming from the south <15 Hz



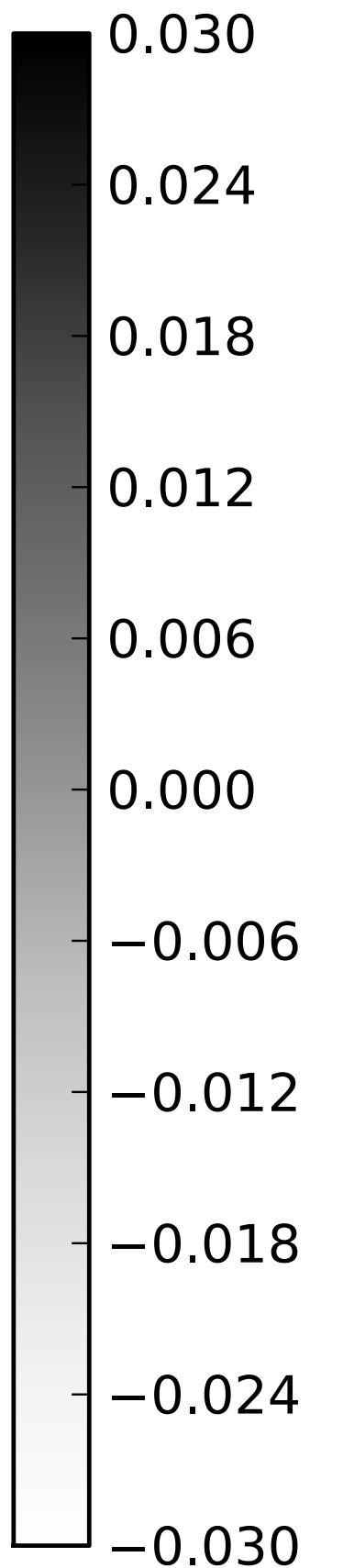
Cross-correlations



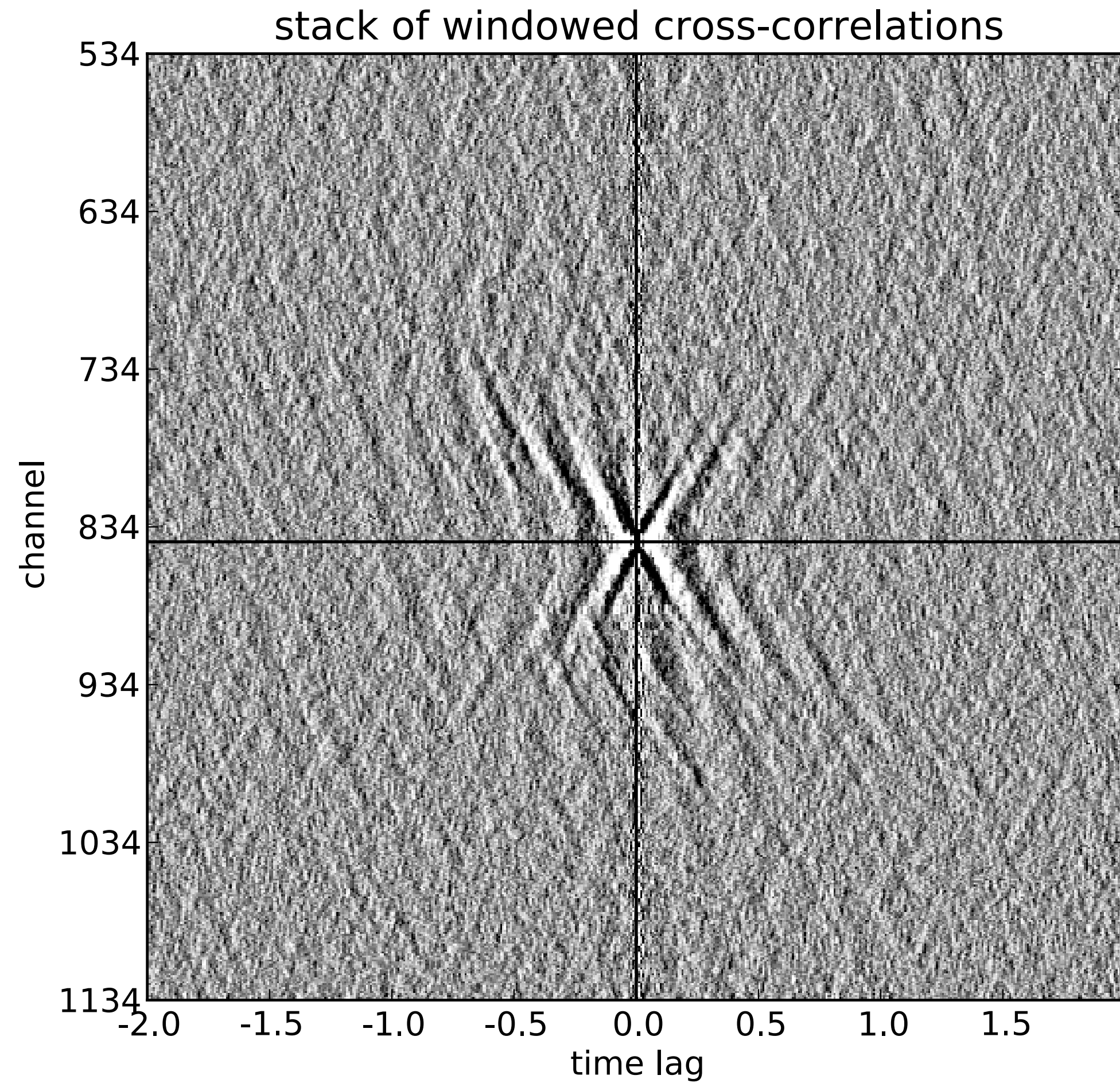
Channel 844



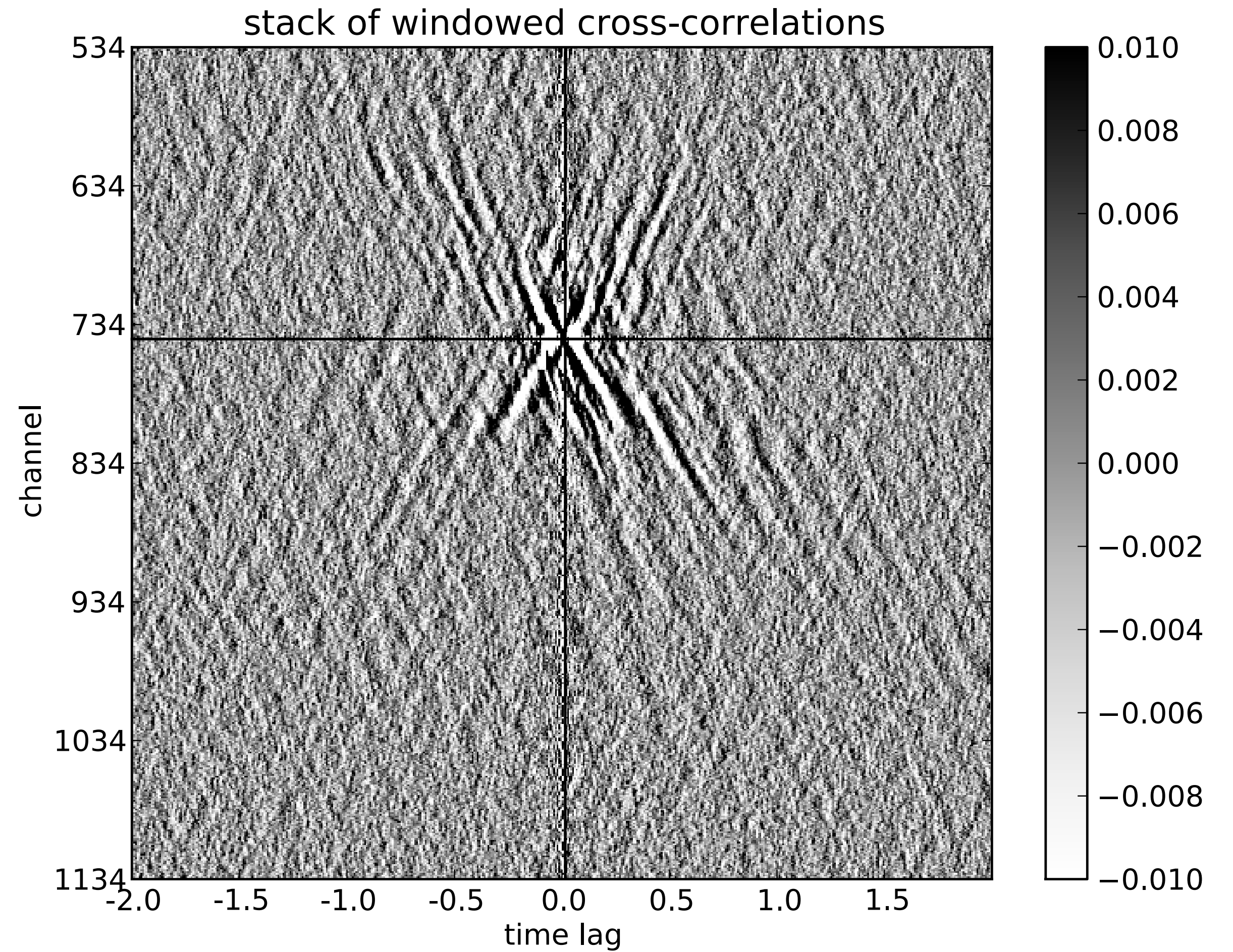
Channel 745



Cross-correlations

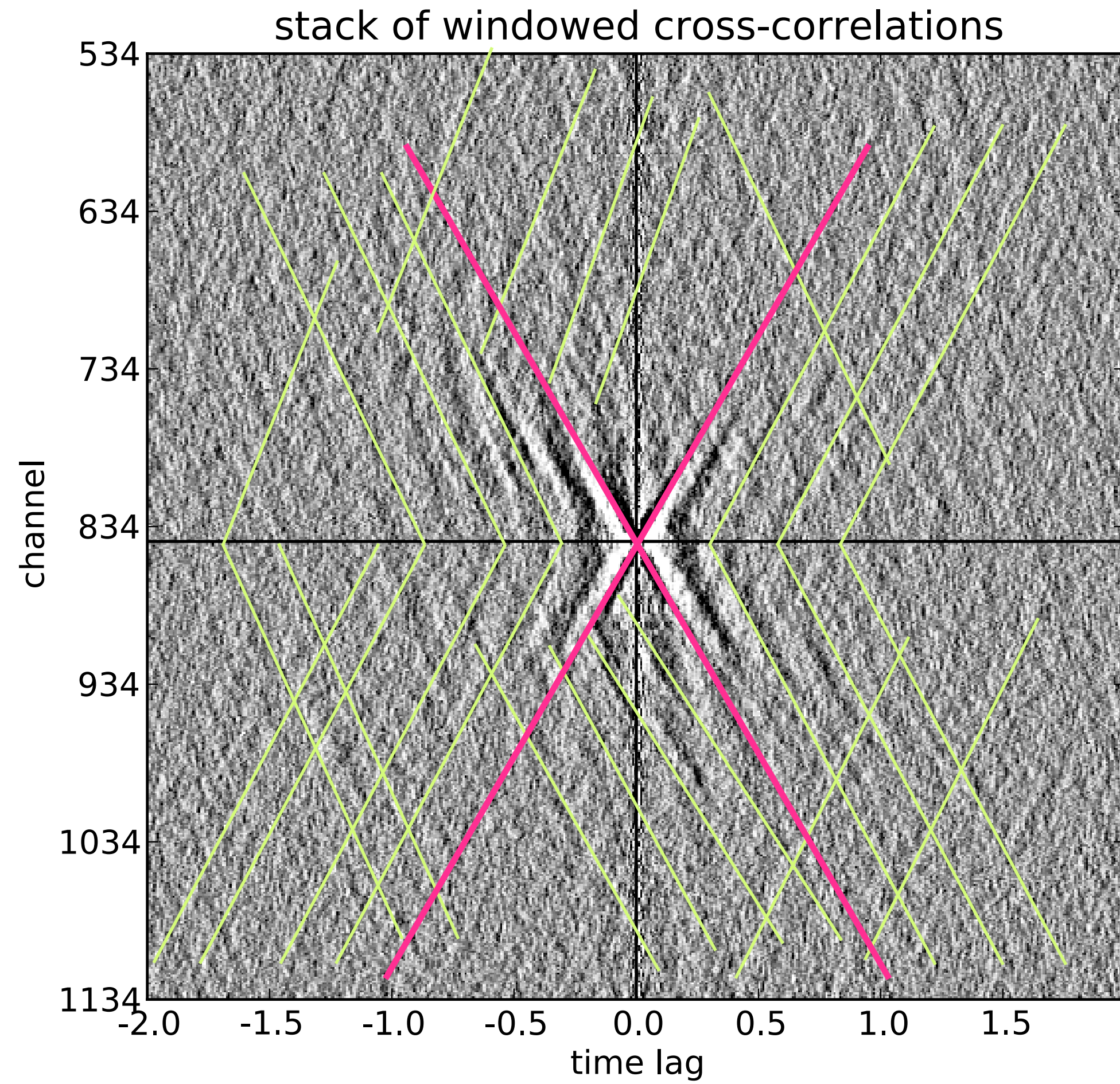


Channel 844

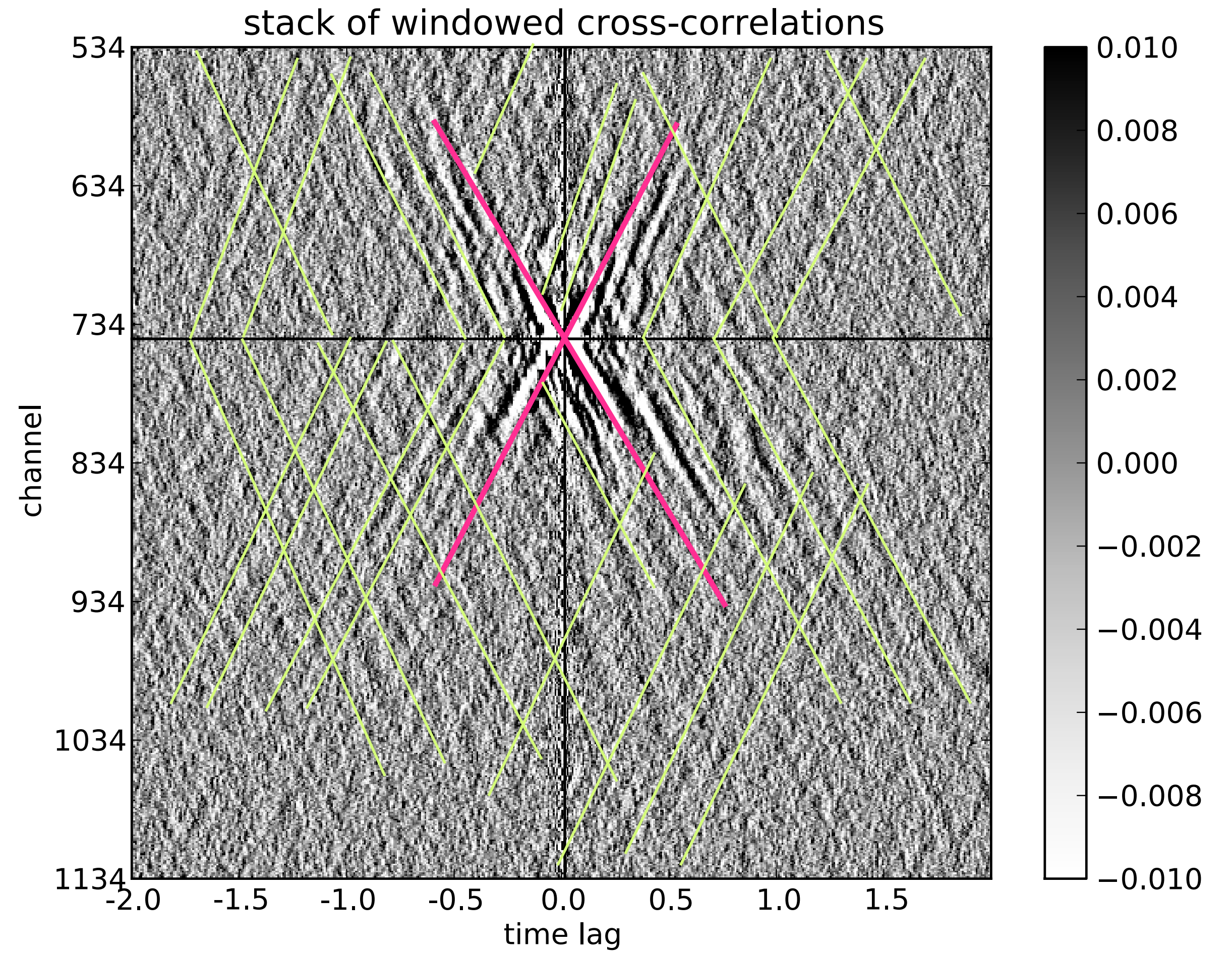


Channel 745

Cross-correlations



Channel 844

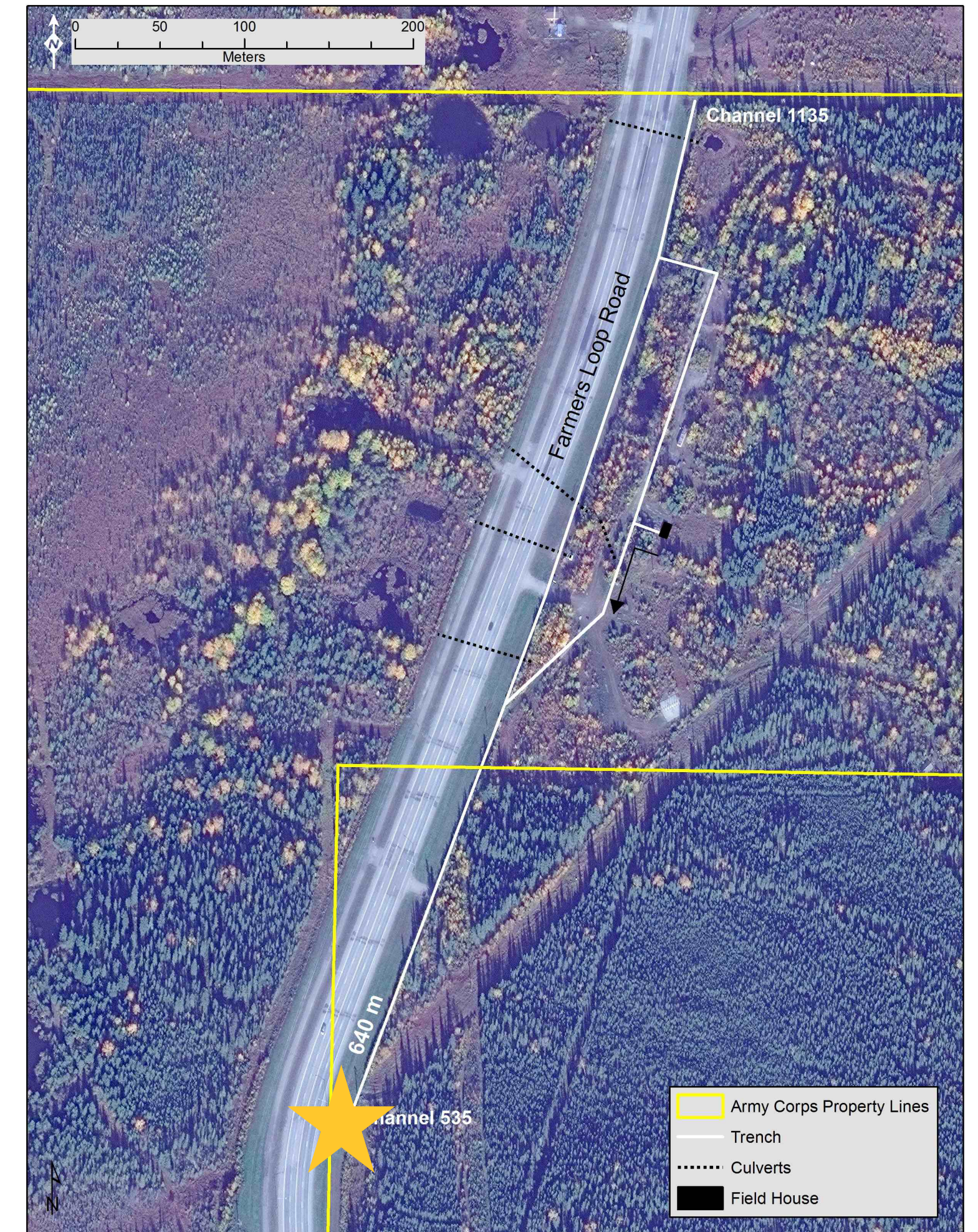
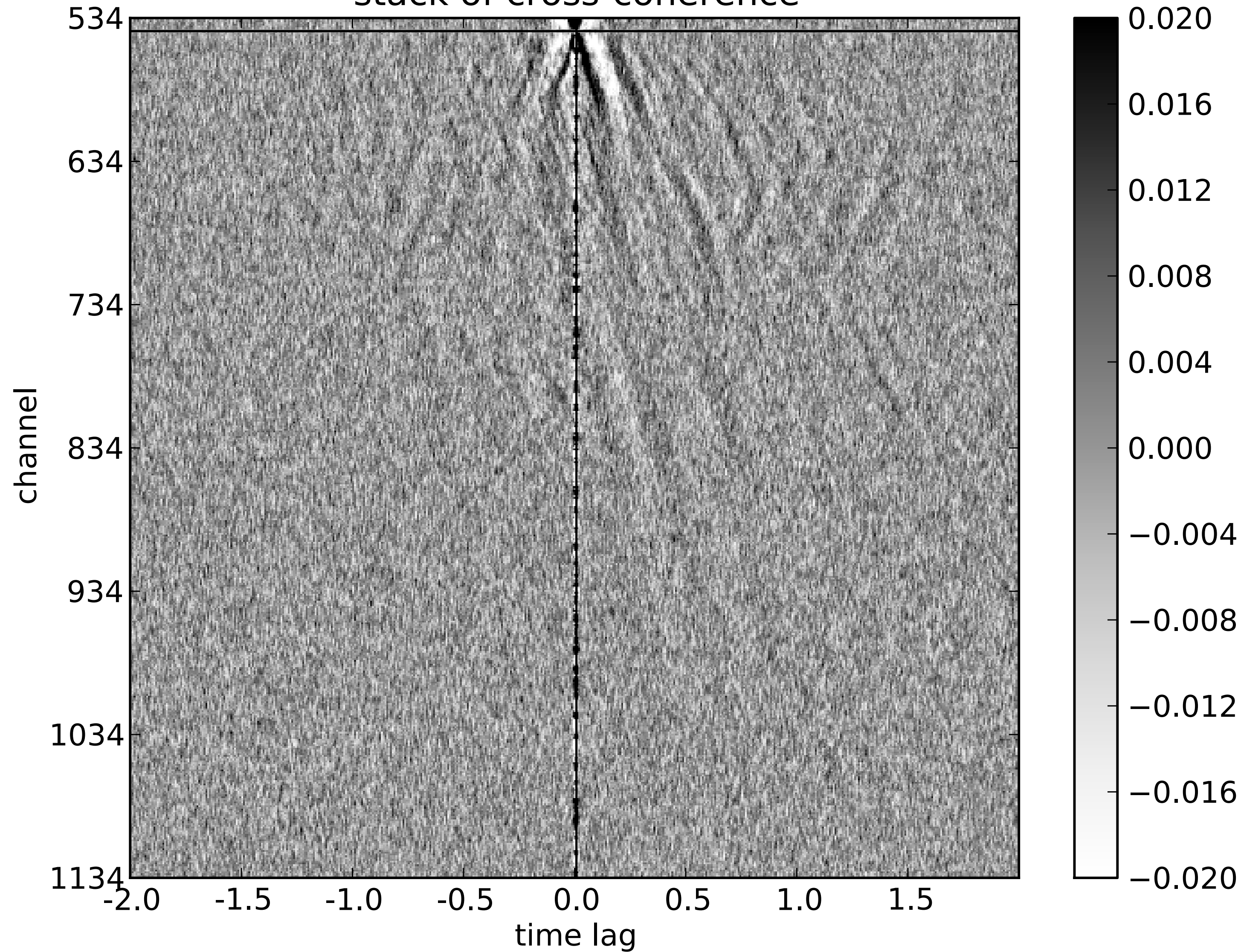


