



UNIVERSITY OF
CALGARY

Passive seismic reservoir monitoring techniques applied to heavy oil production

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CREWES Sponsors Meeting 2006

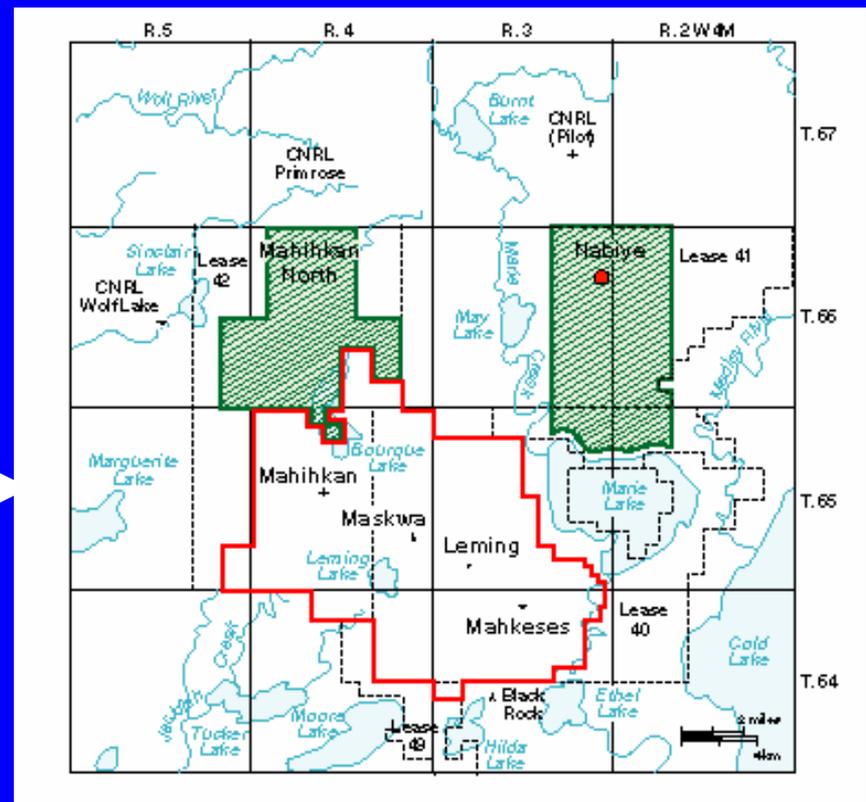
December 1, 2006

Presentation Outline:

- Introduction / Cold Lake background
- Purpose of research
- Algorithms explored
- MATLAB Graphical User Interface application developed
- Initial testing results
- Ongoing and future work
- Conclusions

Introduction / Cold Lake Background:

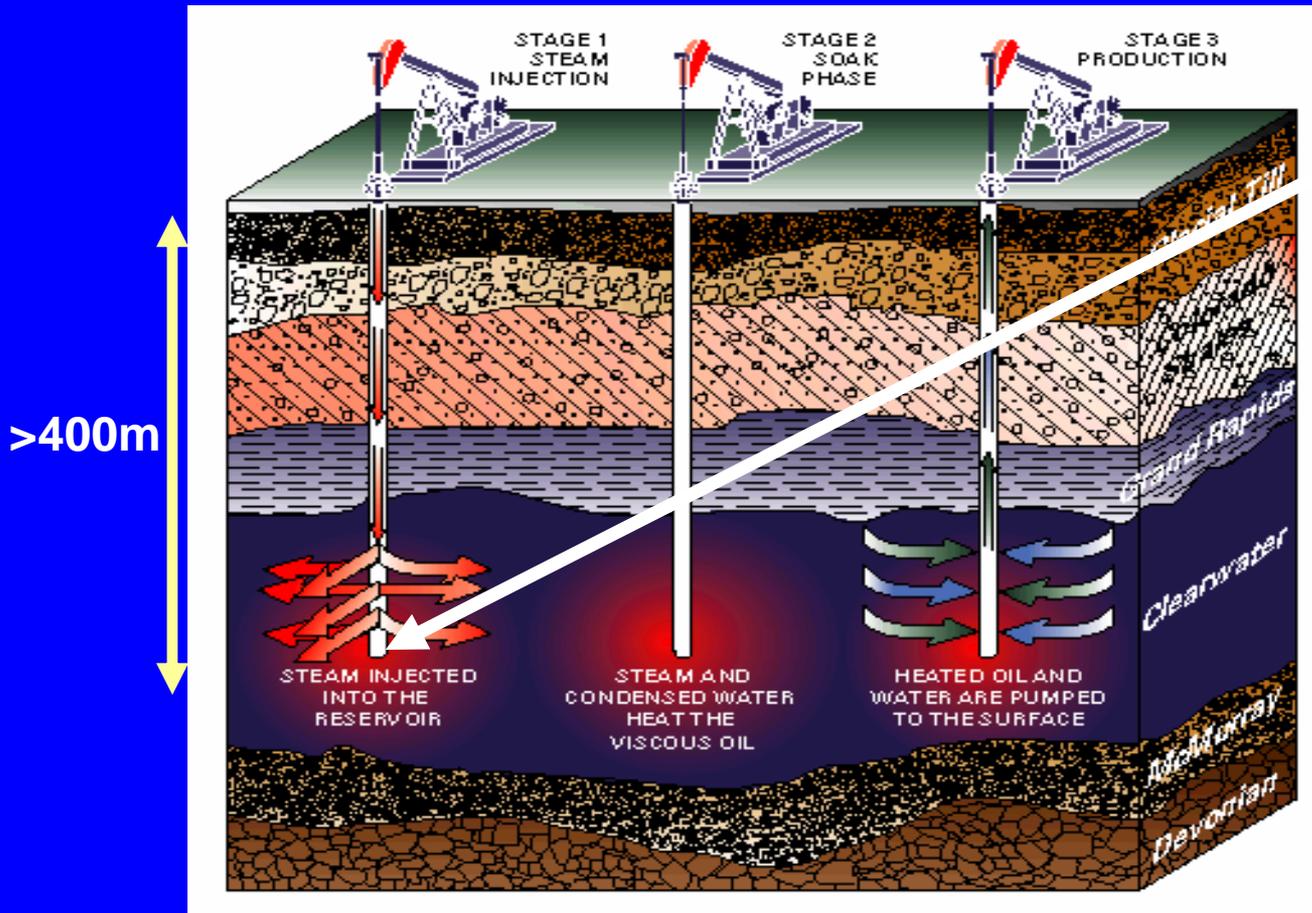
- Imperial Oil Ltd. involved in oil sands production near Cold Lake, Alberta. Proved reserves ~ 850 million barrels. Production > 120,000 bbl/day. ~ 3200 operating wells.



Cold Lake Production Area (Imperial Oil Ltd., 2006)

Cold Lake Background:

- Producing formation > 400m deep
- CSS used during production (Imperial Oil Ltd., 2006):