Channel 745

Cross-coherence

No filtering applied

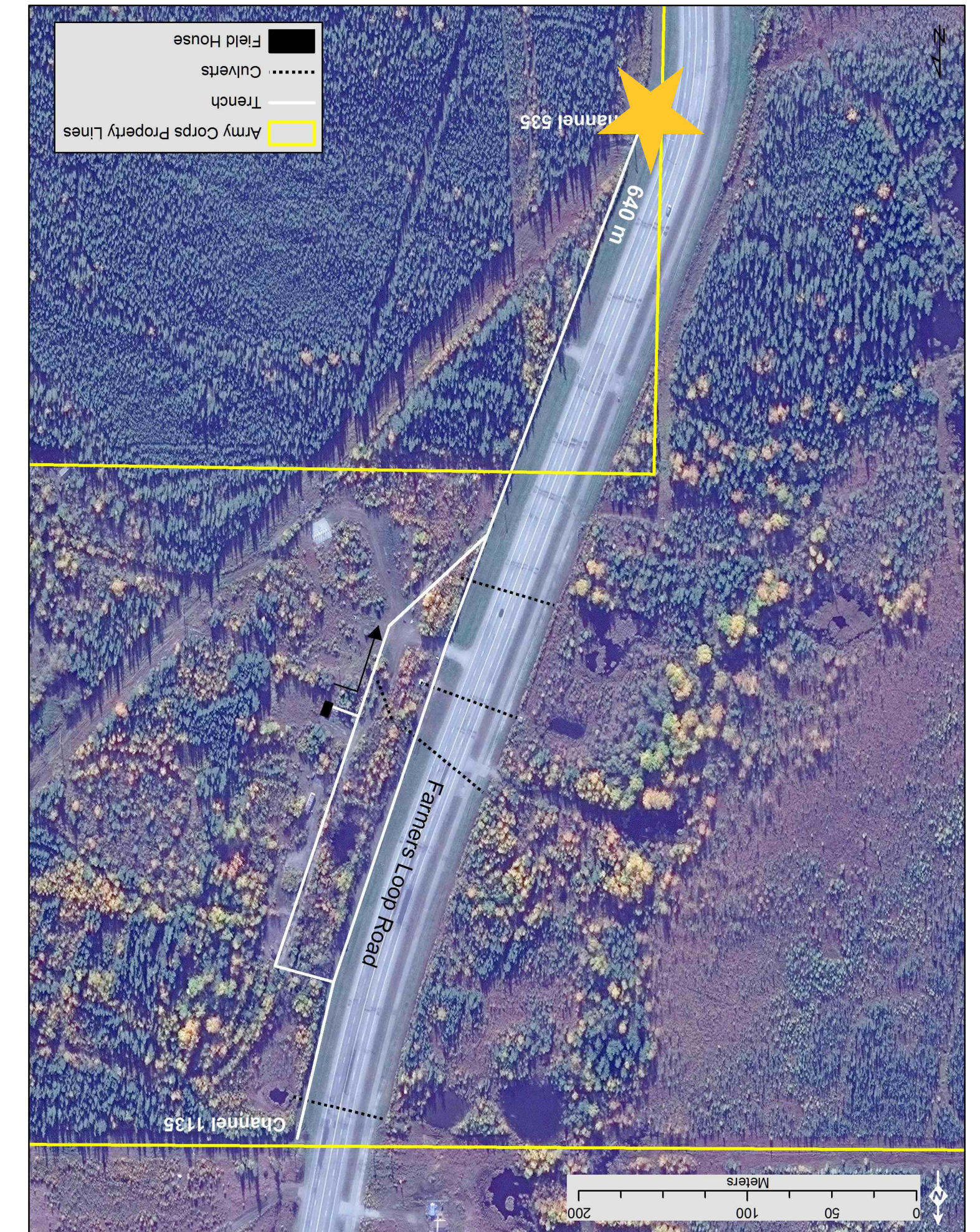
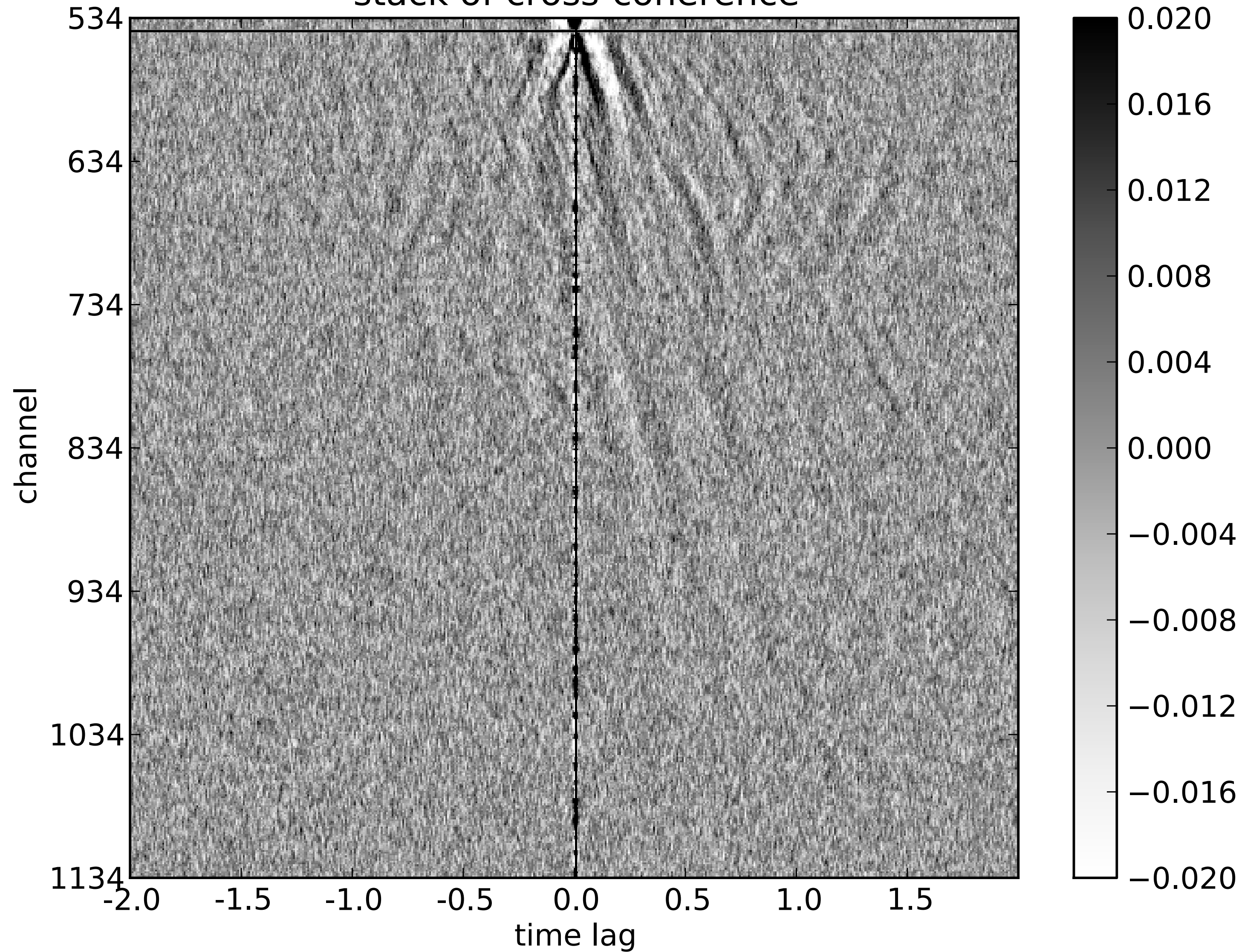
stack of cross-coherence



Cross-coherence

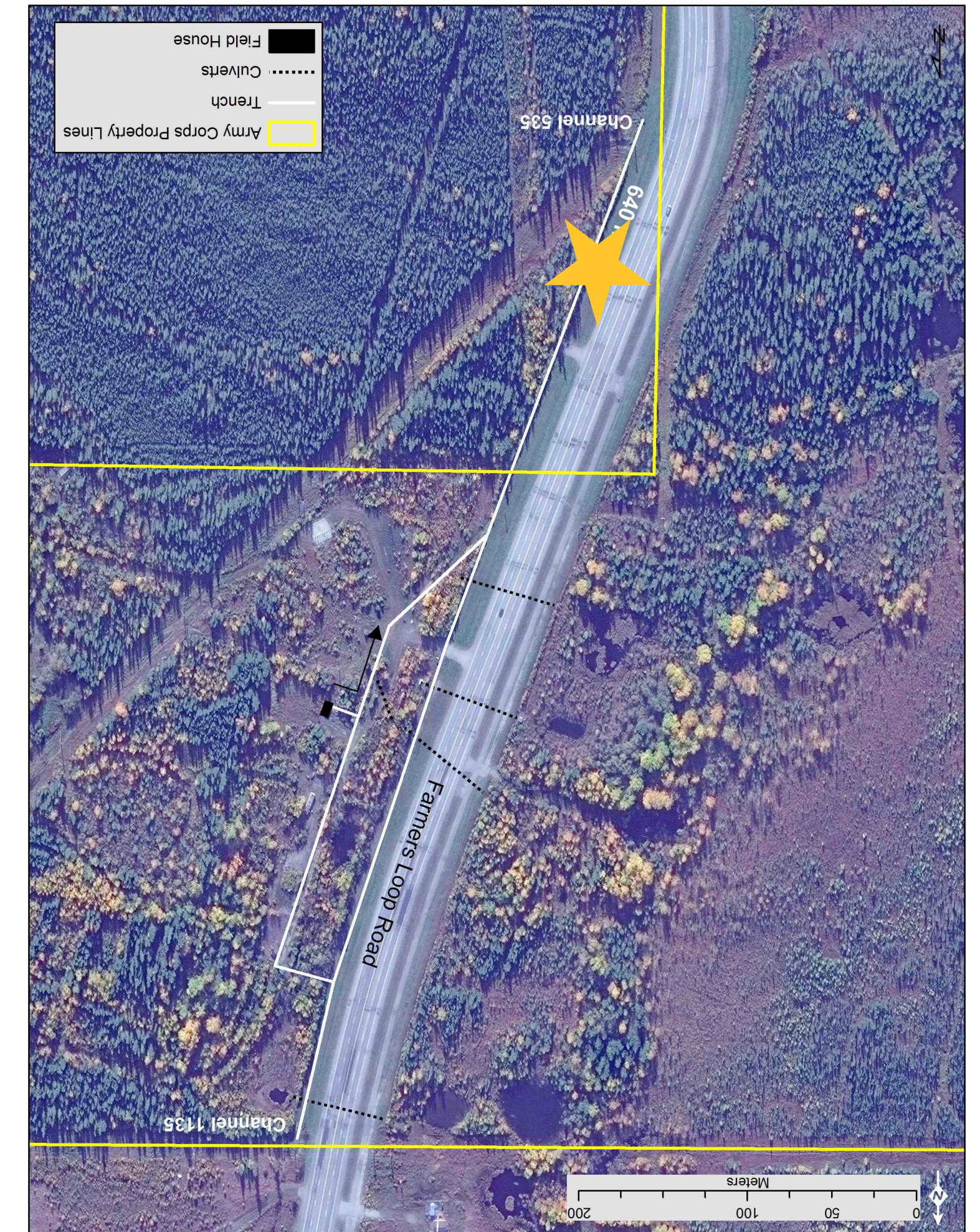
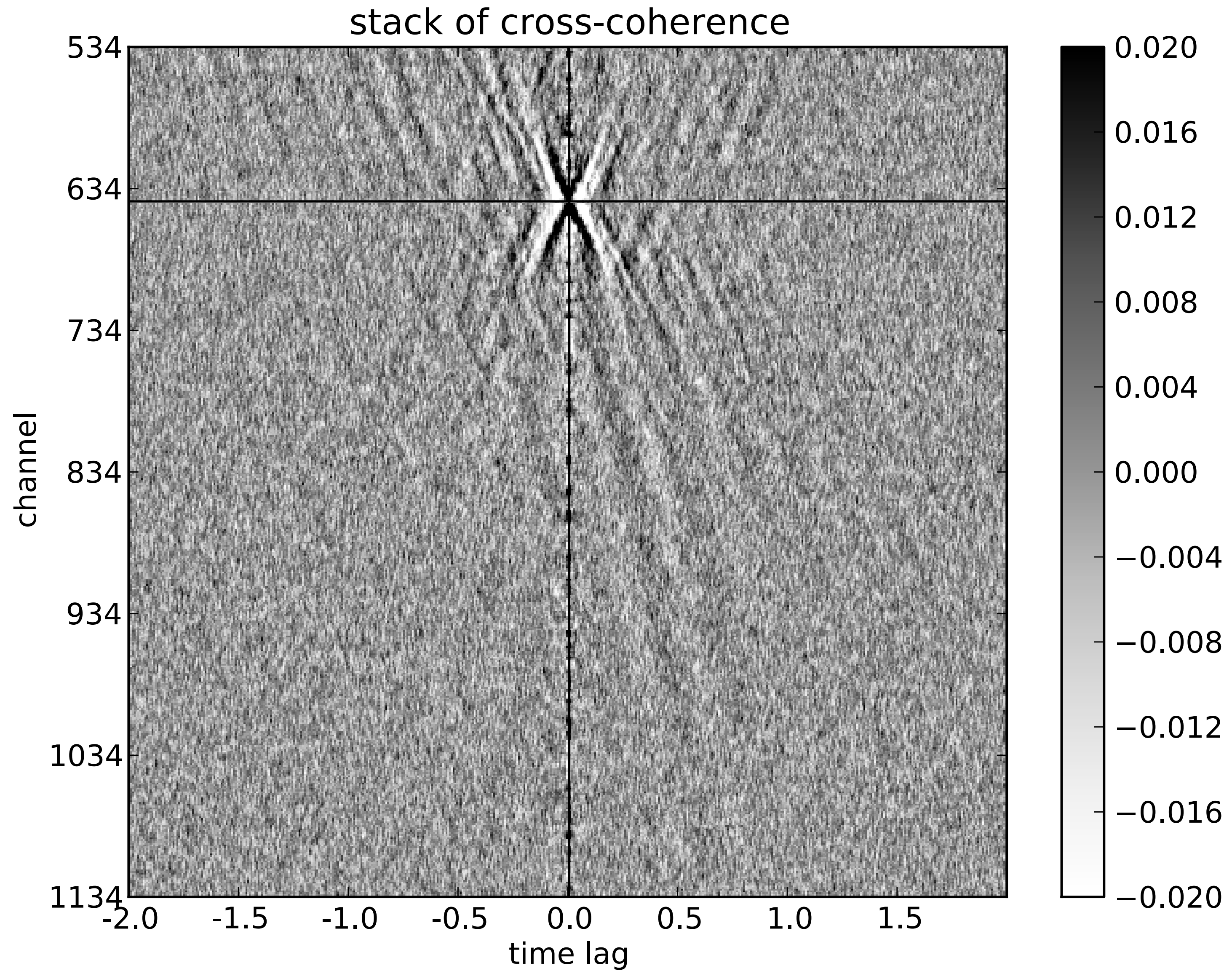
No filtering applied

stack of cross-coherence



Cross-coherence

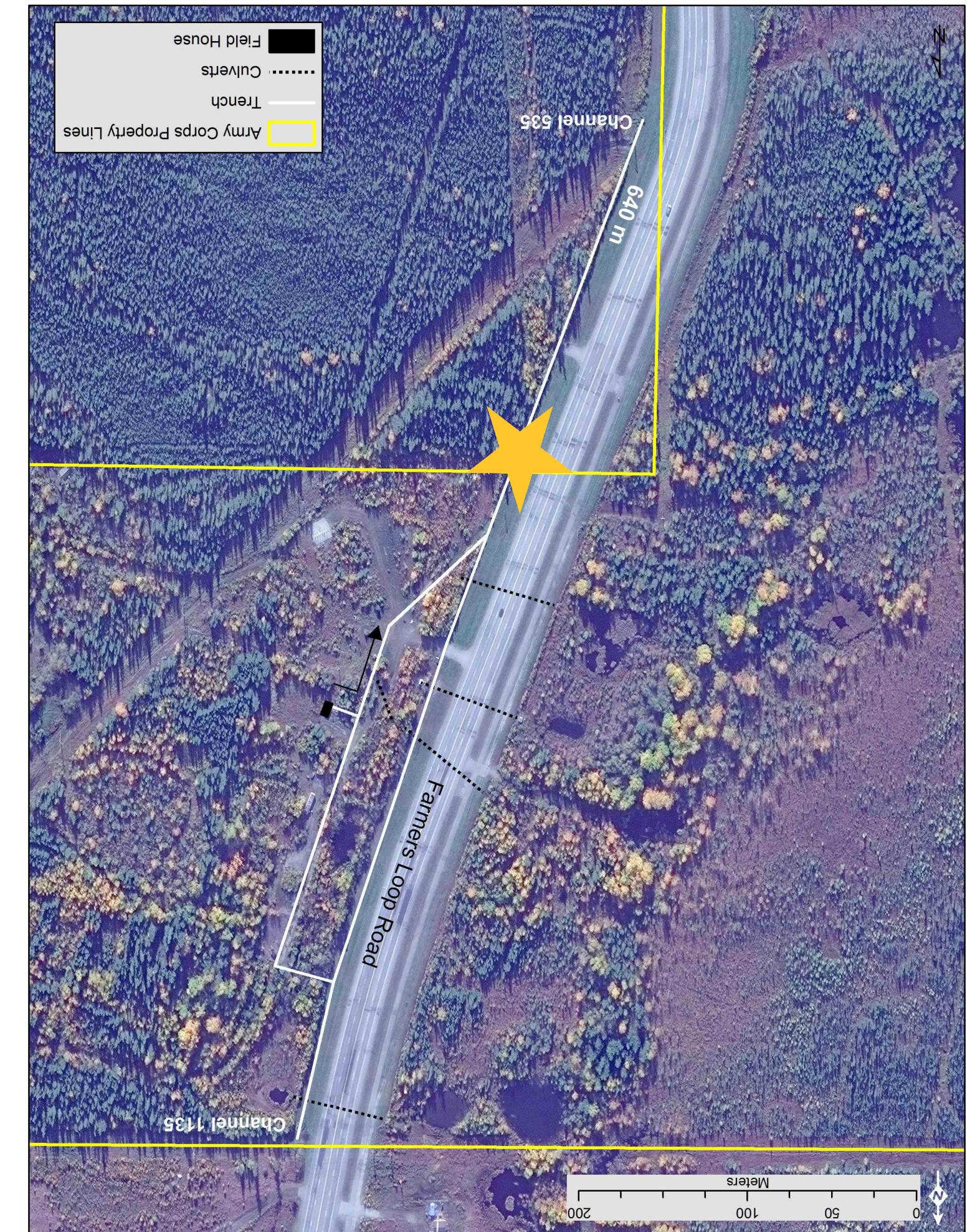
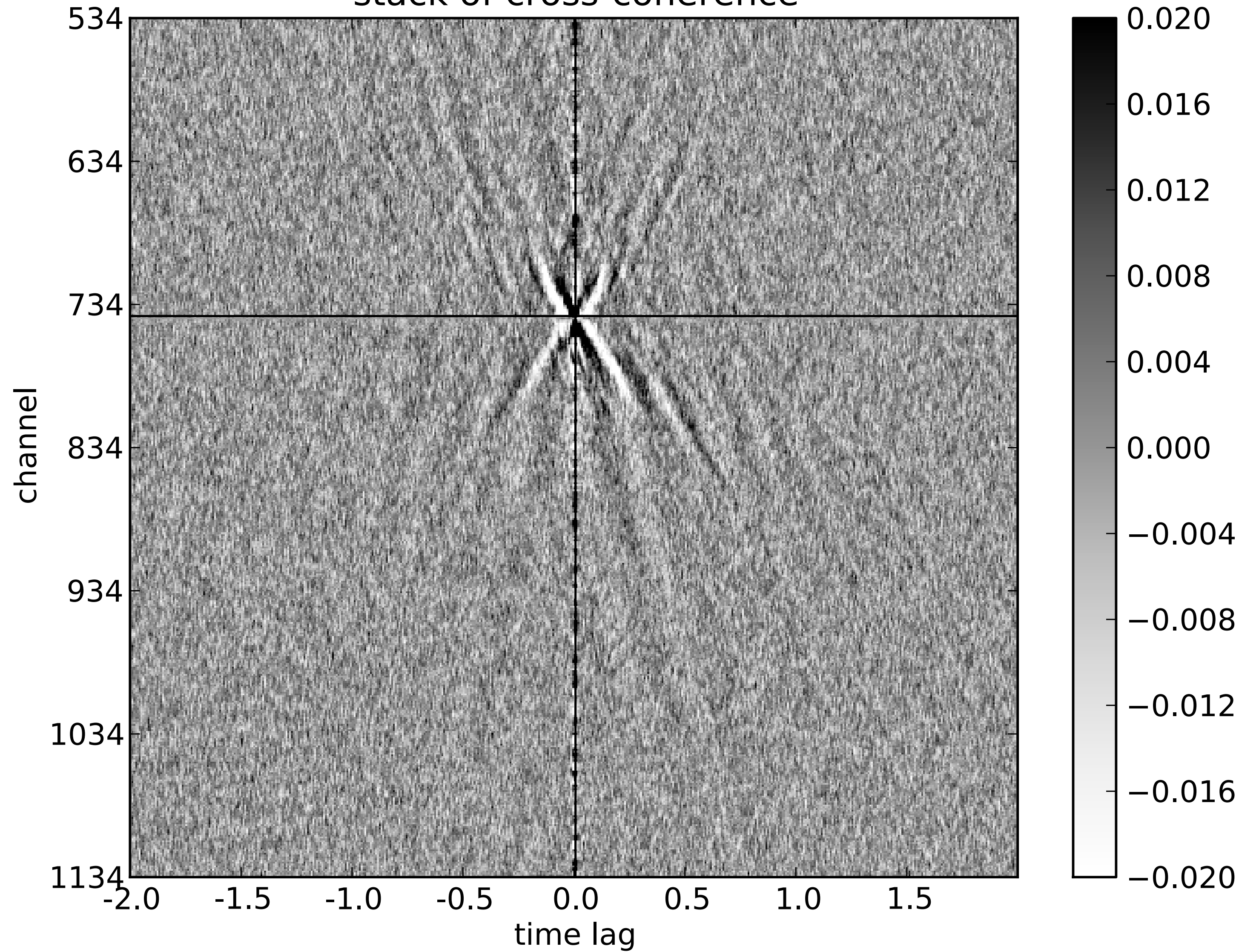
No filtering applied



Cross-coherence

No filtering applied

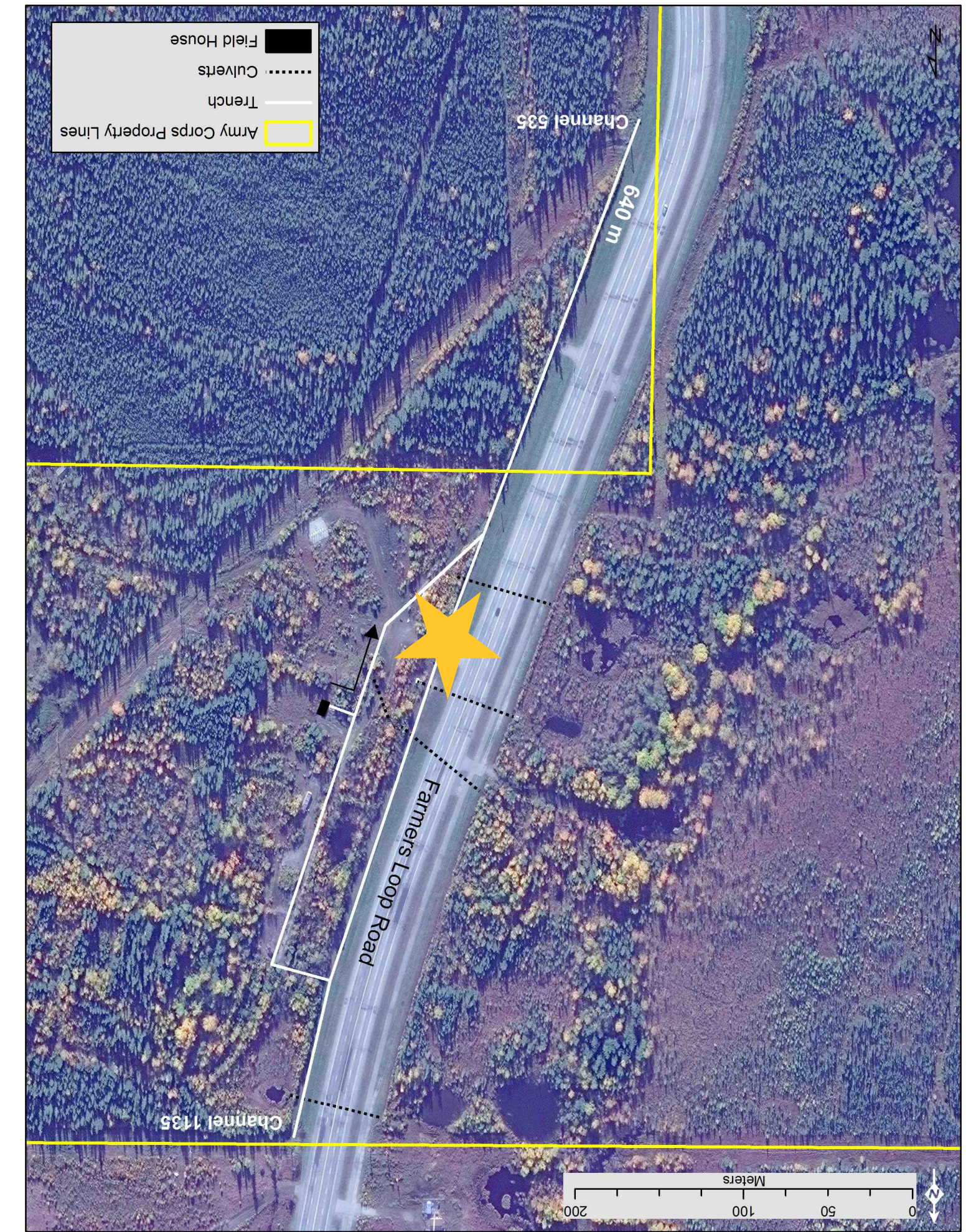
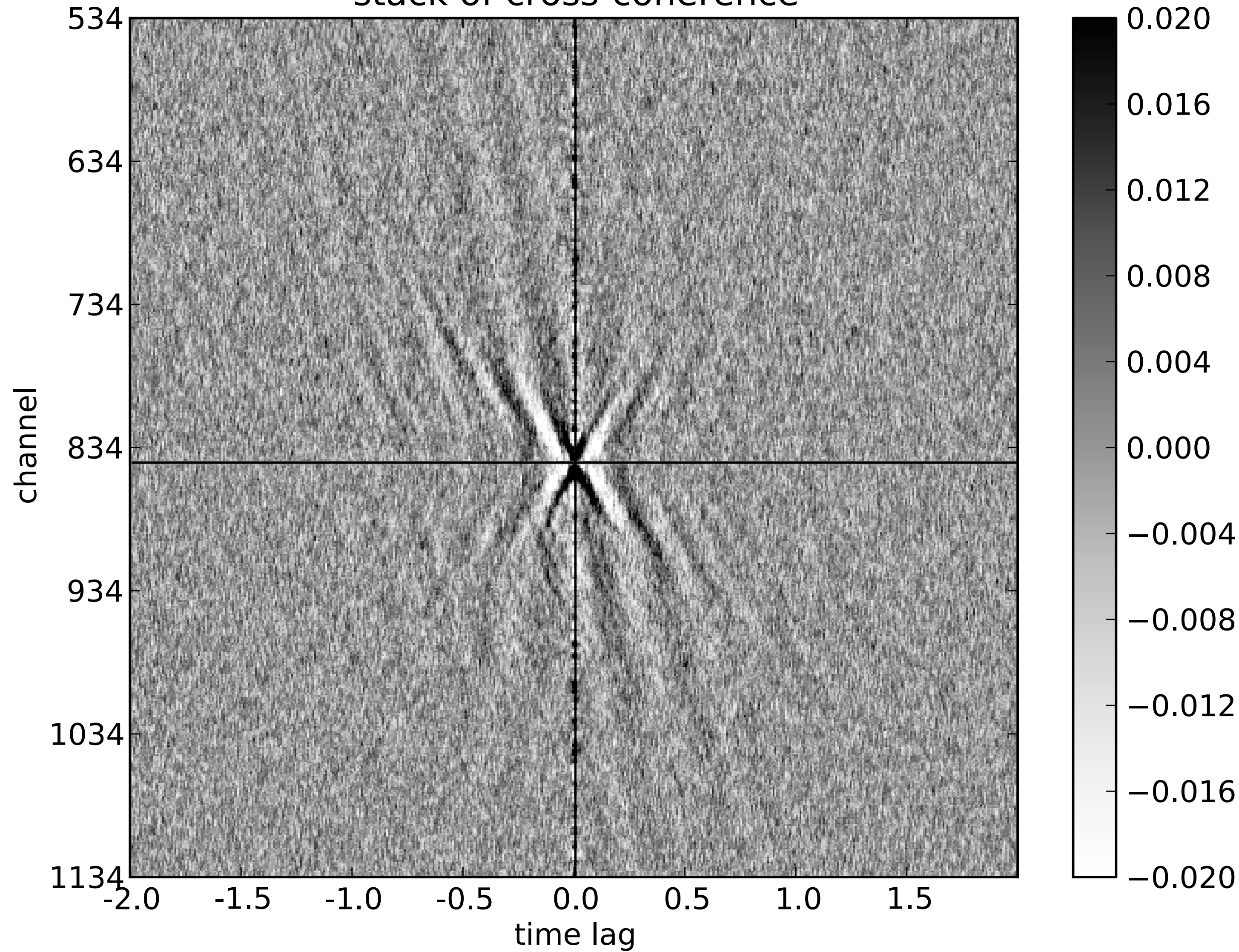
stack of cross-coherence



Cross-coherence

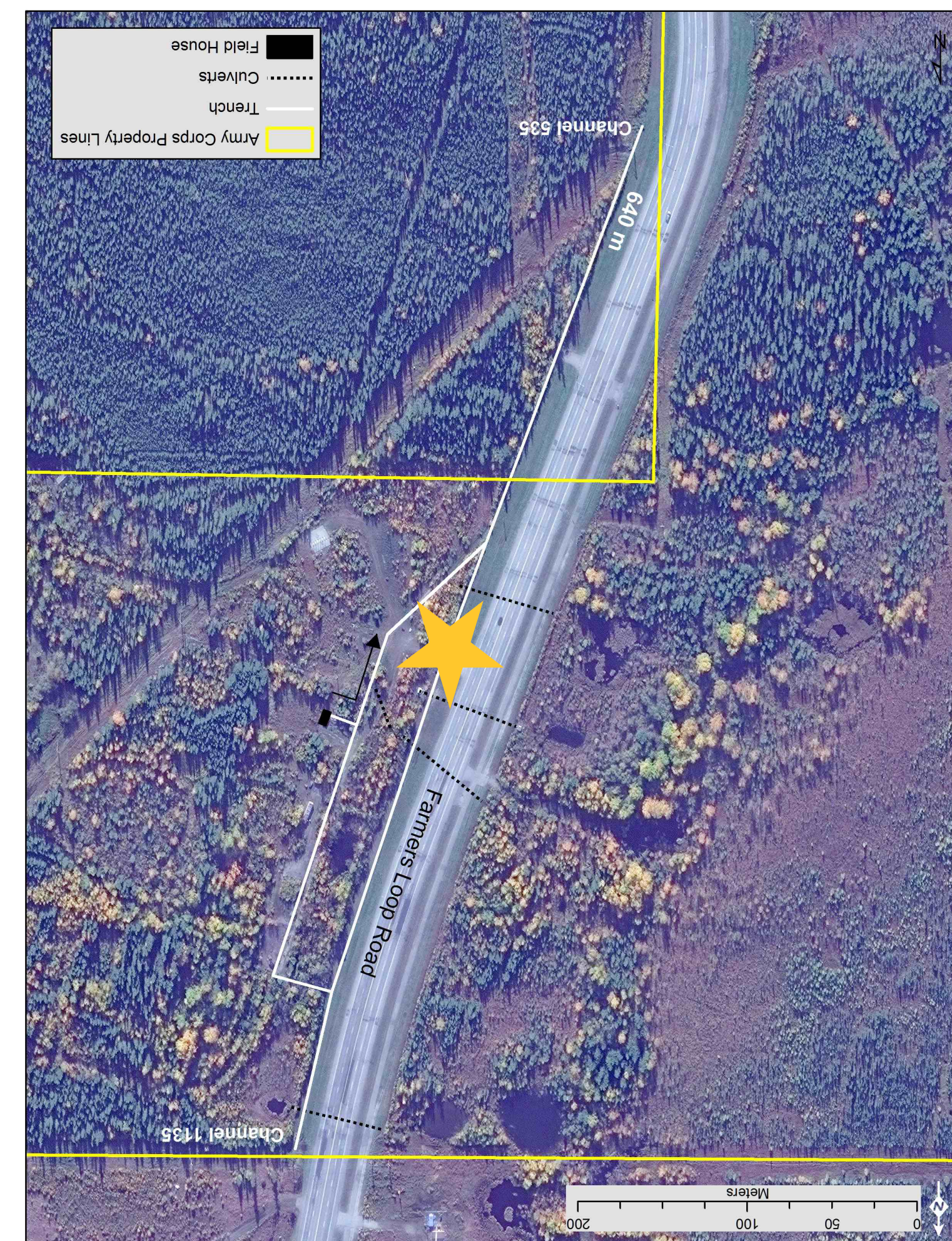
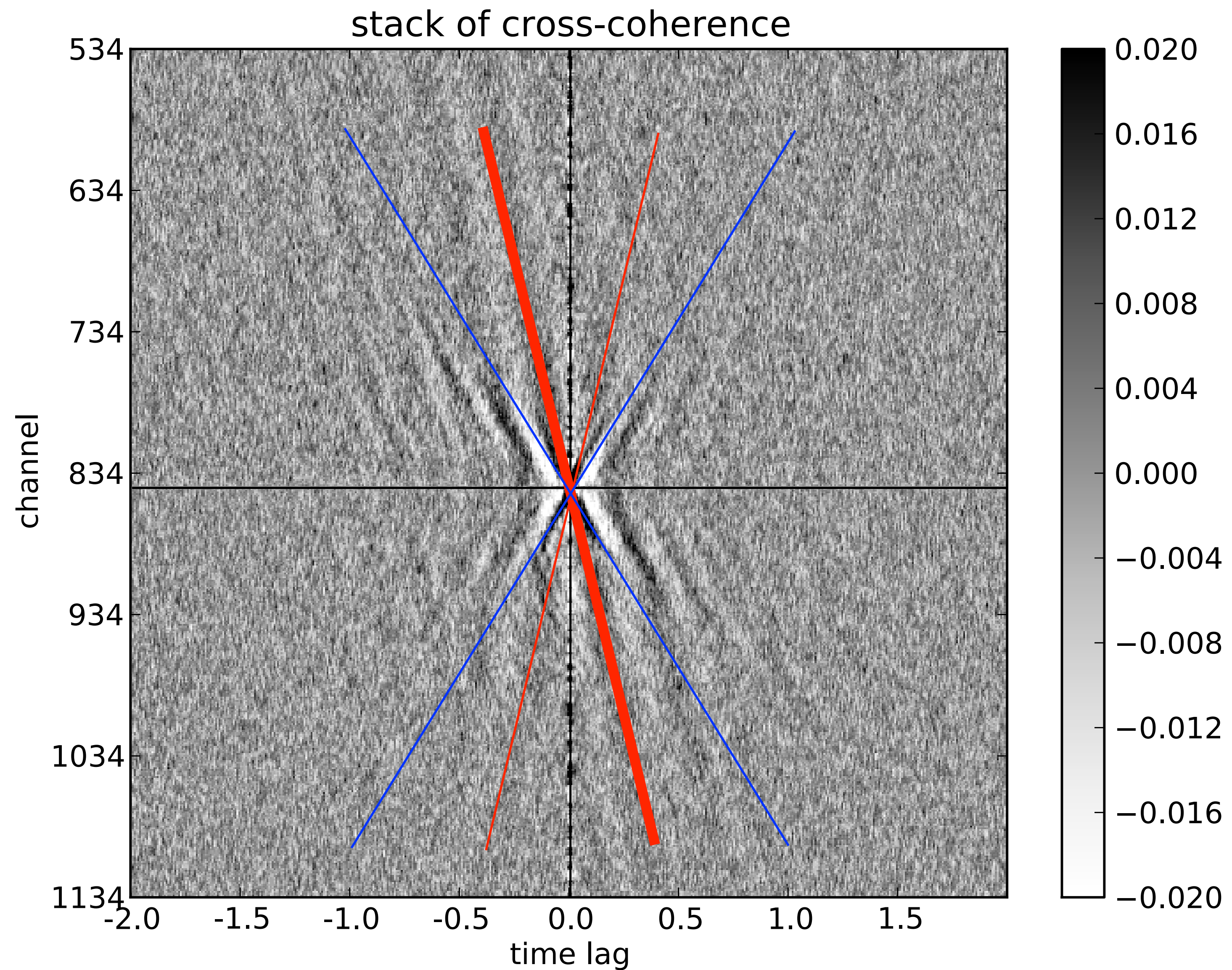
No filtering applied

stack of cross-coherence



Cross-coherence

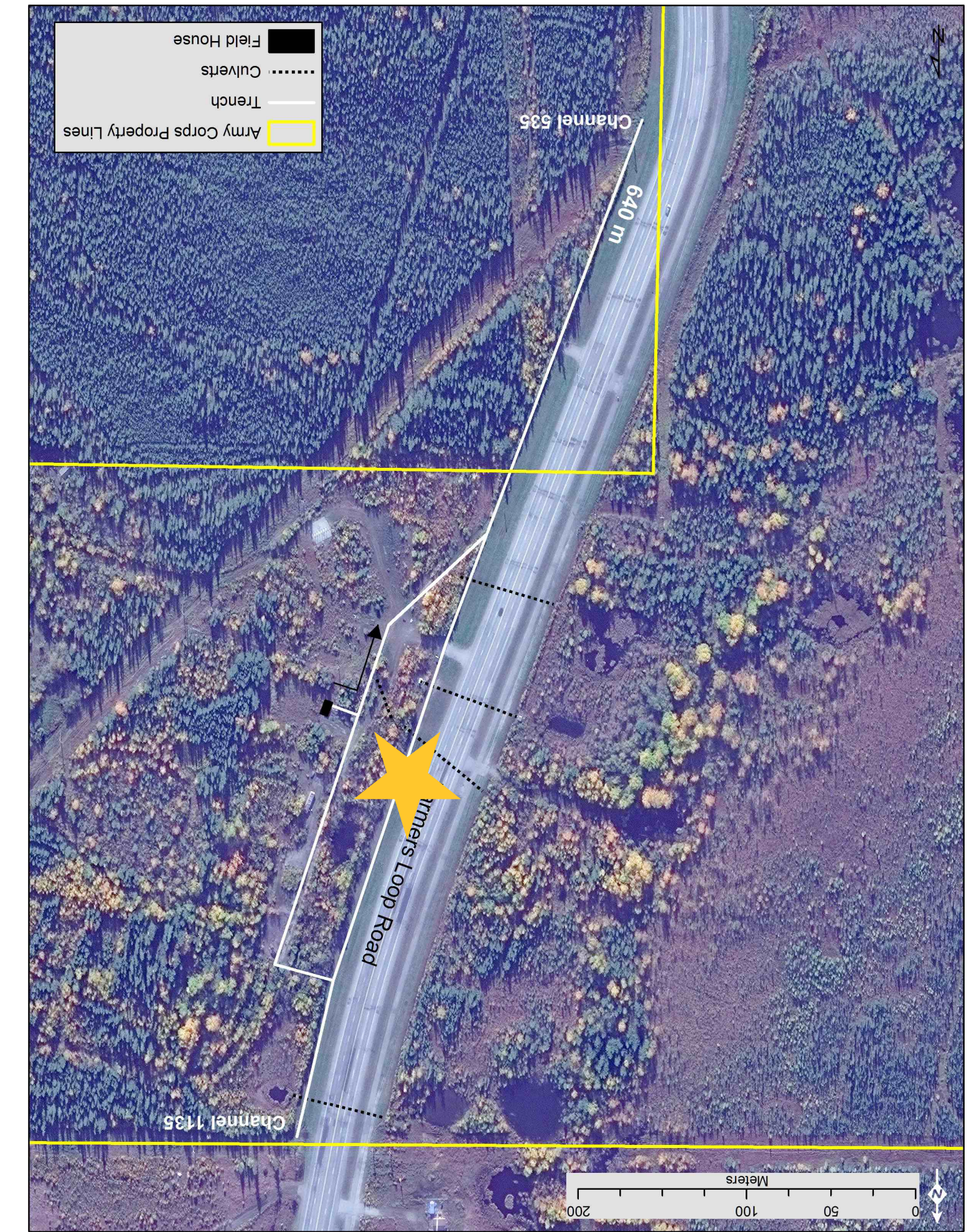
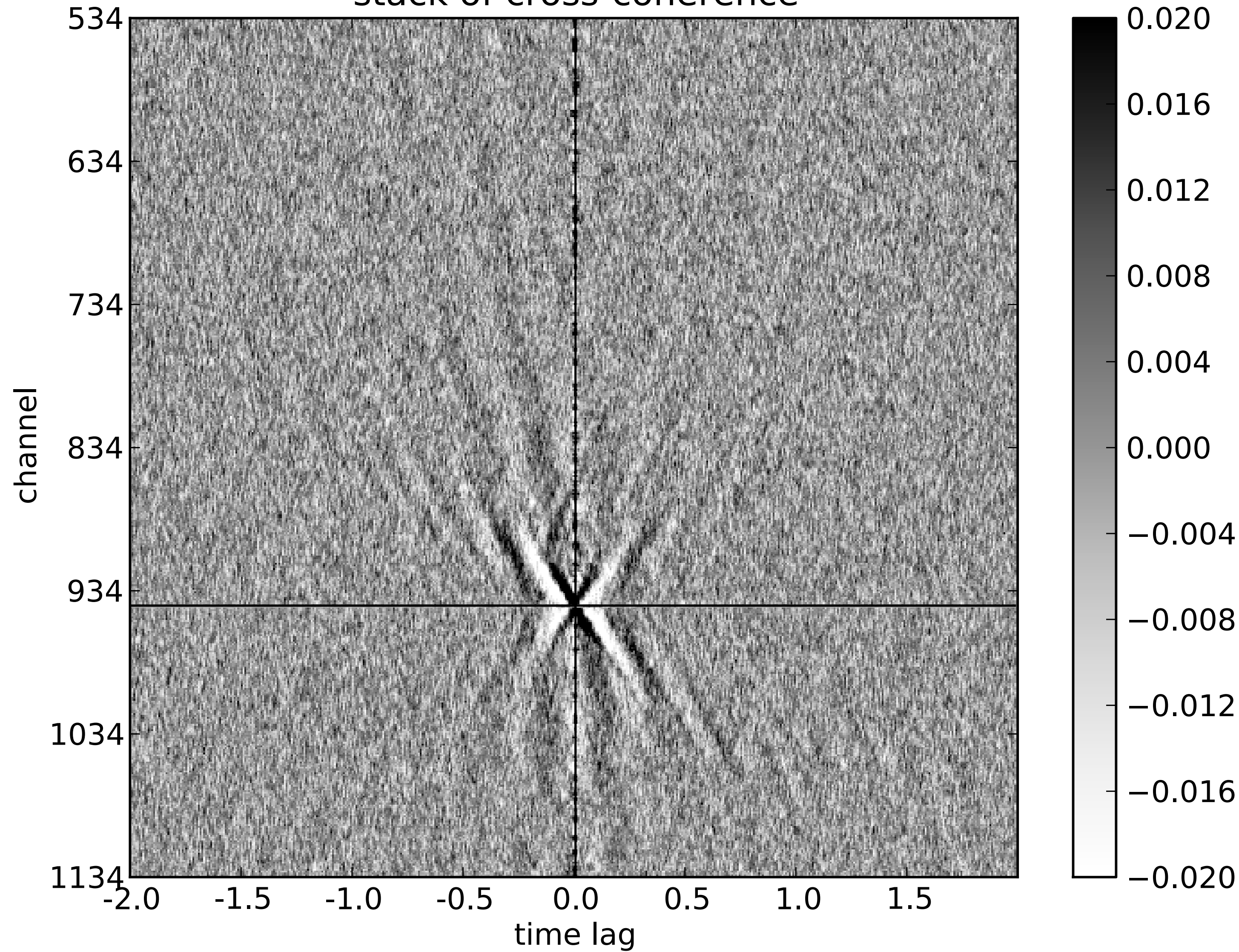
No filtering applied