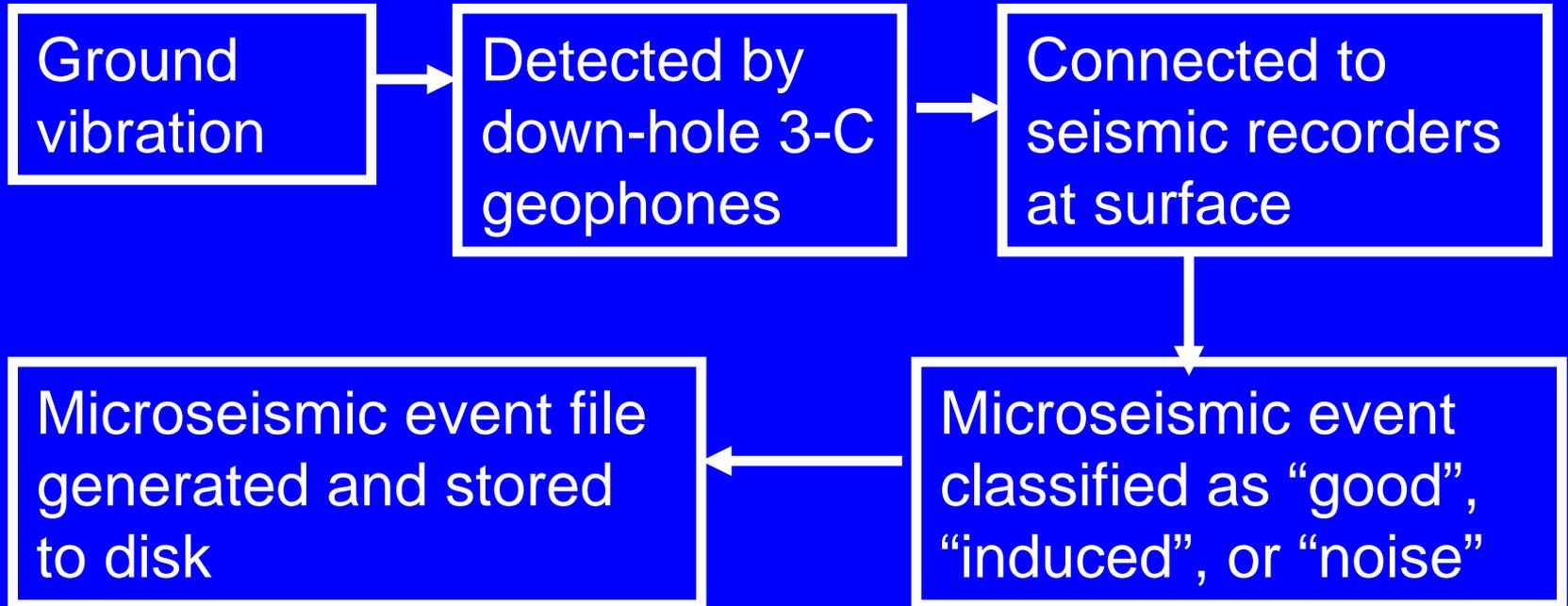
~320°C, 11MPa
Induces stress in overburden.

↓
Cement cracks,
casing failures
possible.

↓
Passive seismic
monitoring

Cold Lake Background:

Passive seismic system operation:



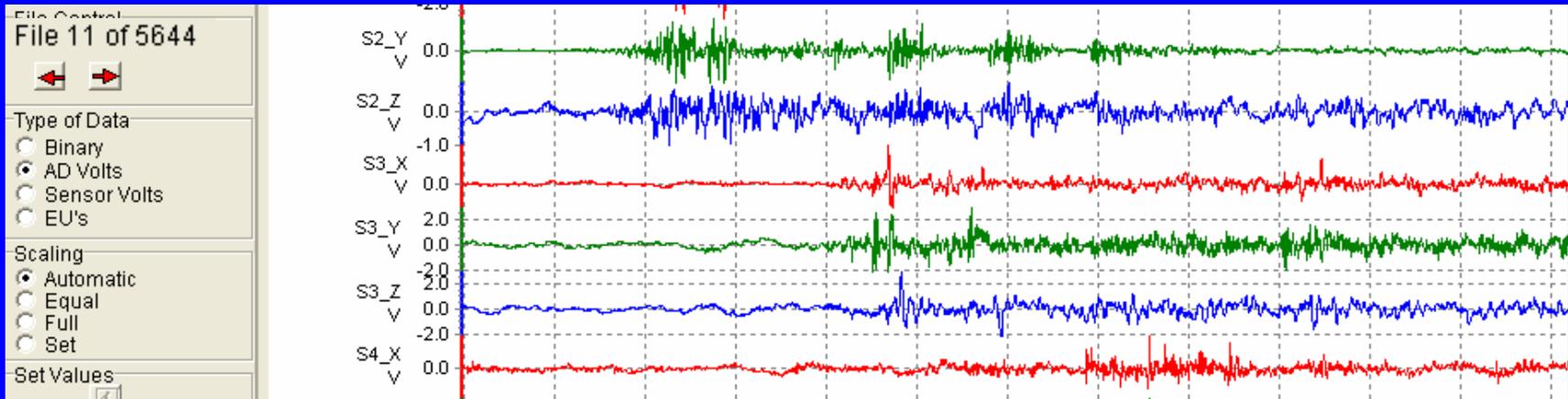
Theoretically investigate all "good" files, discard the rest.

Noise events ~ 99% of all microseismic events detected

Purpose of Research:

Problem: Event-file classification software misclassifies files.