Cross-coherence

No filtering applied

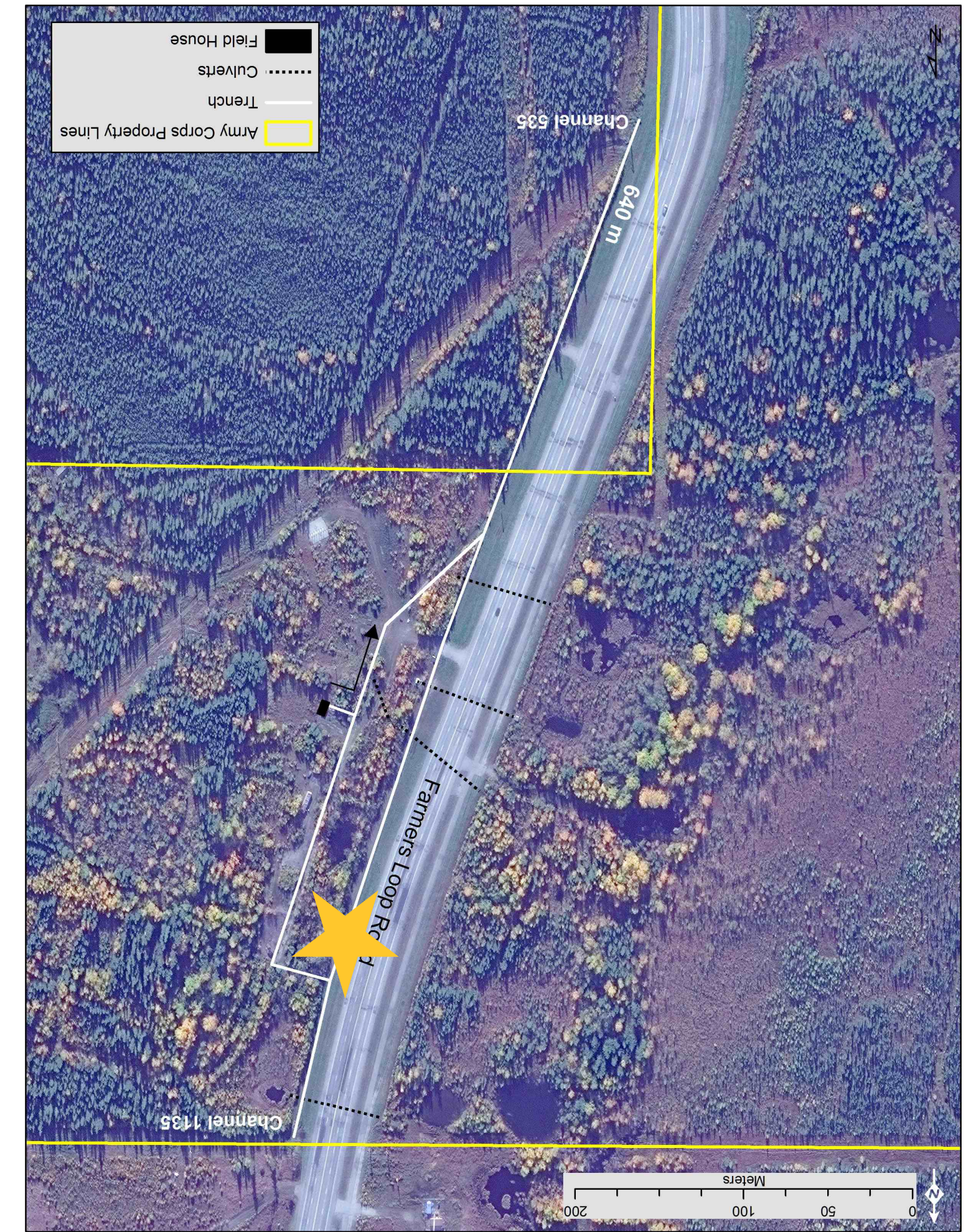
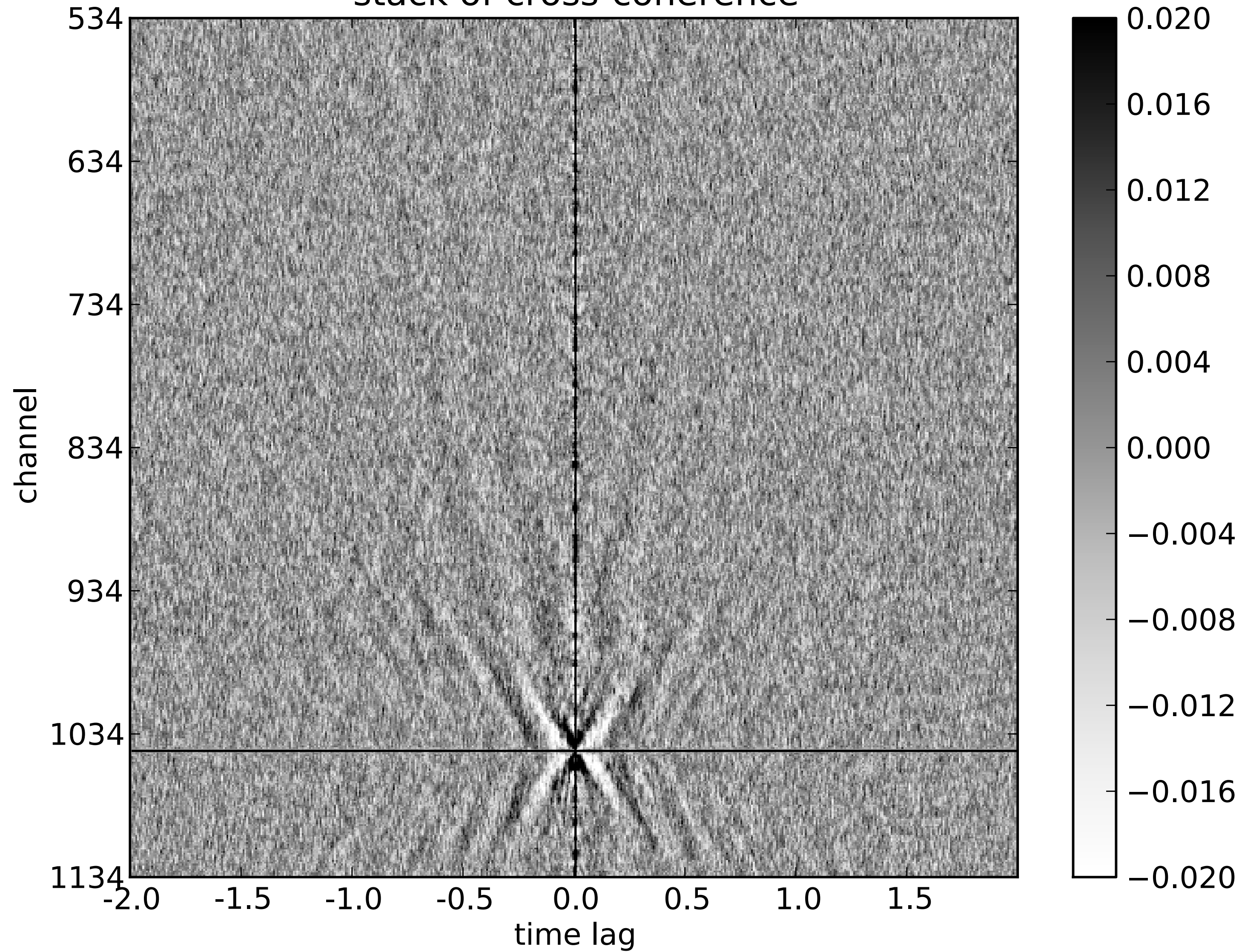
stack of cross-coherence



Cross-coherence

No filtering applied

stack of cross-coherence

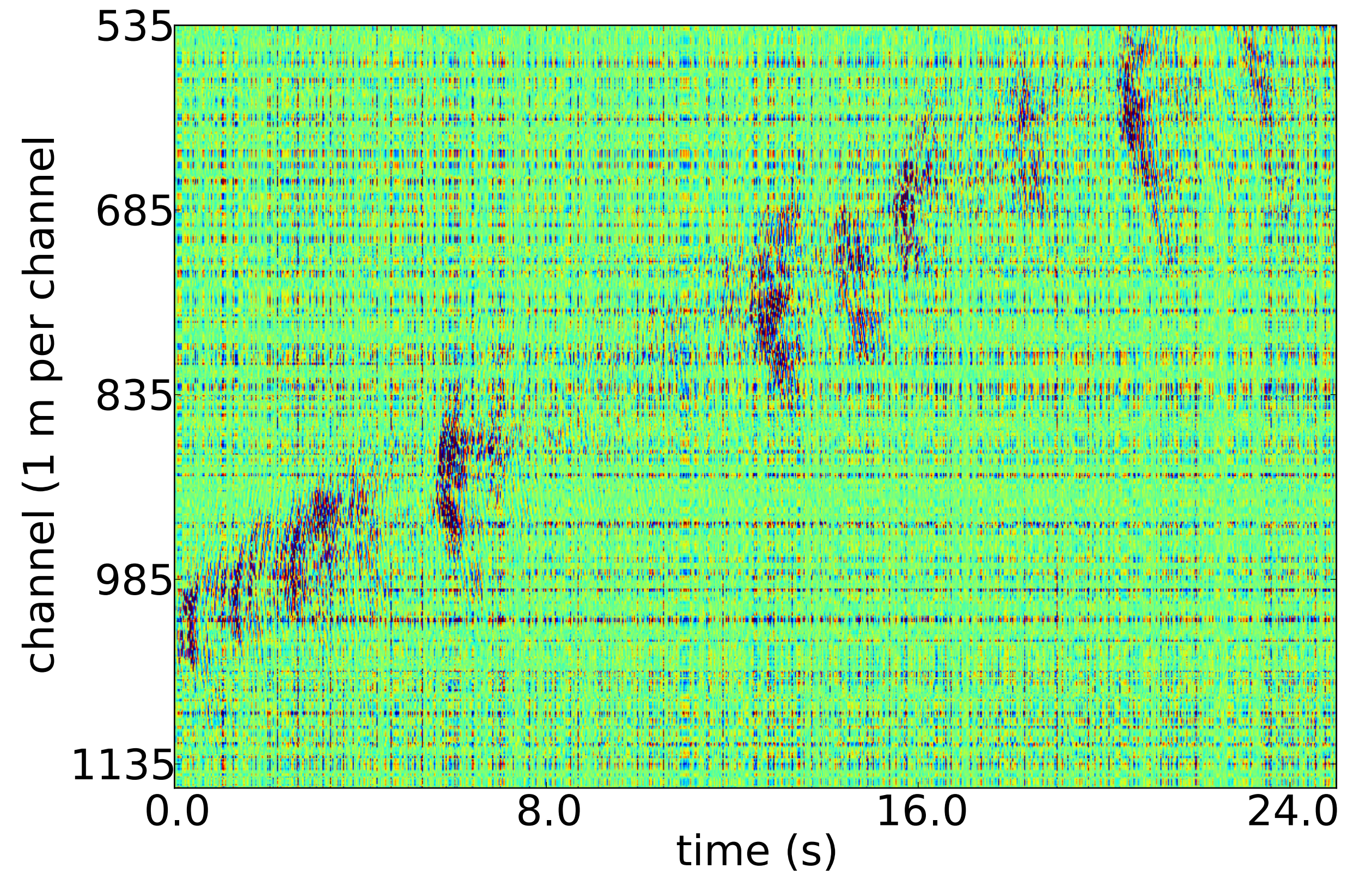
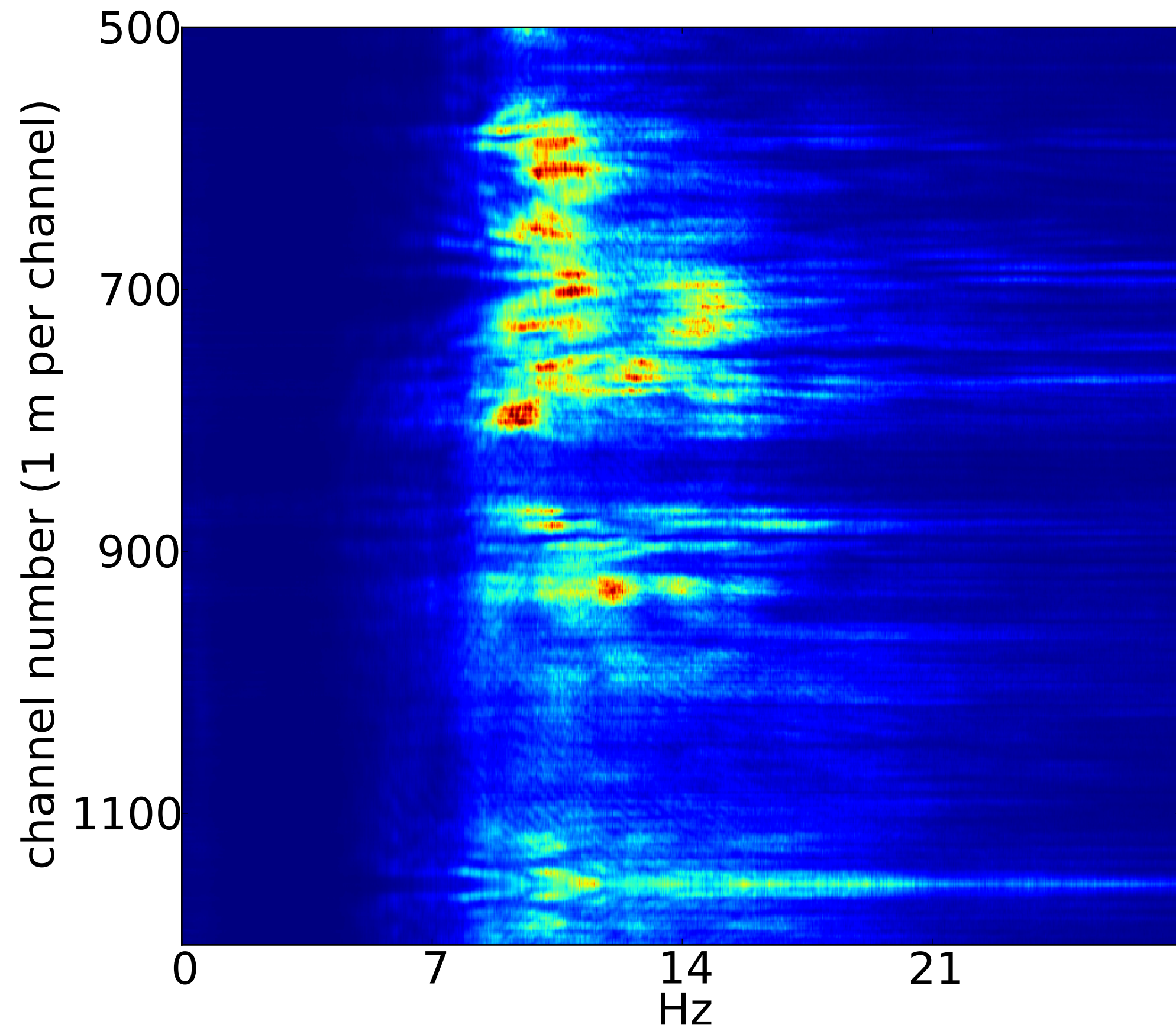


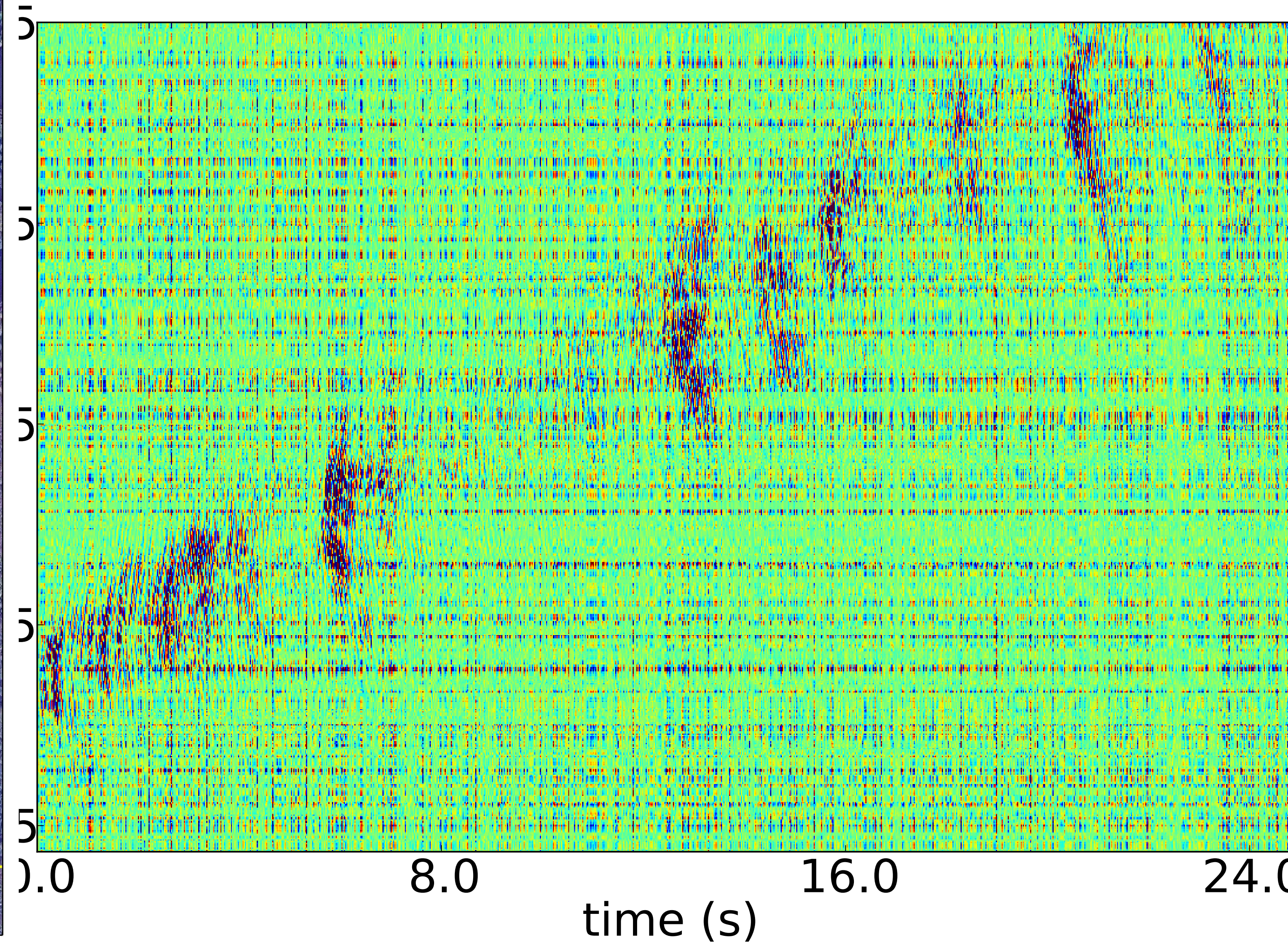
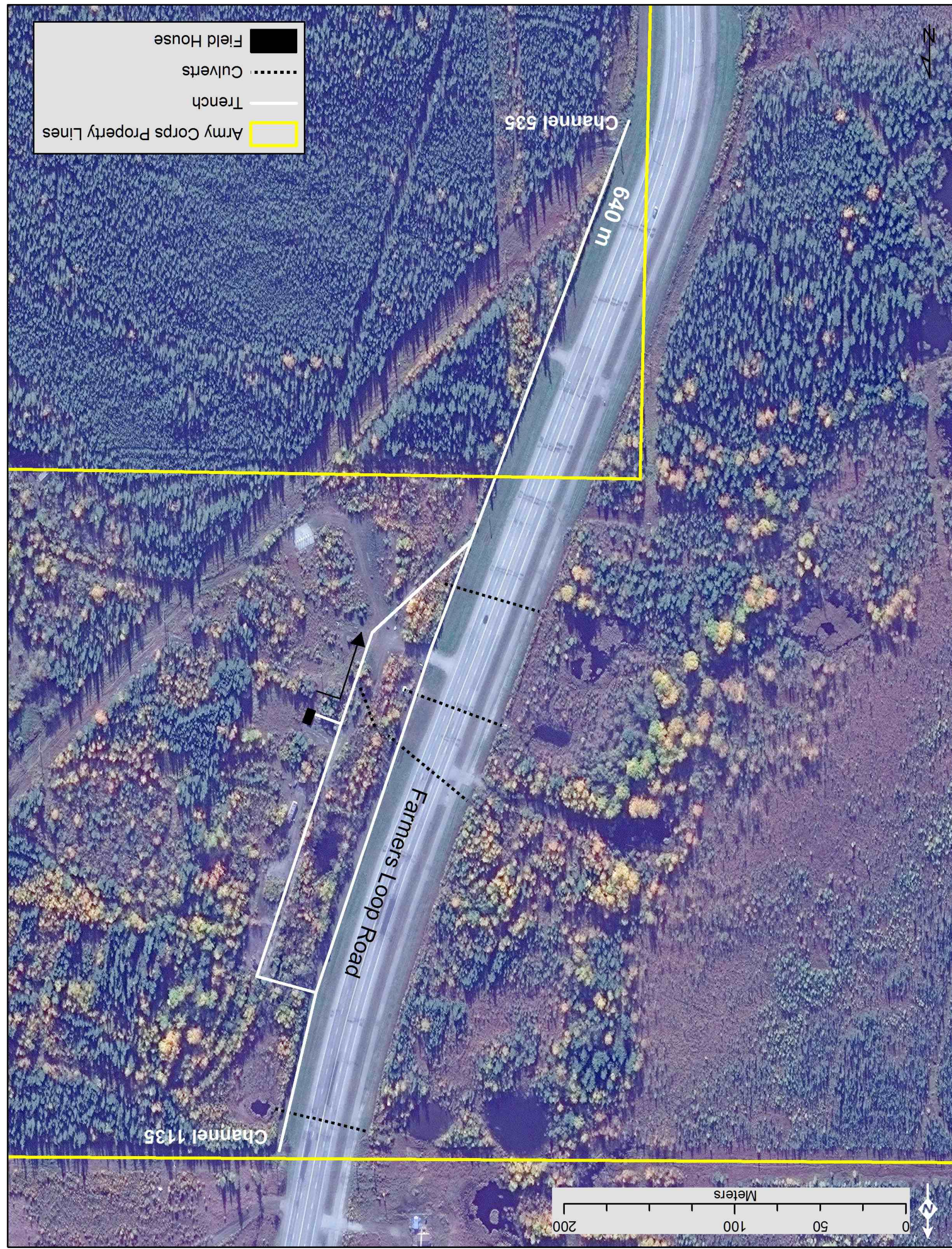
where the report stops

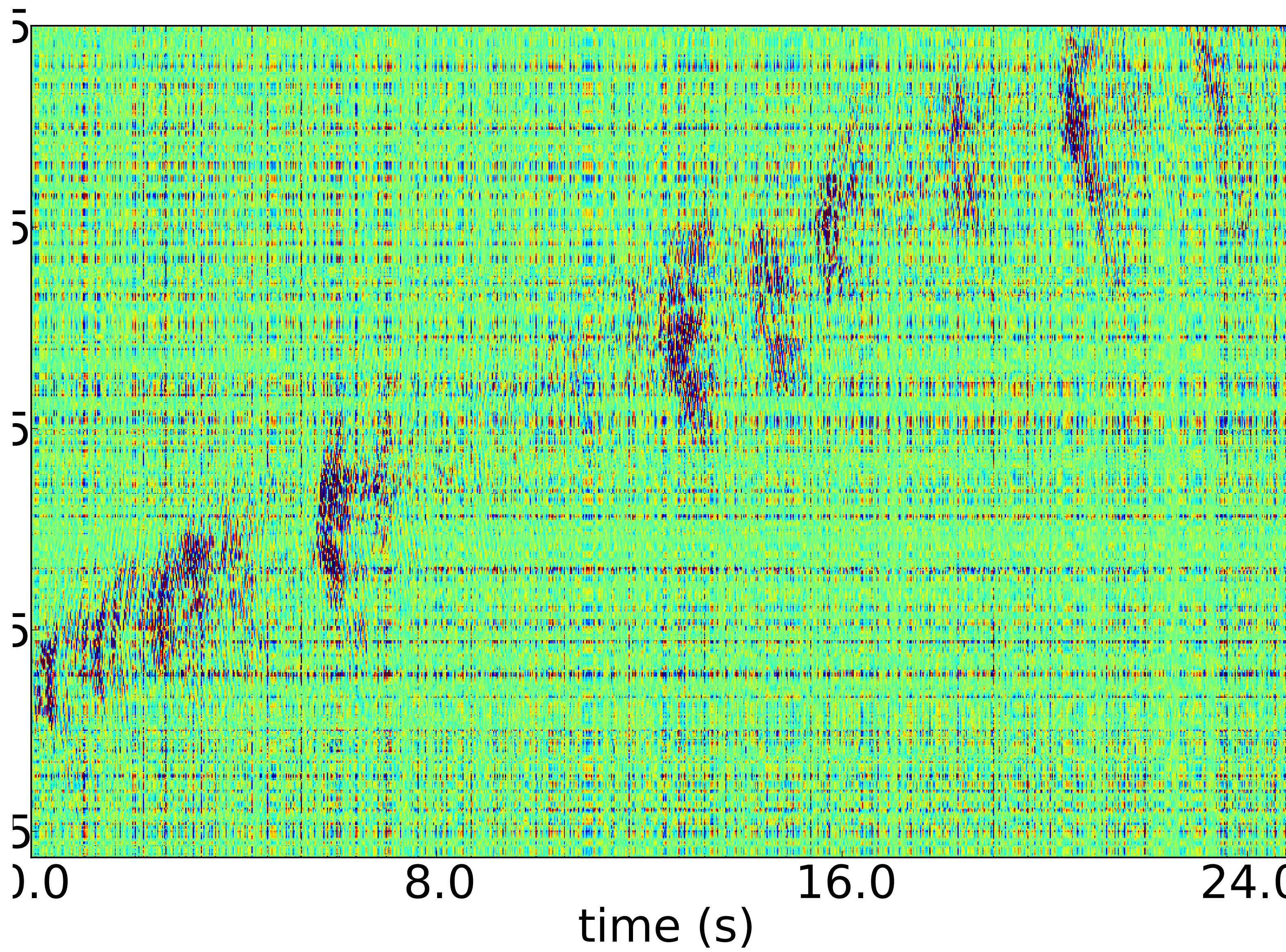
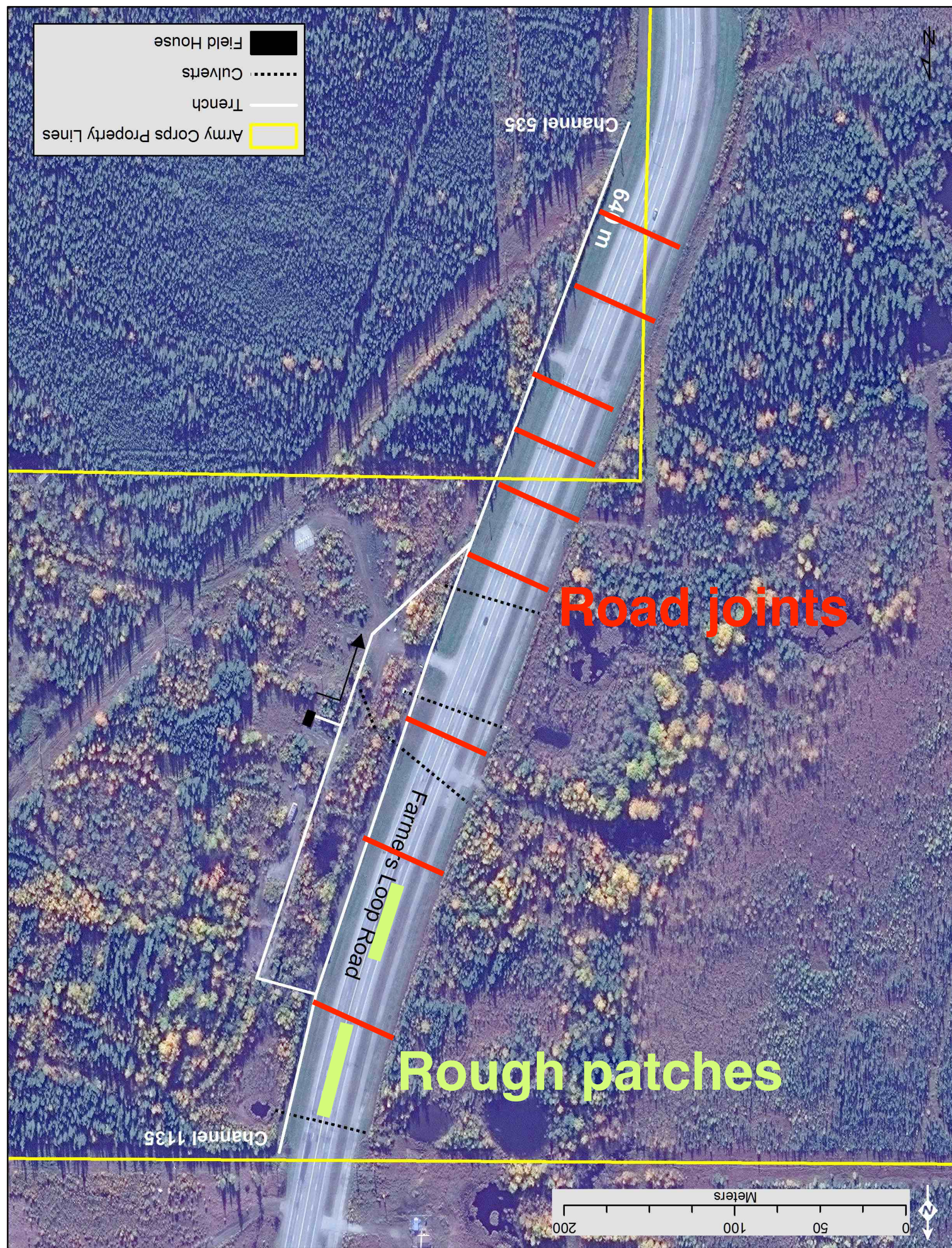
Why do we get extra copies of the virtual source responses?

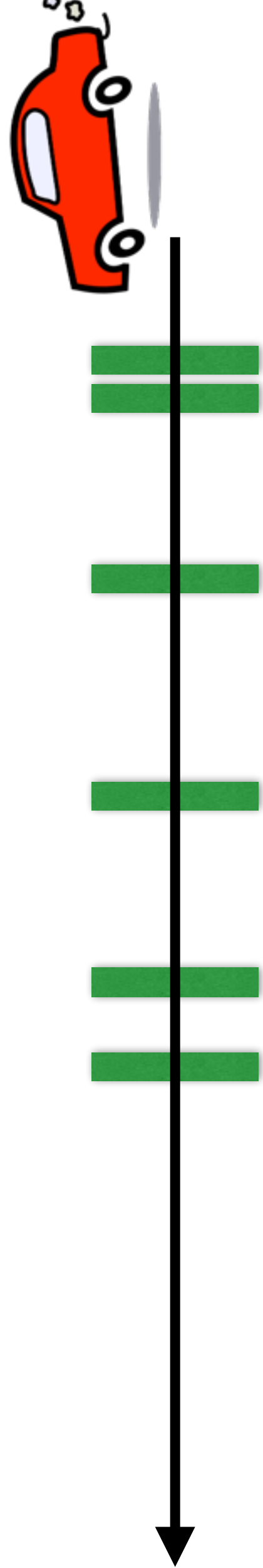
Why does naive cross-coherence work better than any filtering before cross-correlation?

Identifying bumps







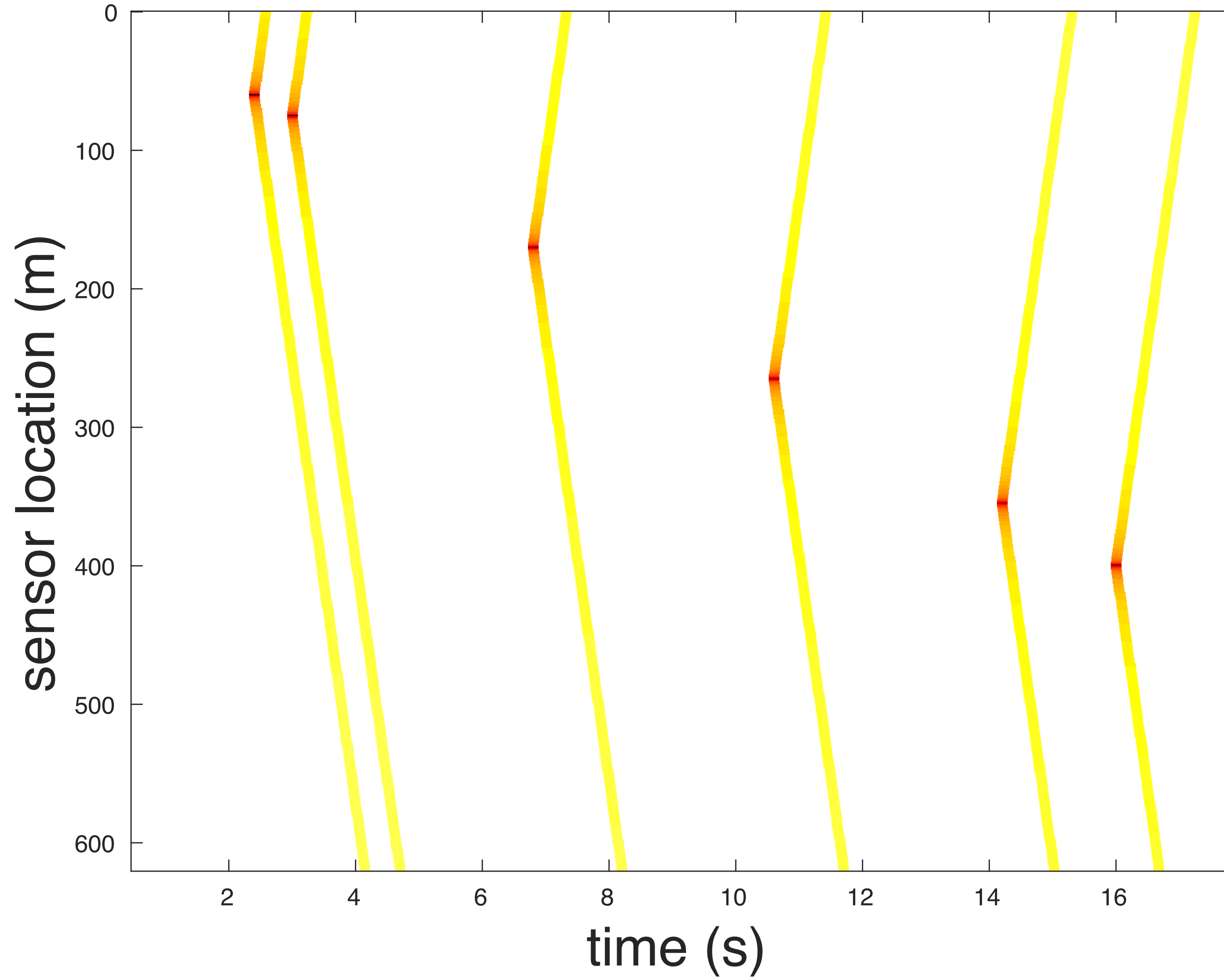


1D synthetic with bumps

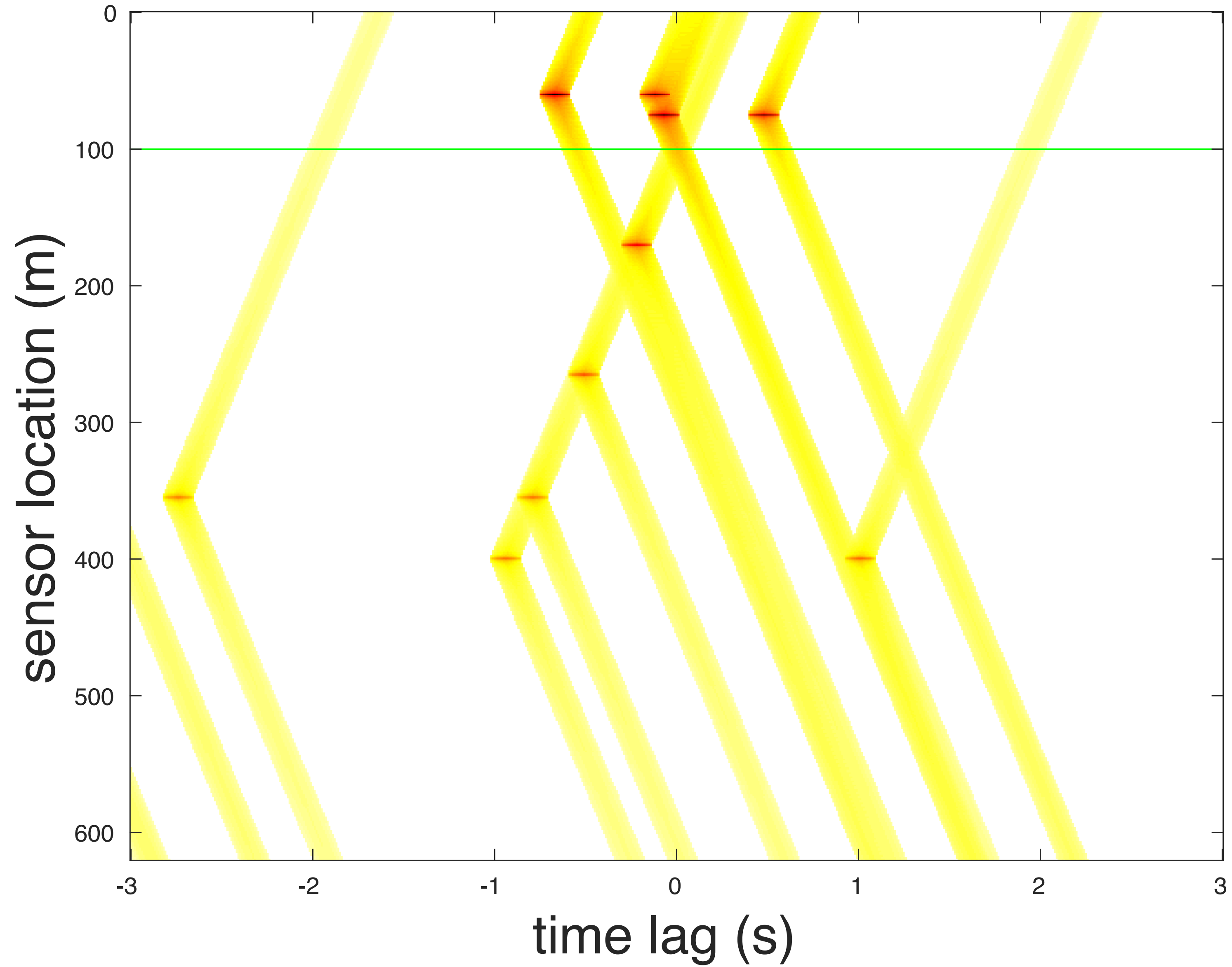
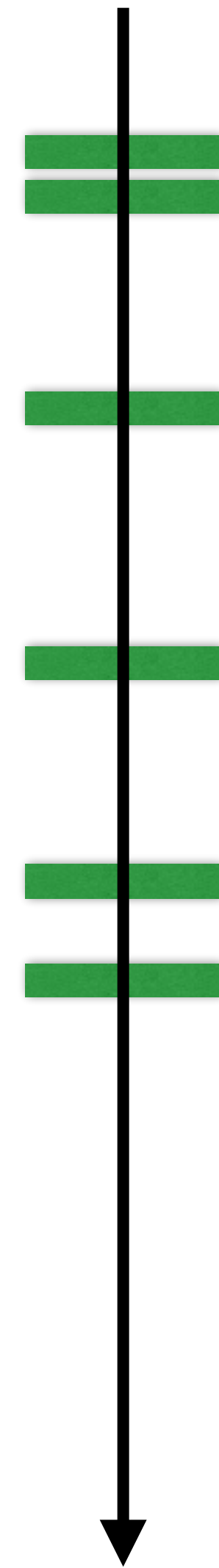
- acoustic constant density
- homogeneous medium, 320 m/s
- car travels parallel to array, 25 m/s
- when car hits a bump, emit a single square pulse