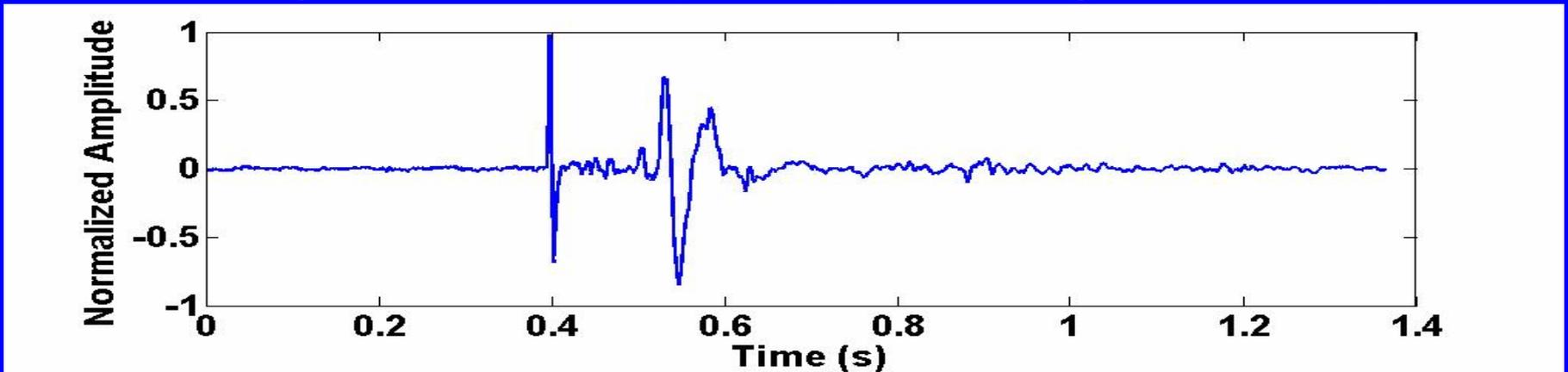
Importance: Manual analysis of thousands of misclassified files time-consuming & inefficient.



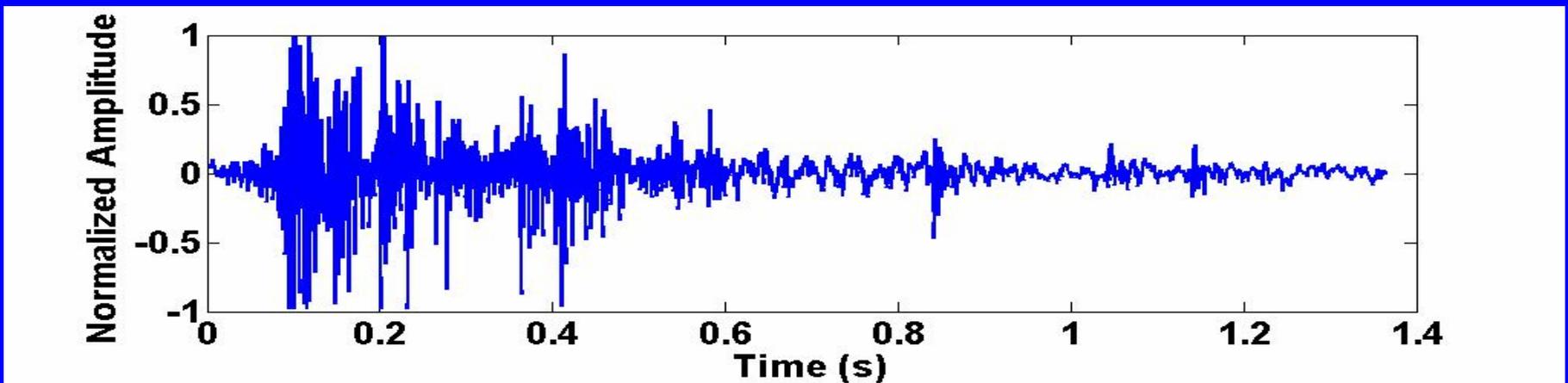
Solution (in progress): Generate an application containing algorithms capable of accurately differentiating between “good” and “noise” files / traces.

Purpose of Research:

How are signals like this (example of a “good” trace)...