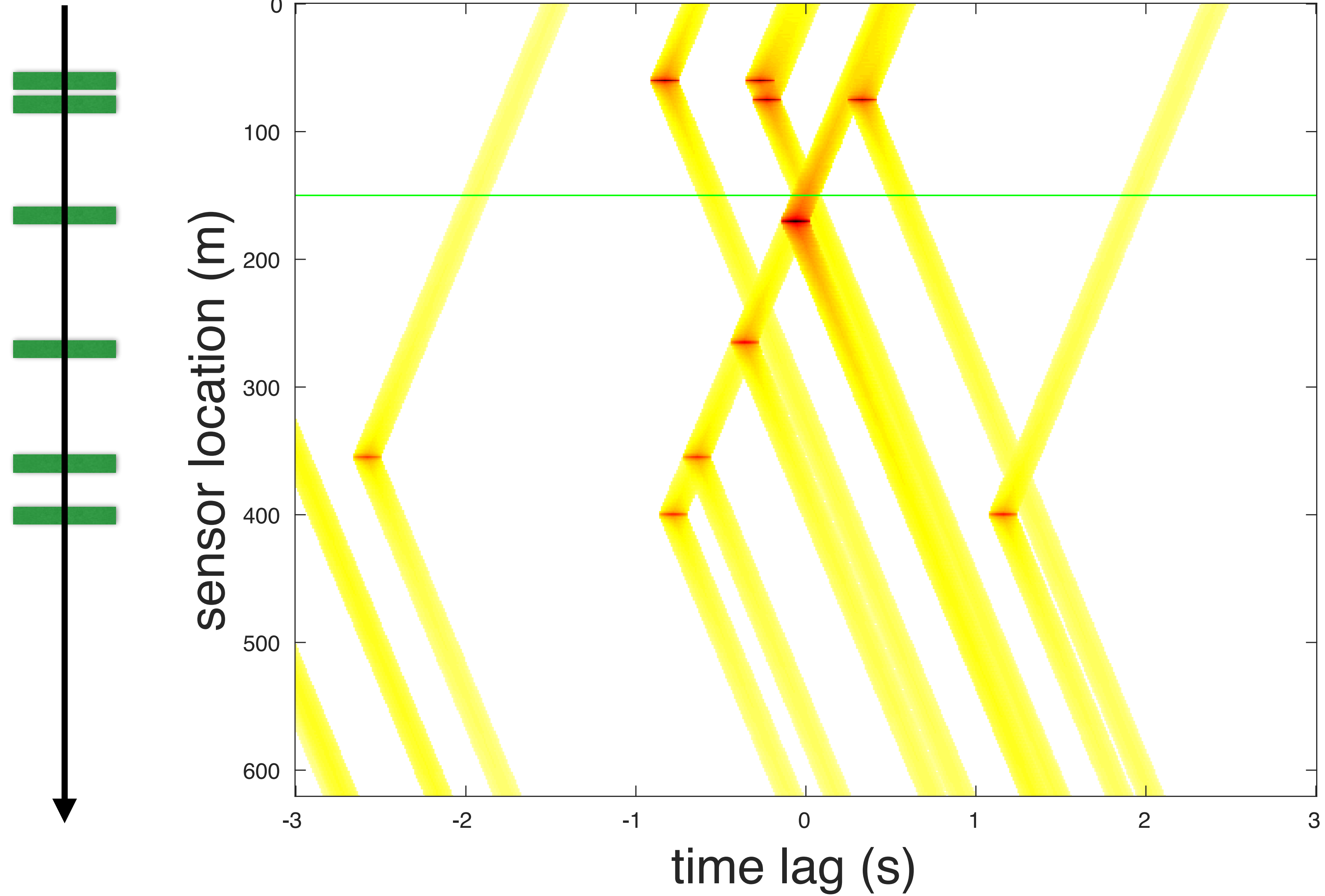
Time records



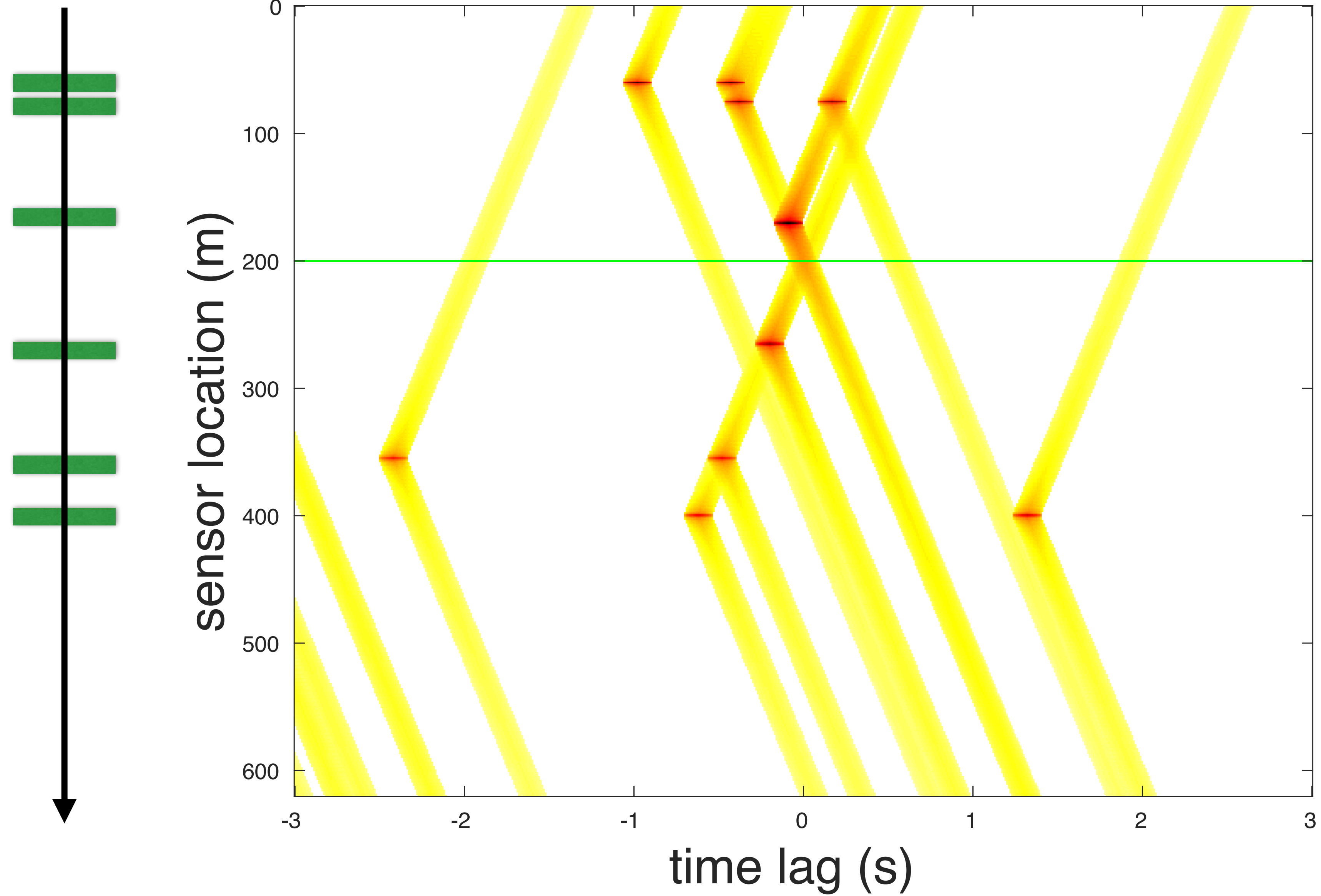
Cross-correlation Virtual Source Ch 100



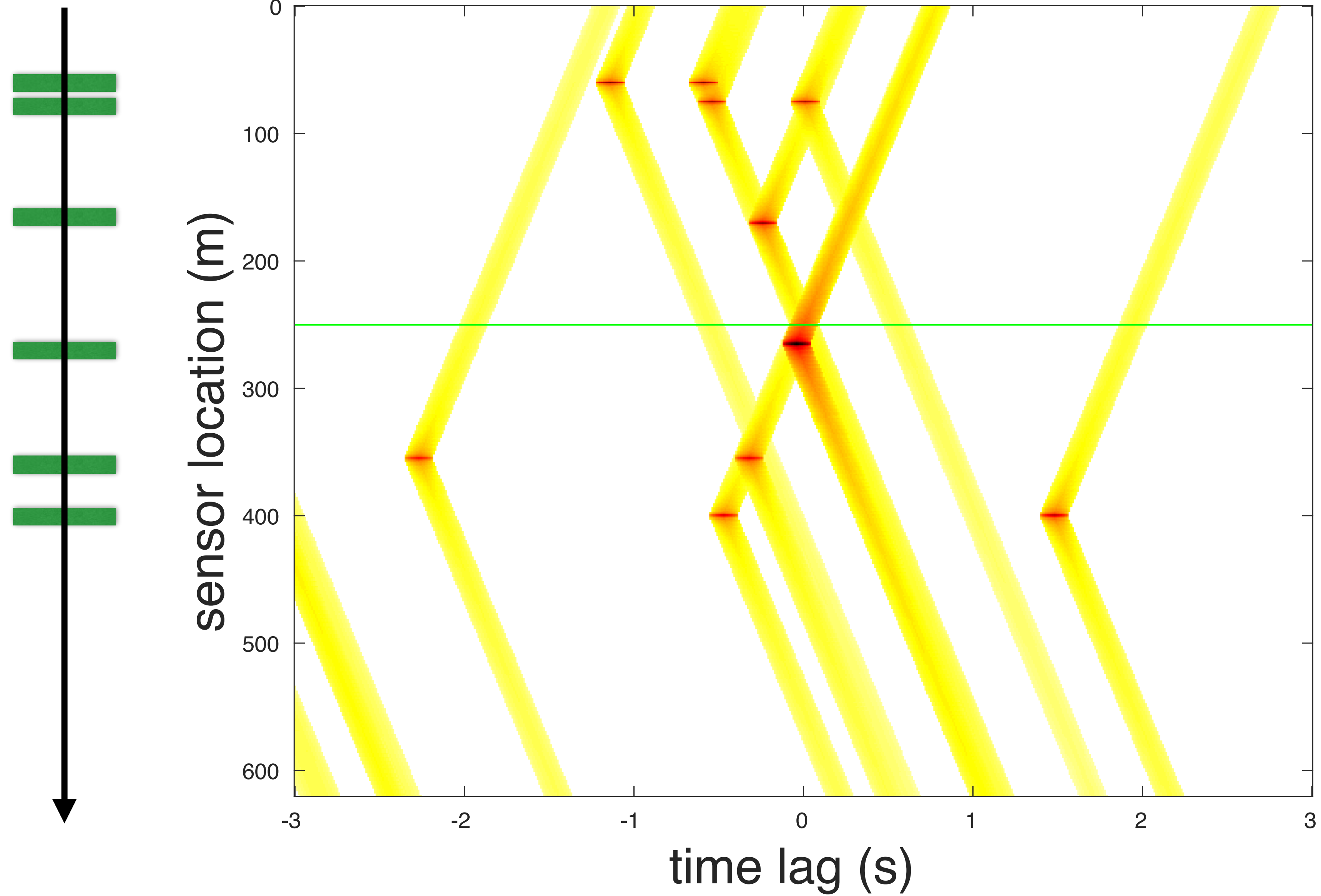
Cross-correlation Virtual Source Ch 150



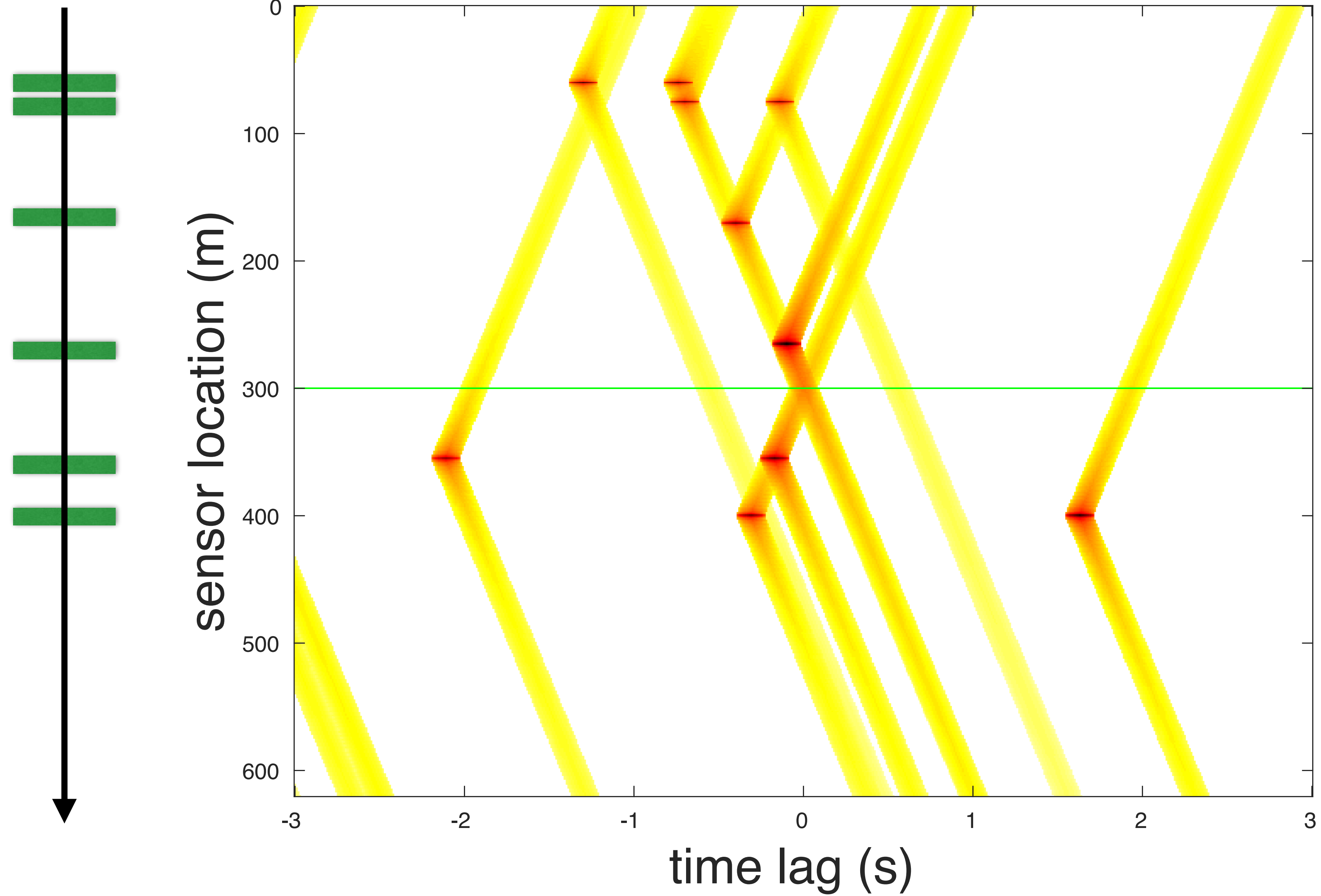
Cross-correlation Virtual Source Ch 200



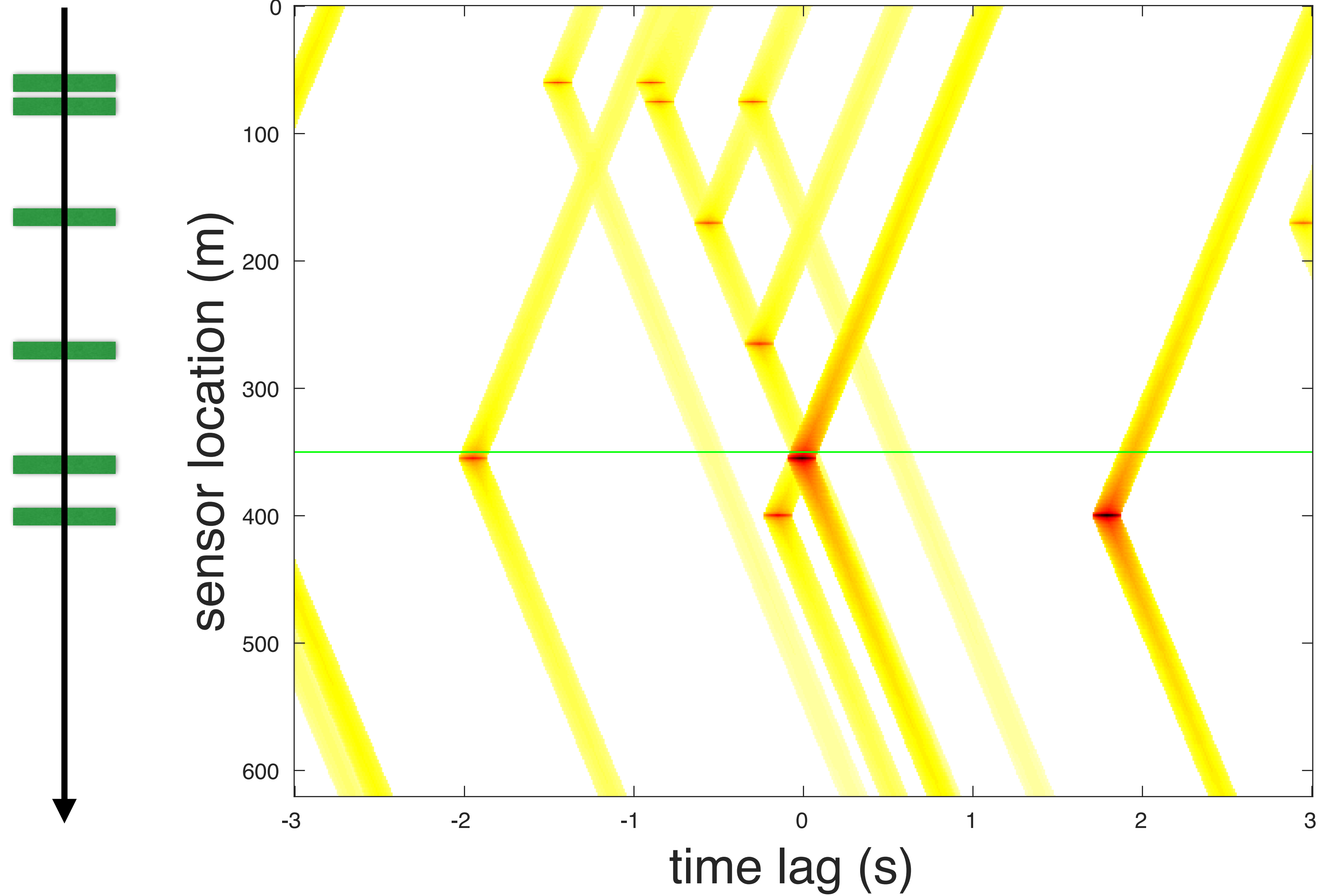
Cross-correlation Virtual Source Ch 250



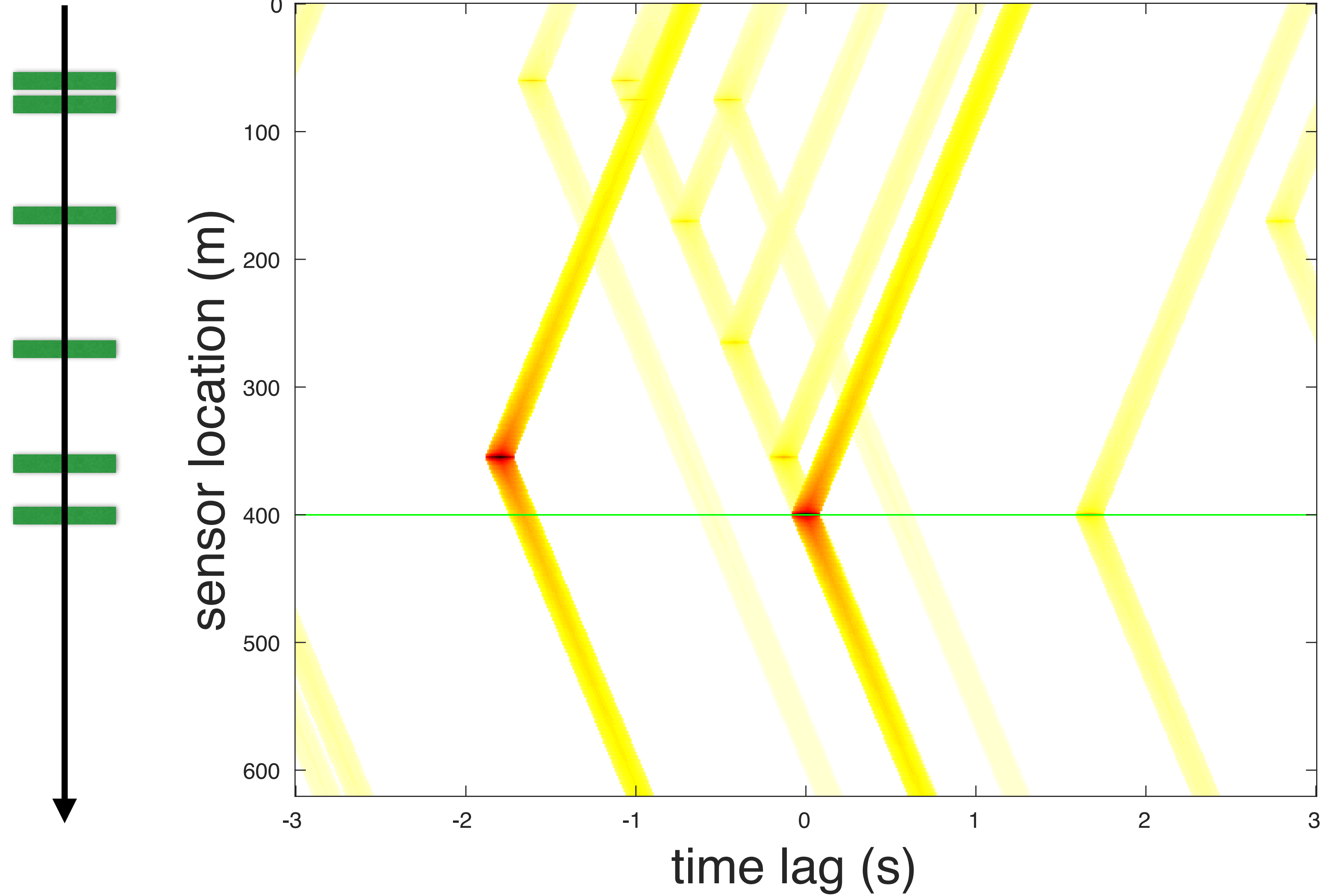
Cross-correlation Virtual Source Ch 300



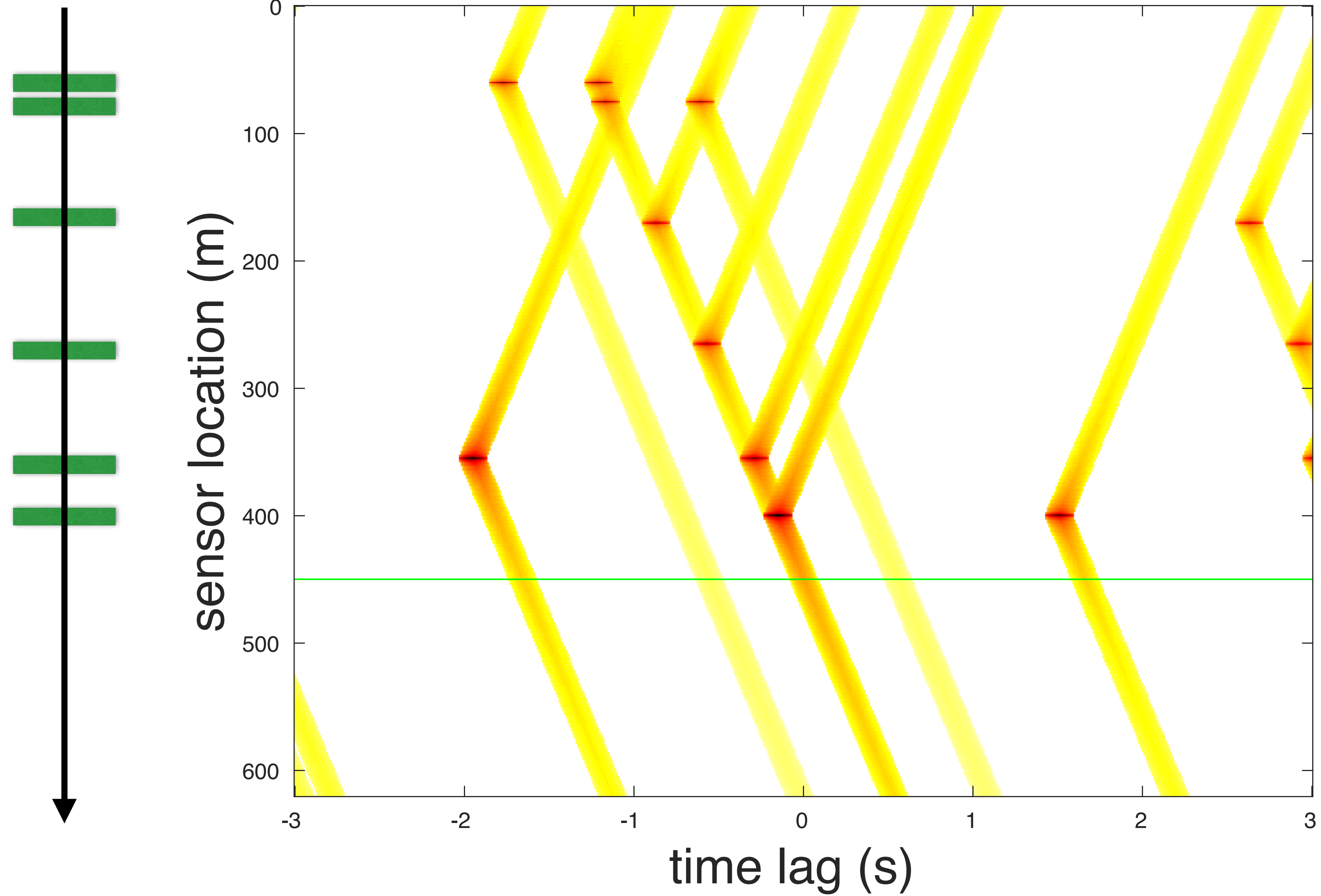
Cross-correlation Virtual Source Ch 350



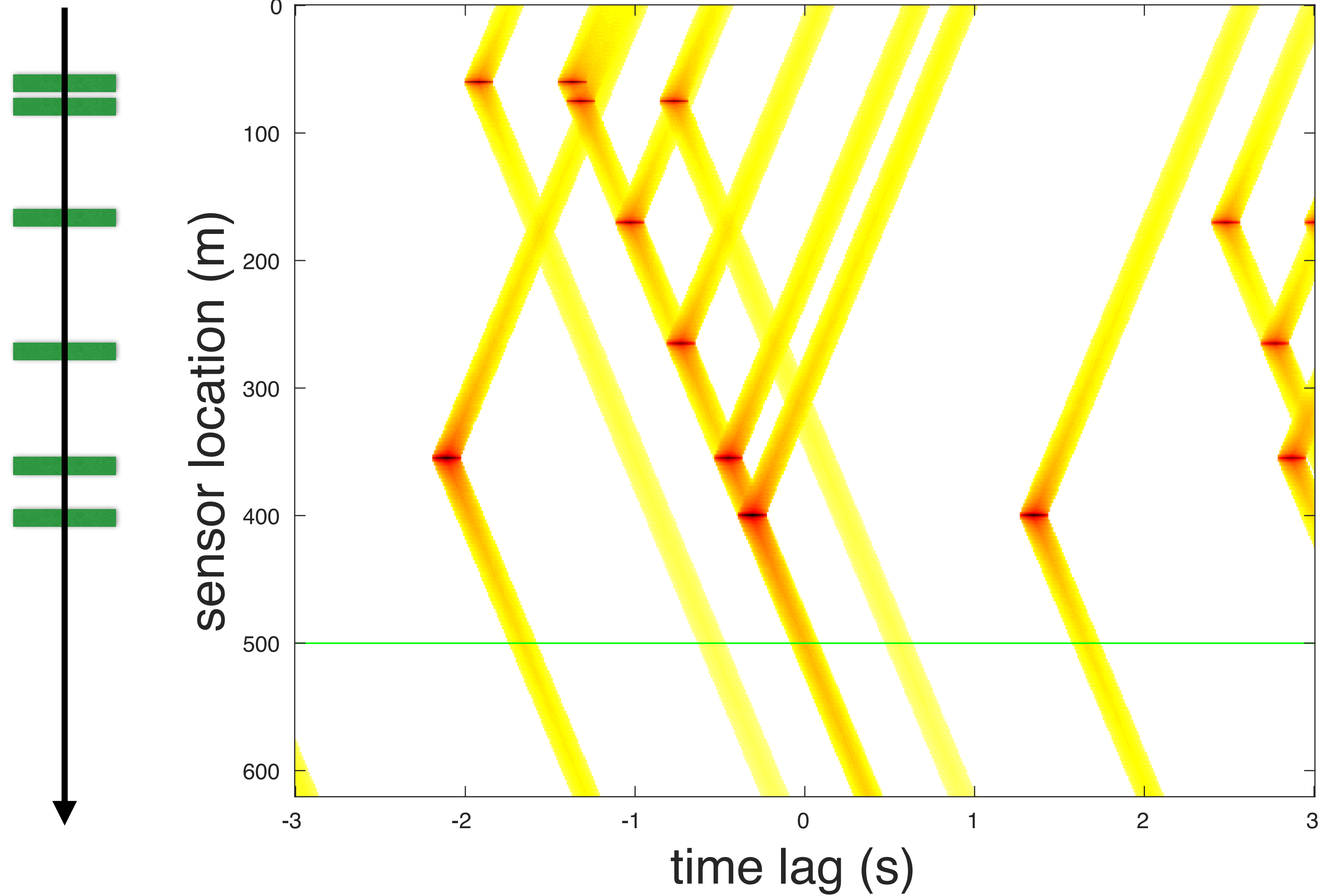
Cross-correlation Virtual Source Ch 400



Cross-correlation Virtual Source Ch 450

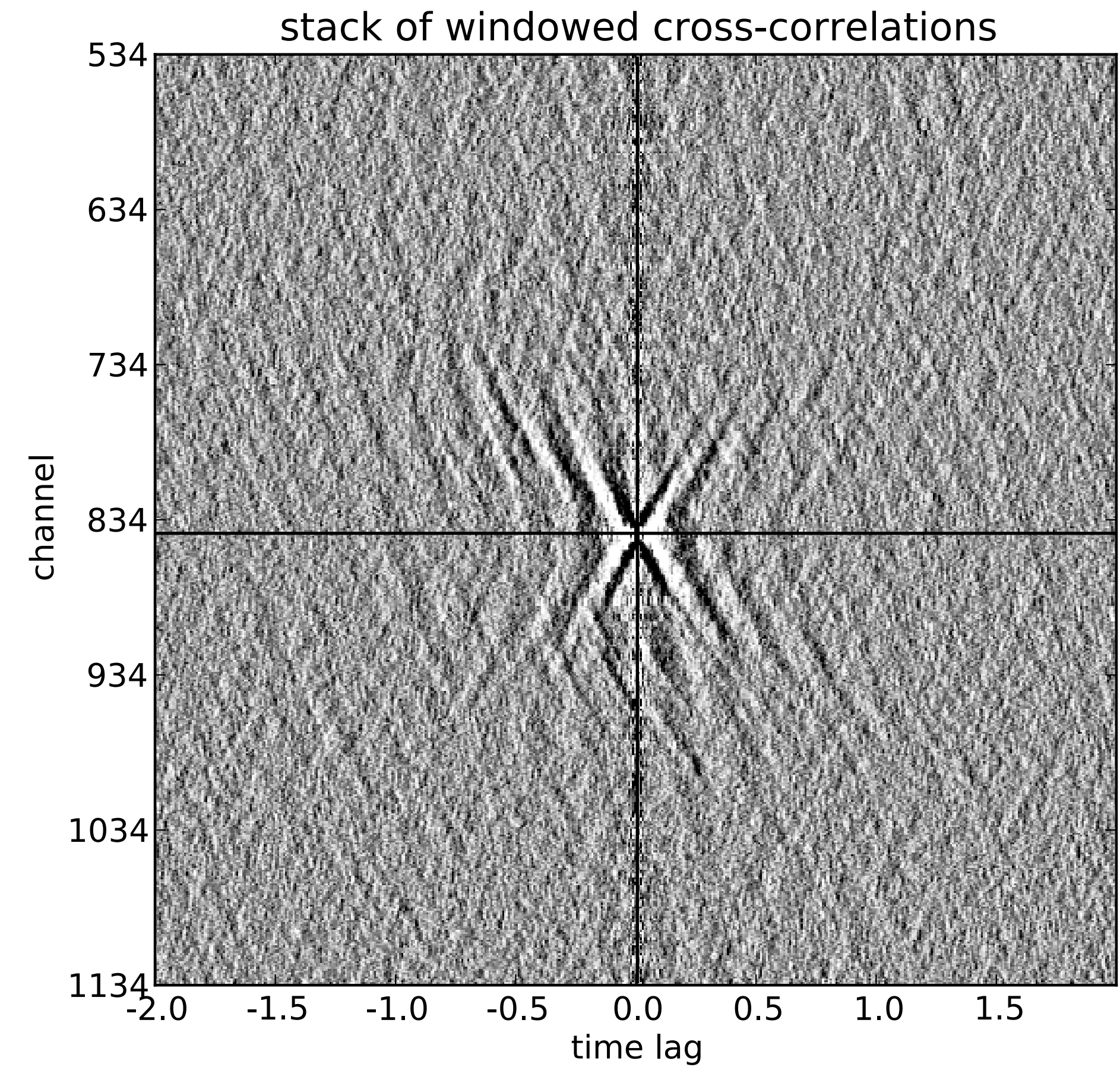
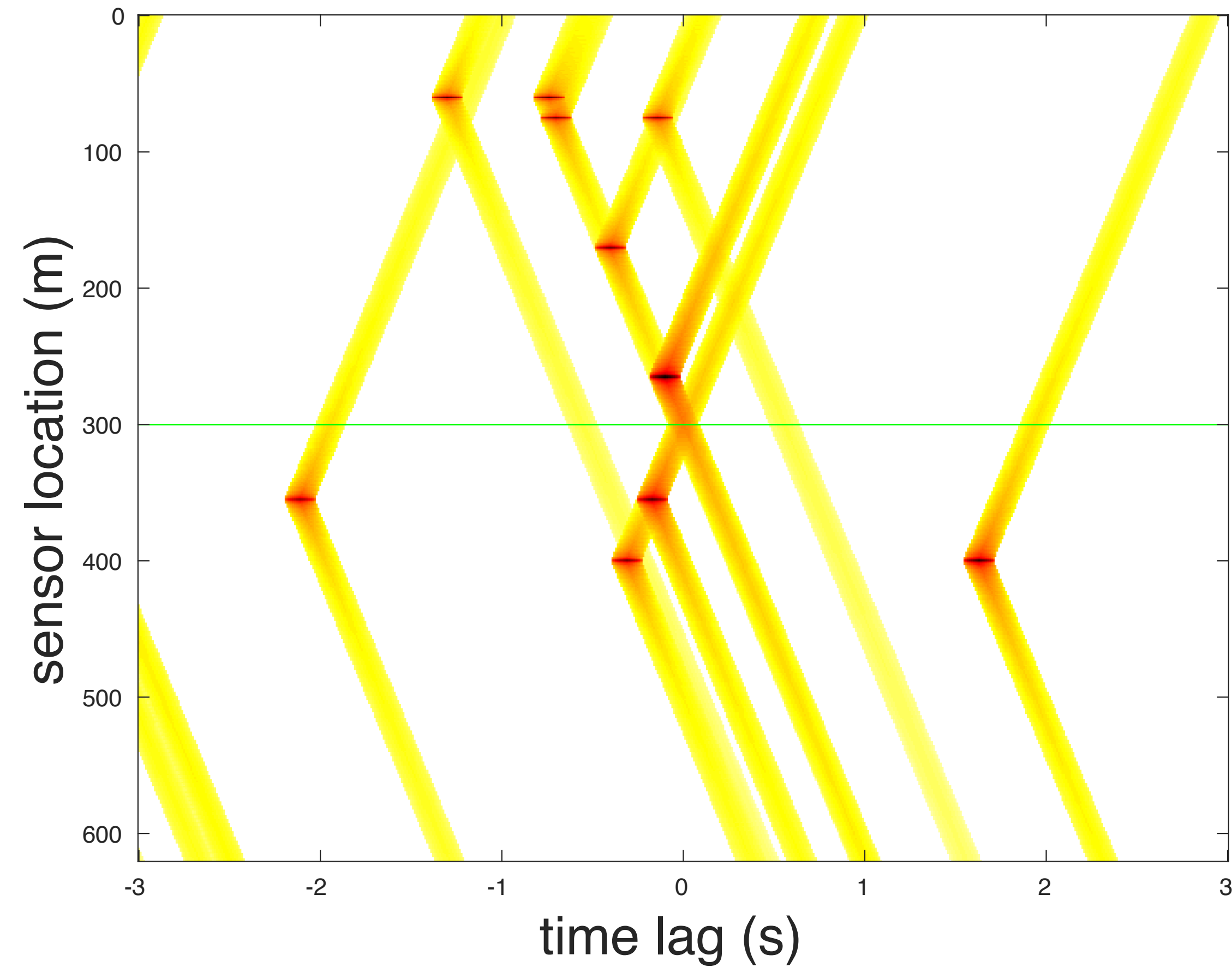


Cross-correlation Virtual Source Ch 500



Similar to copies in cross-correlations

Cross-correlation Virtual Source Ch 300



Let's say it's bumps. What's the fix?

1. Use cross-coherence instead of cross-correlation for virtual source response estimation (Nakata et al. *Geophysics*, 2011).

2. Downweight tau-p transforms at tau far from 0.

Let's say it's bumps. What's the fix?

1. Use cross-coherence instead of cross-correlation for virtual source response estimation (Nakata et al. *Geophysics*, 2011).

Cross-correlation

$$u_A(s, \omega)u_B^*(s, \omega) = |W(s, \omega)|^2 G_A(s, \omega)G_B^*(s, \omega)$$

source
wavelet must
be estimated

Cross-coherence

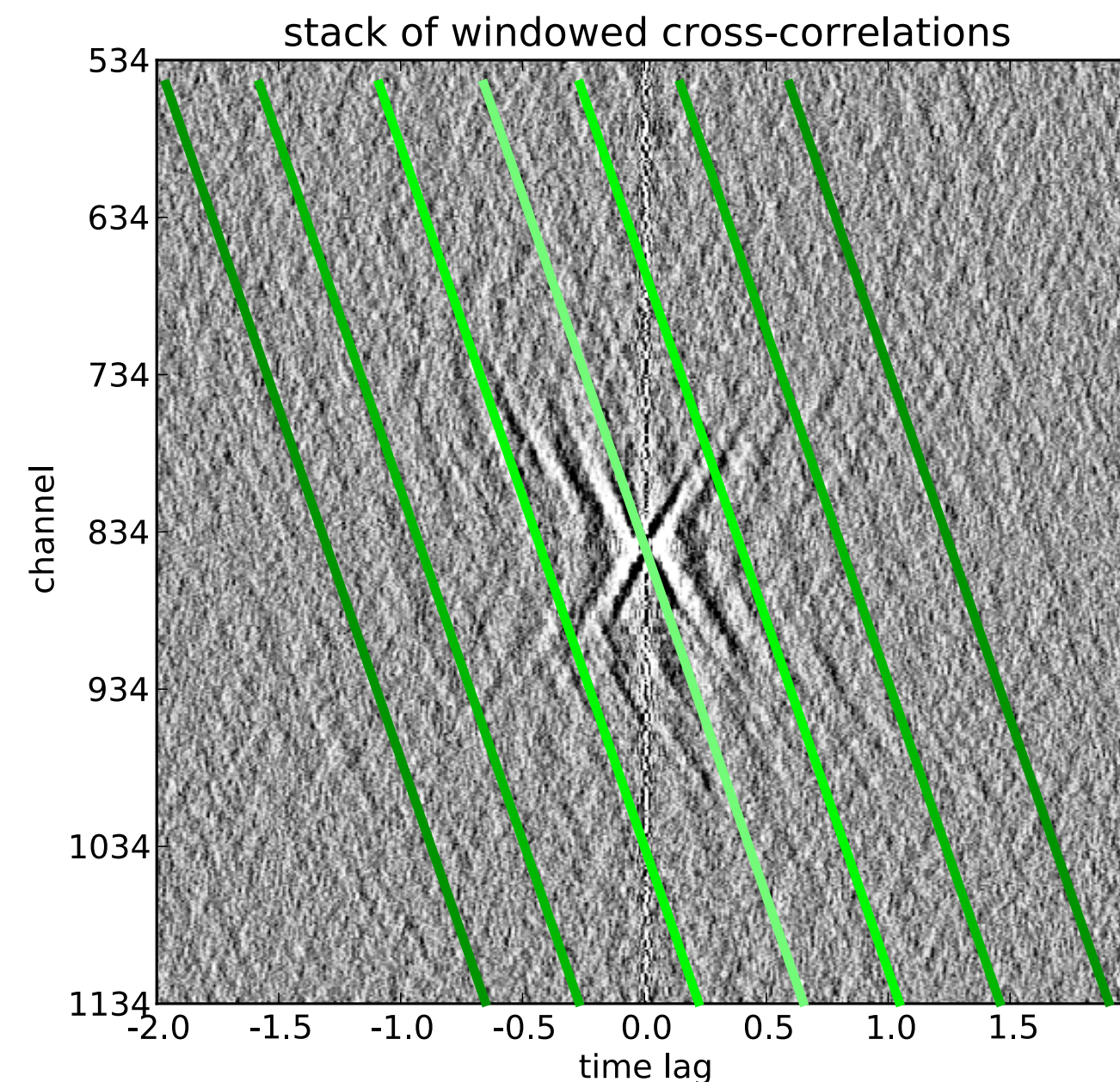
$$\frac{u_A(s, \omega)u_B^*(s, \omega)}{|u_A(s, \omega)||u_B(s, \omega)|} = \frac{|W(s, \omega)|^2 G_A(s, \omega)G_B^*(s, \omega)}{|W(s, \omega)|^2 |G_A(s, \omega)||G_B^*(s, \omega)|}$$

source
wavelet
cancels

2. Downweight tau-p transforms at tau far from 0.

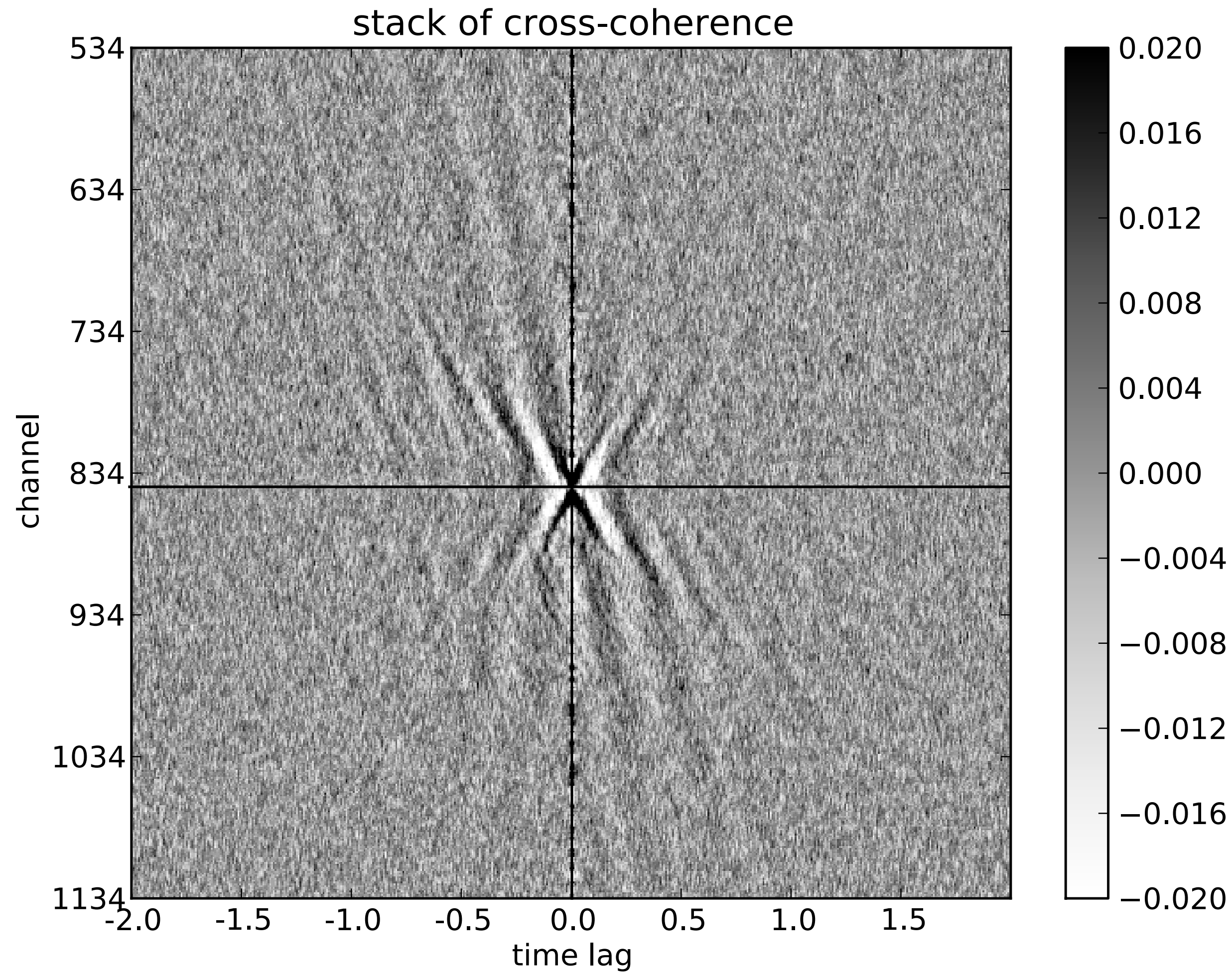
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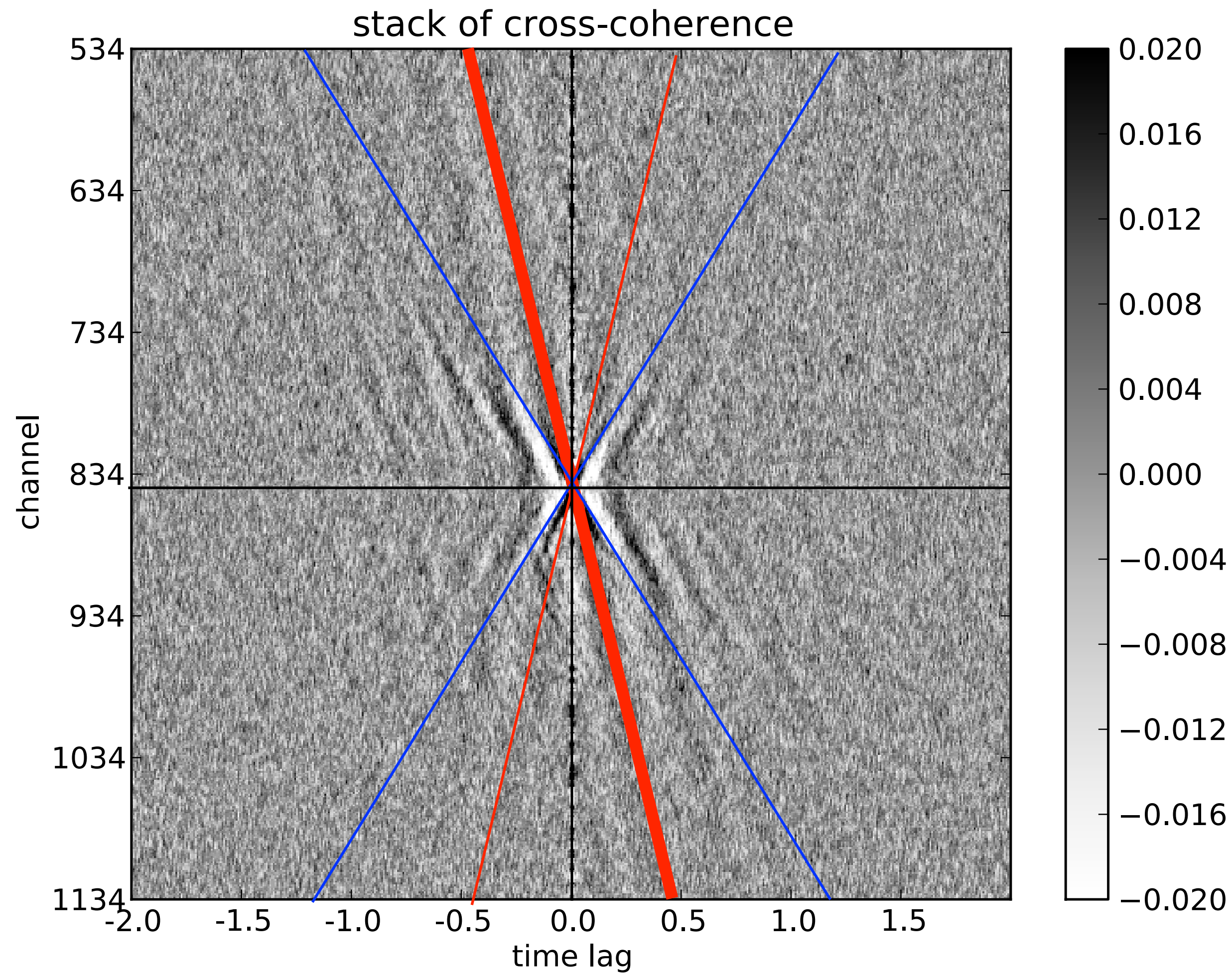


2. Downweight tau-p transforms at tau far from 0.

Dispersion images

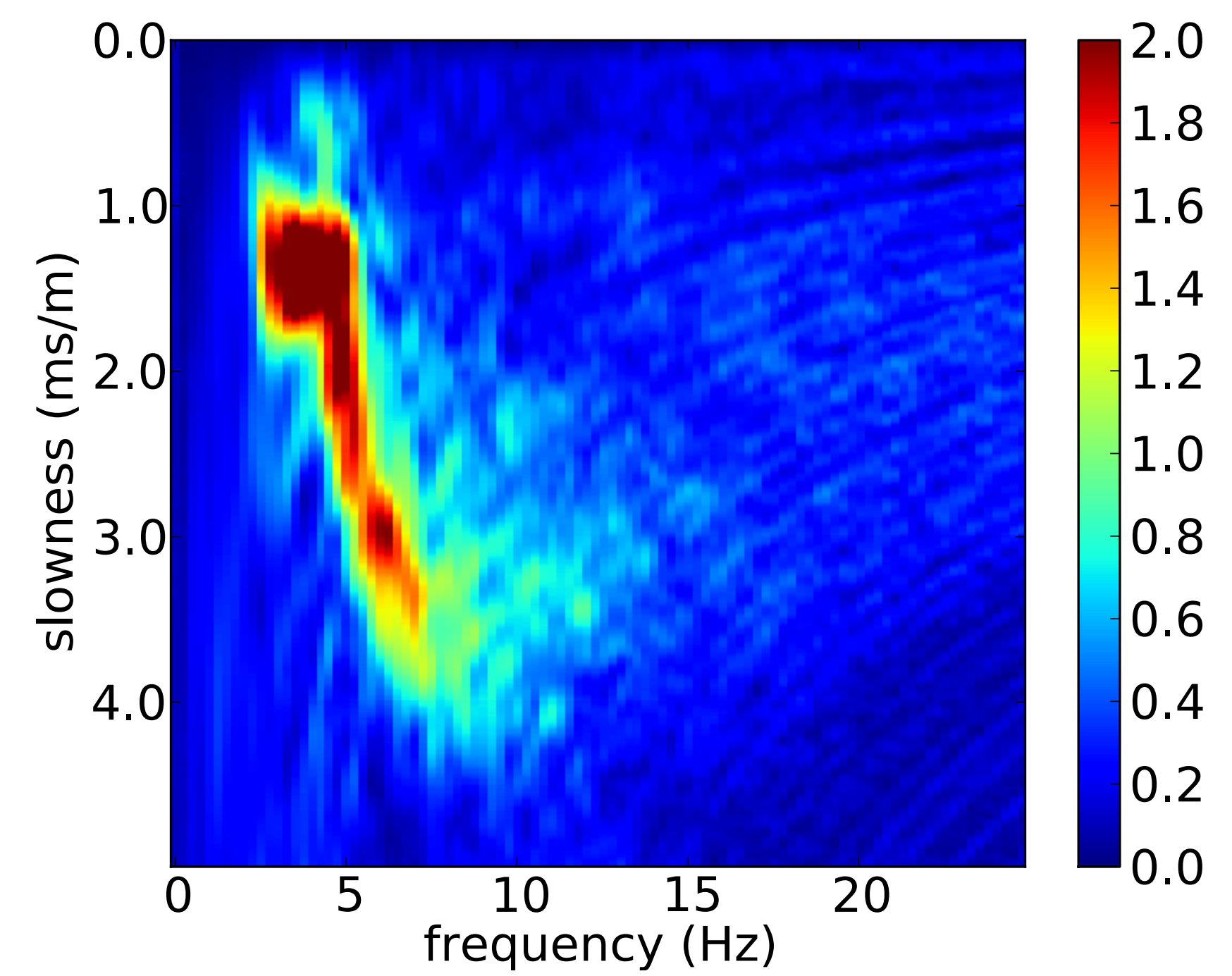
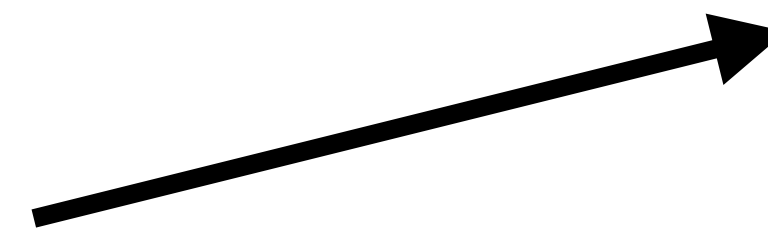
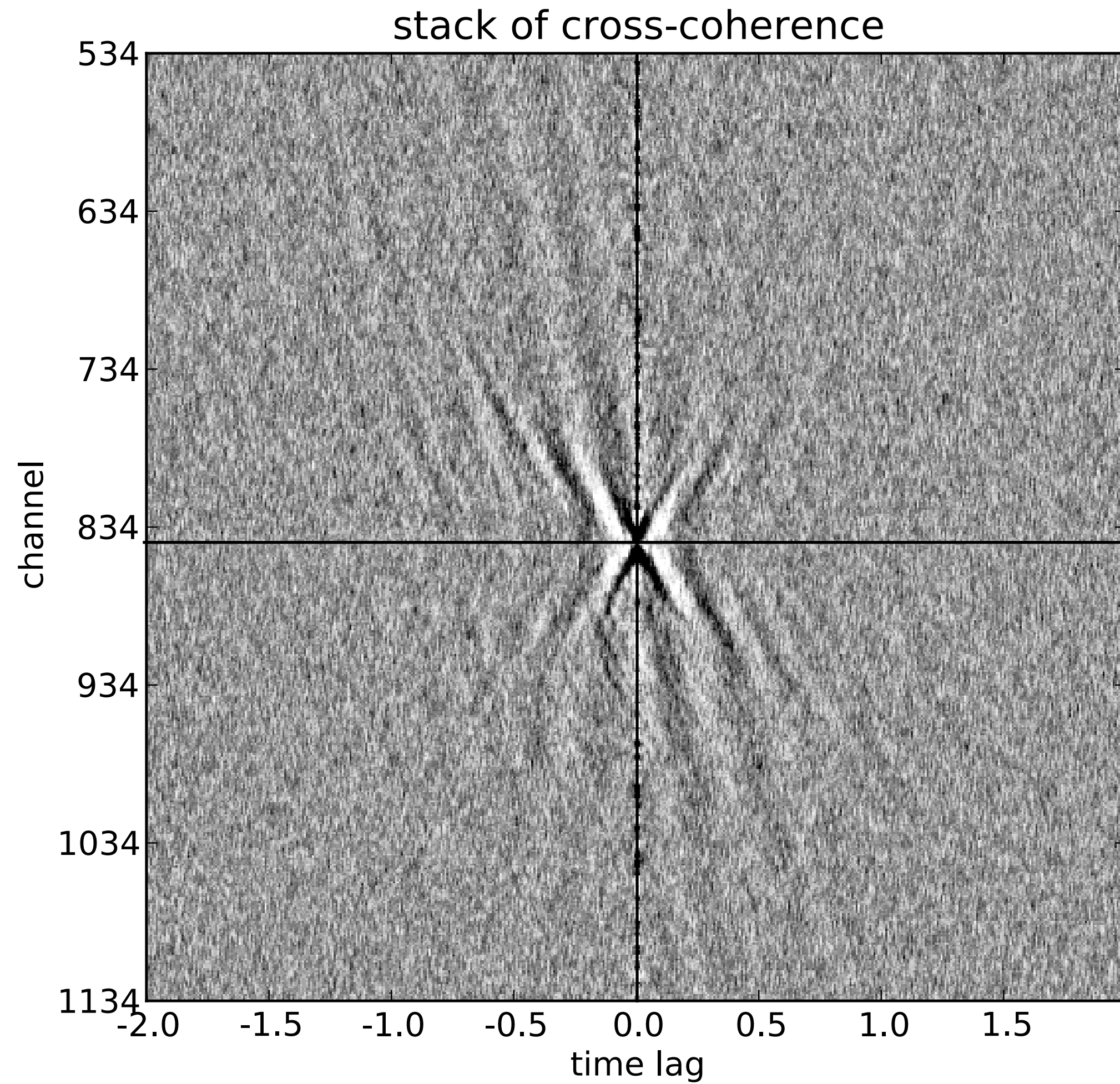


Dispersion images

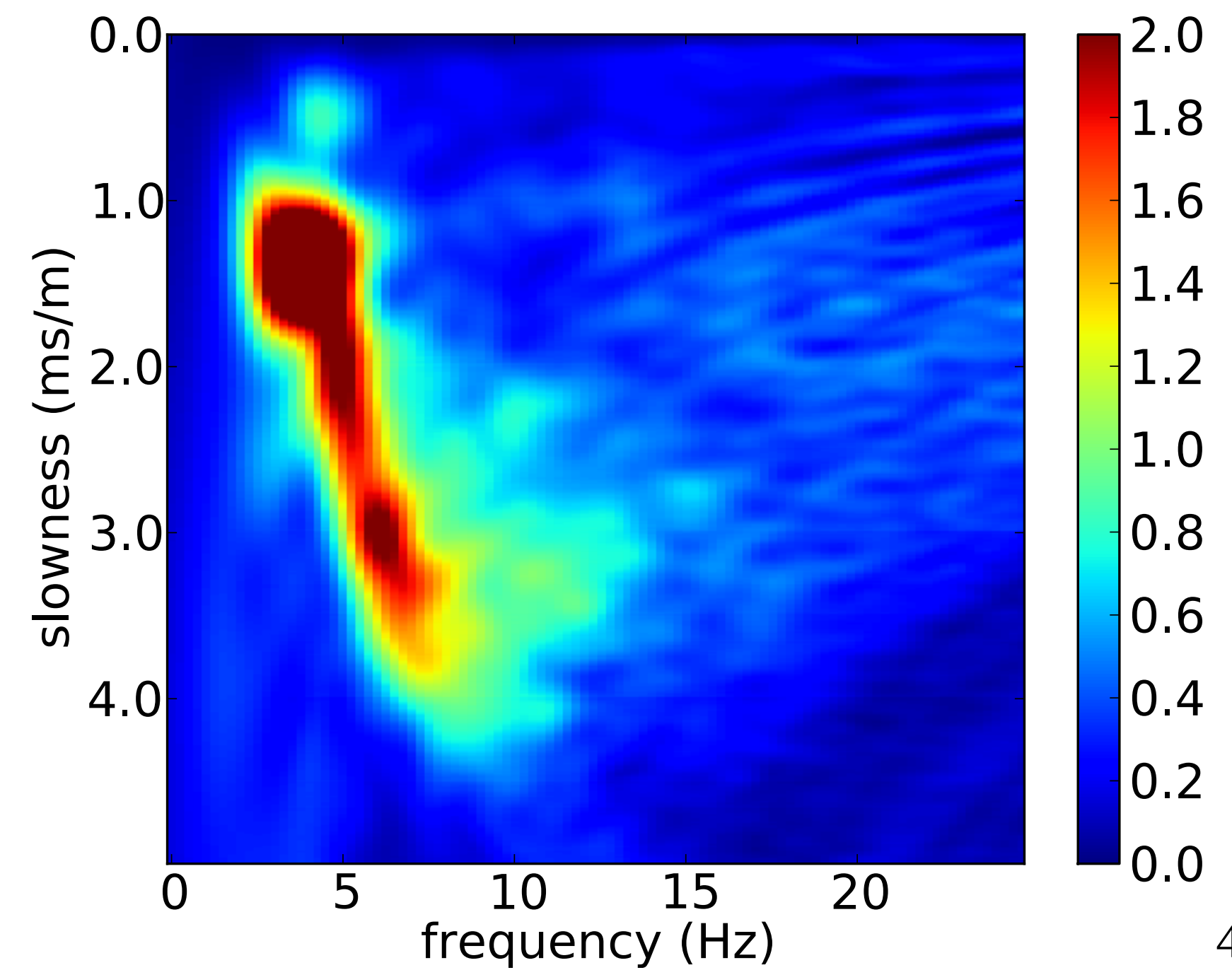
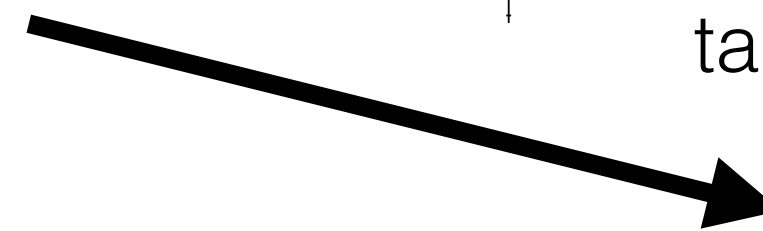
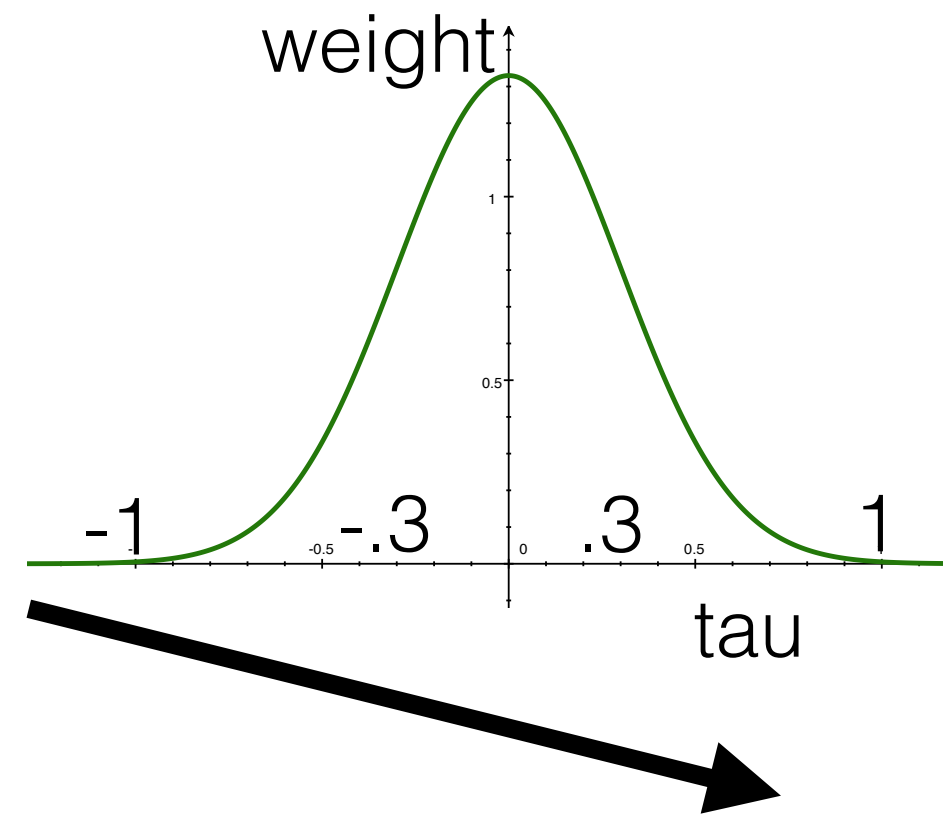
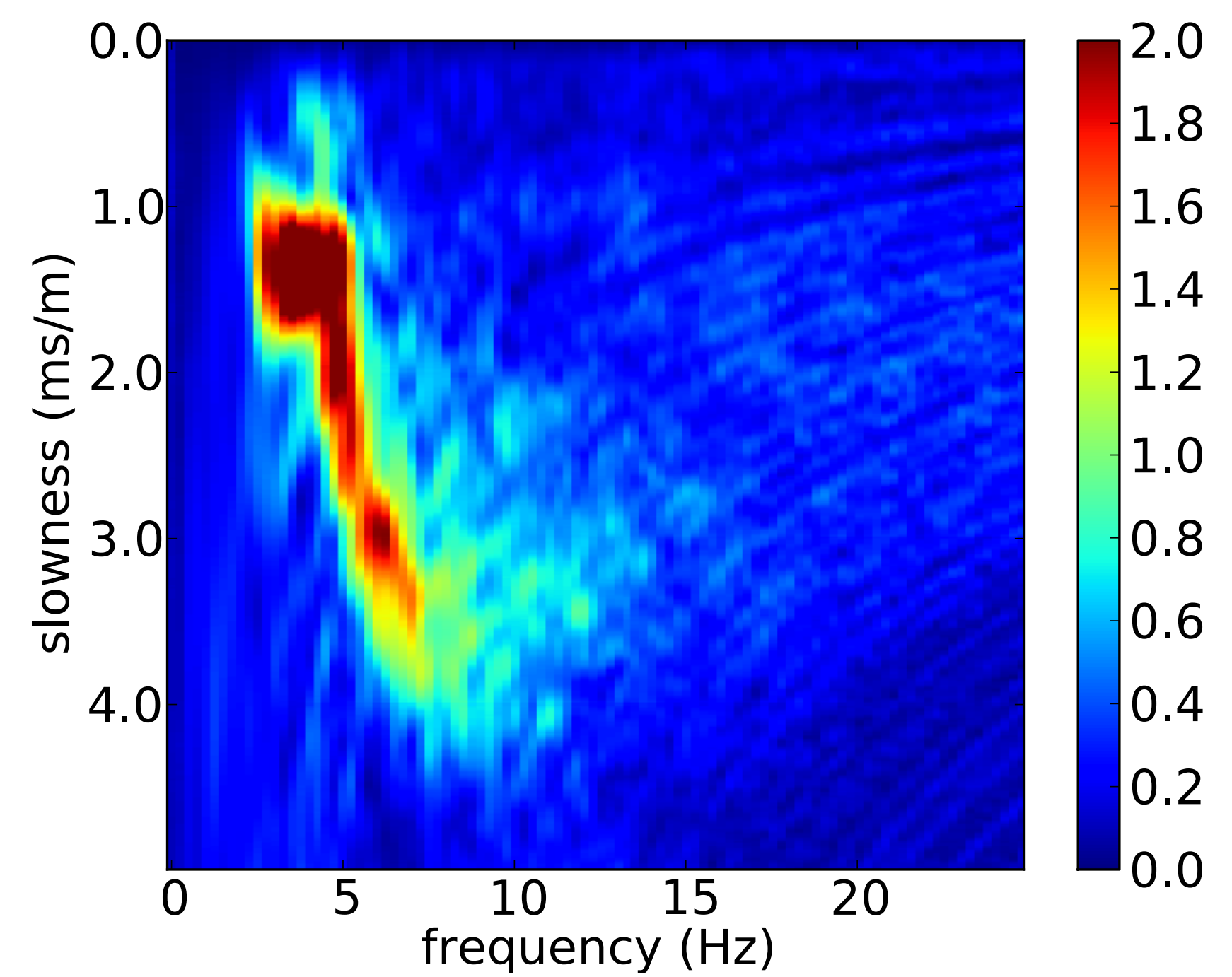
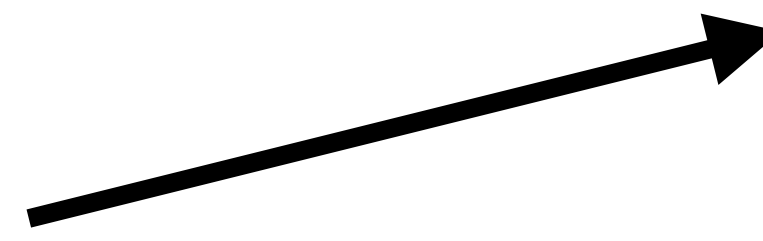
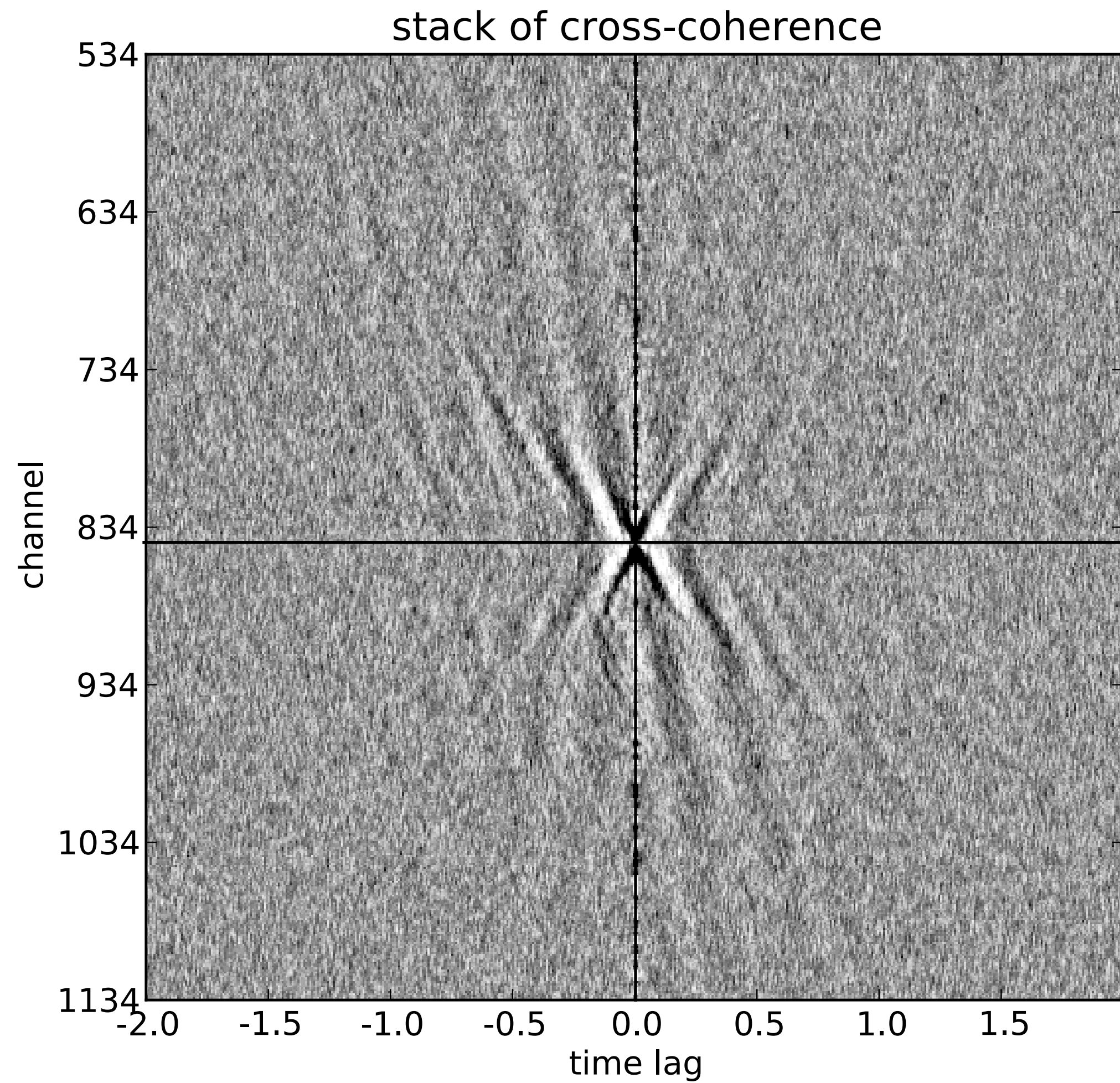


Faster, lower frequency event
Slower, higher frequency event

Dispersion images



Dispersion images



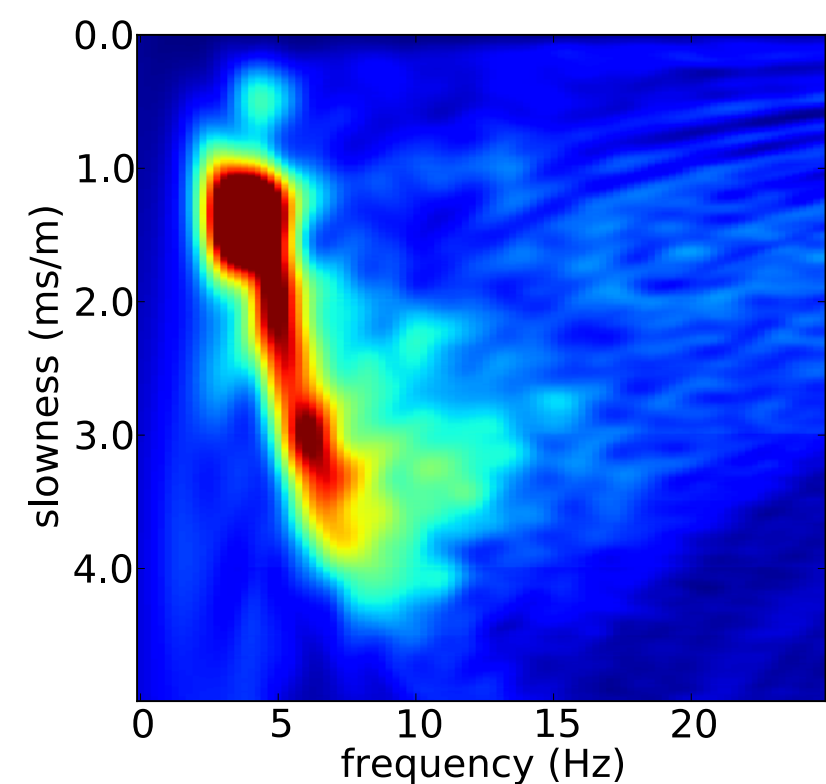
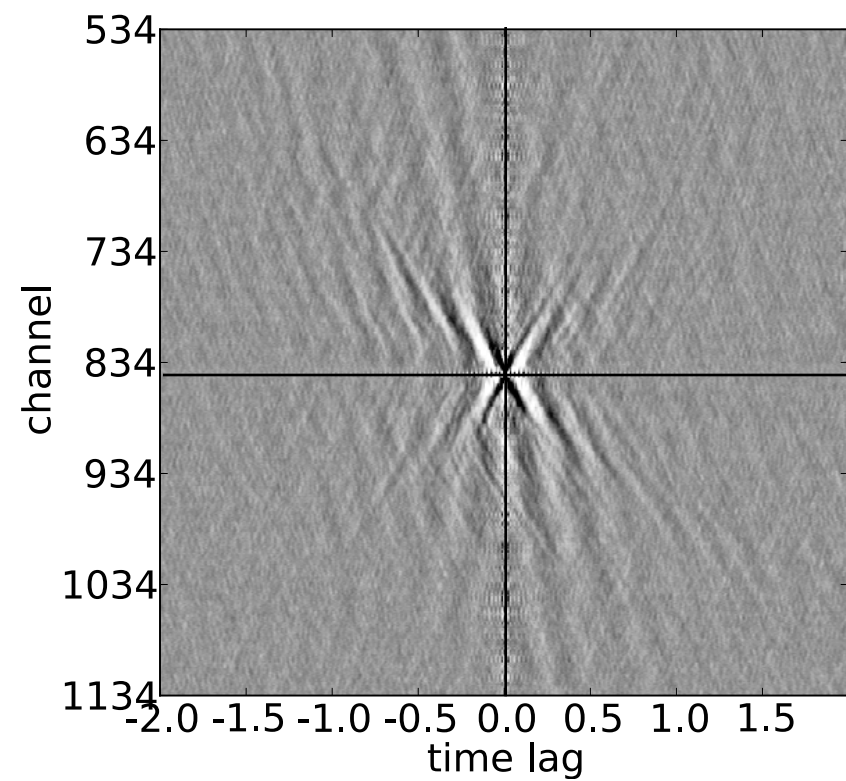
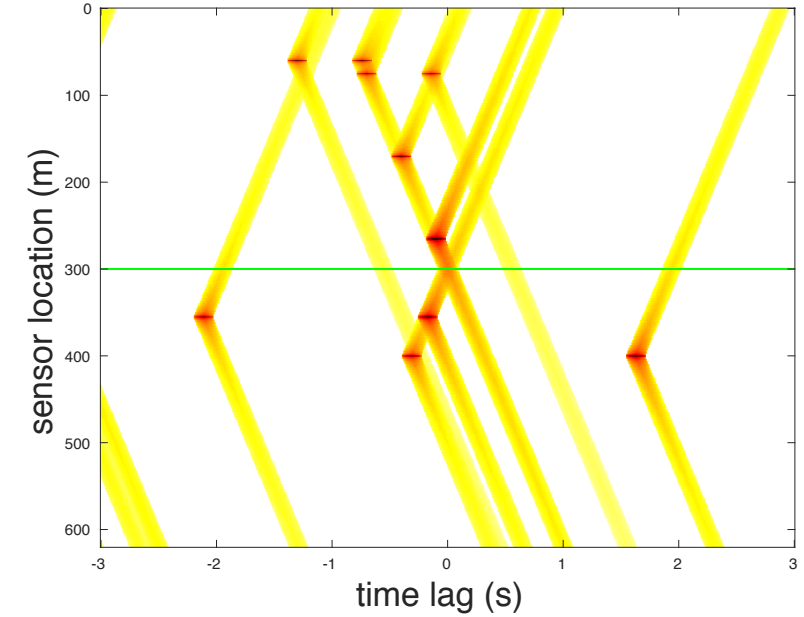
Conclusions

Repeating sources can cause apparent copies of virtual source response functions

Cross-coherence reduces non-ideal source effects

Tau-p weighting reduces the effect of artifacts, but we continue searching for ways to extract useful information from these artifacts

Cross-correlation Virtual Source Ch 300



Acknowledgements



- Field experiments and some authors supported by US Dept of Defense, SERDP grant RC-2437
- Work at LBNL funded by US Dept of Energy contract DE-AC02-05CH11231
- I'm supported by US Dept of Energy grant DE-FG02-97ER25308
- Staff at CRREL for field work support
- Thanks to Stanford/SEP colleagues for useful discussions, especially Jason Chang, Nori Nakata, Sjoerd de Ridder, Biondo Biondi, Bob Clapp and Stewart Levin



Looking forward to dark fiber array

Collaborators:

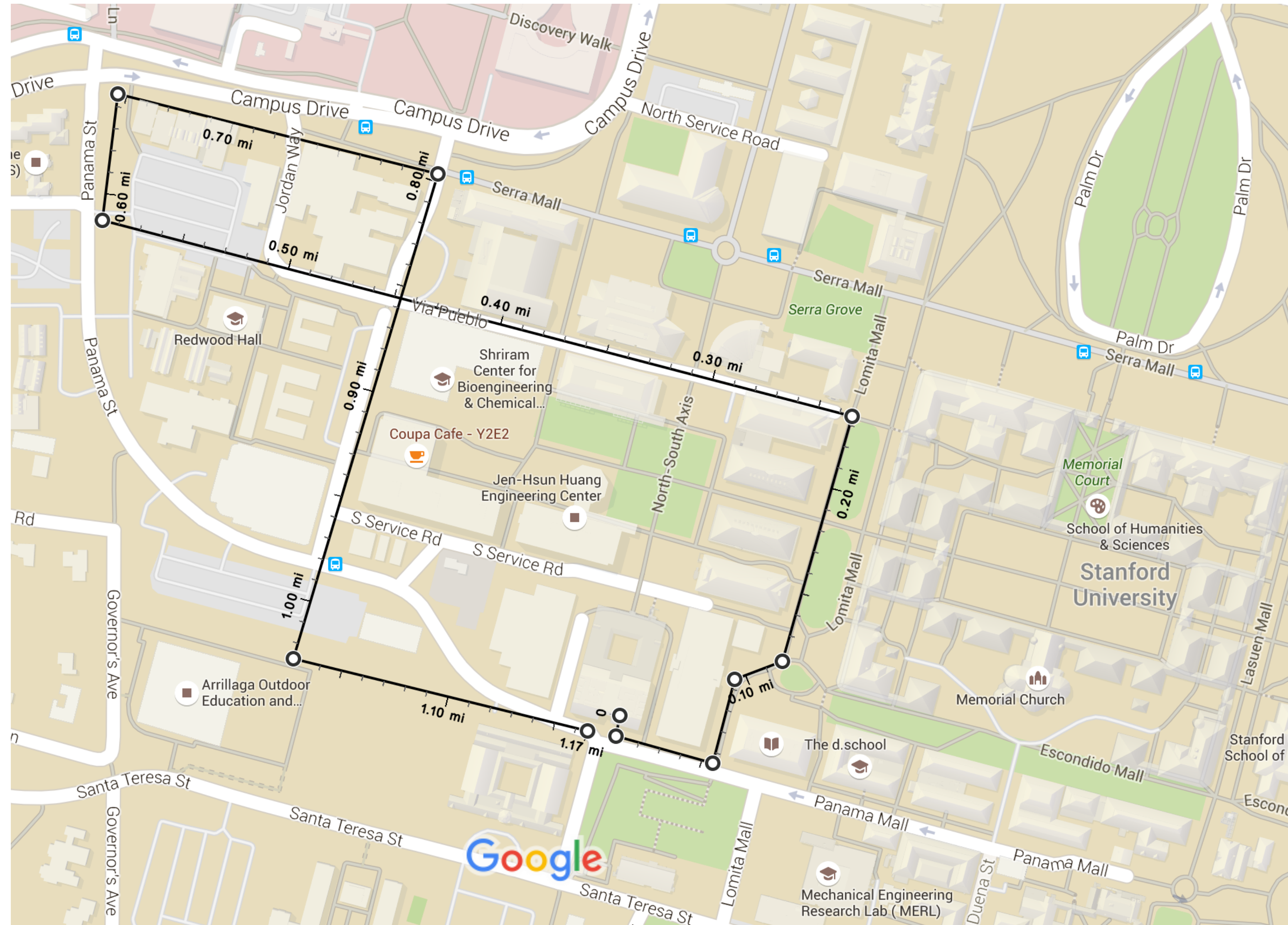
Biondo Biondi

Bob Clapp

Stewart Levin

Stanford IT

Martin Karrenbach
and **OptaSense**[®]
a QinetiQ company



Looking forward to dark fiber array

Collaborators:

Biondo Biondi

Bob Clapp

Stewart Levin

Stanford IT

Martin Karrenbach
and **OptaSense**[®]
a QinetiQ company



Could it be caused by two axles?

Any signal emitted by the front axle hitting a bump is repeated by the back axle.



wheelbase	2 m	3.5 m	20 m
time between hits, 20 m/s (45 mph)	0.1 s	0.175 s	1 s
time between hits 25 m/s (55 mph)	0.08 s	0.14 s	0.8 s

...but (i) this road doesn't have many 18 wheelers and
(ii) doesn't cause non-stationary cross-correlation artifacts