...different from this (example of a “noise” trace)?:



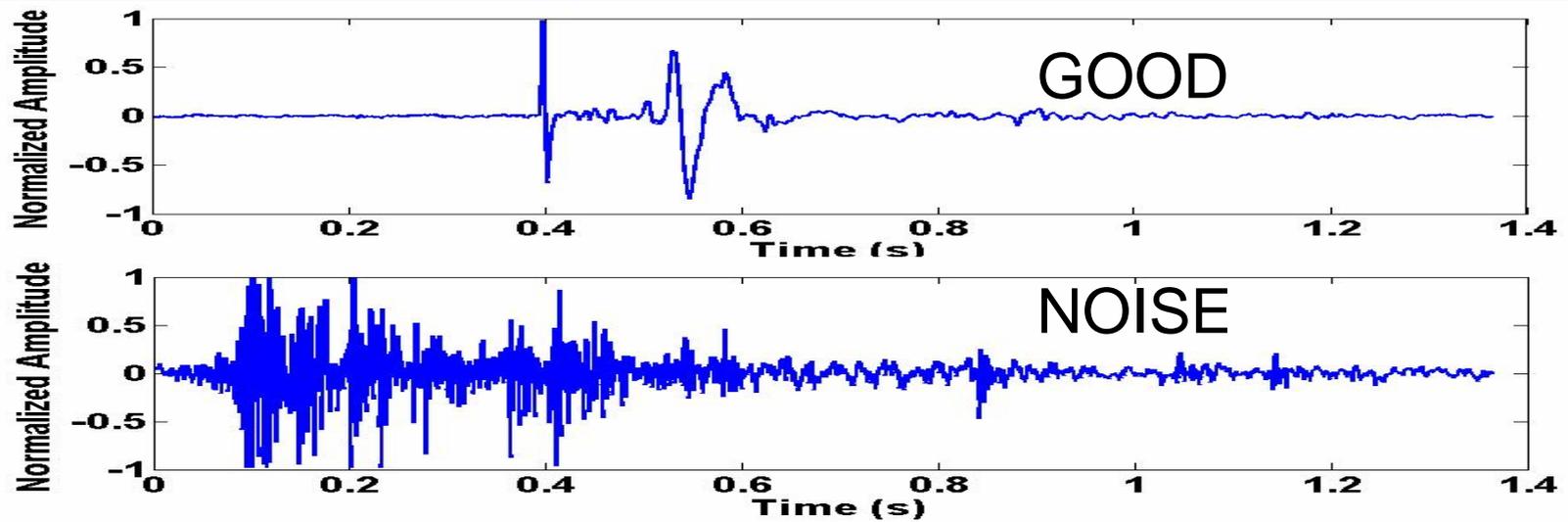
Algorithms Explored:

Classification Techniques Tested:

Frequency filtering: Preliminary datasets suggest some “noise” signals contain higher frequencies than “good” ones.

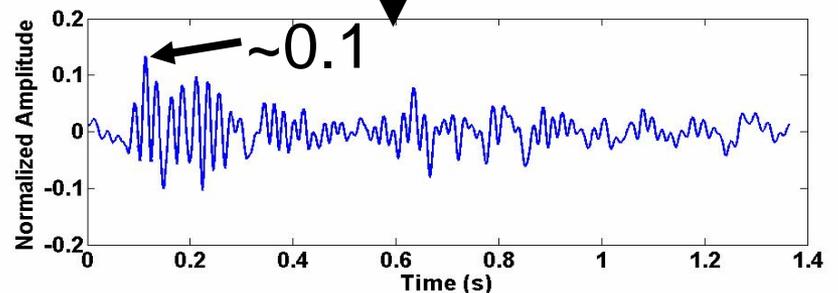
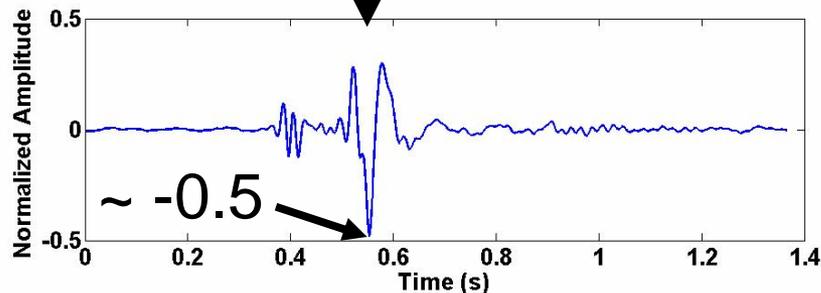
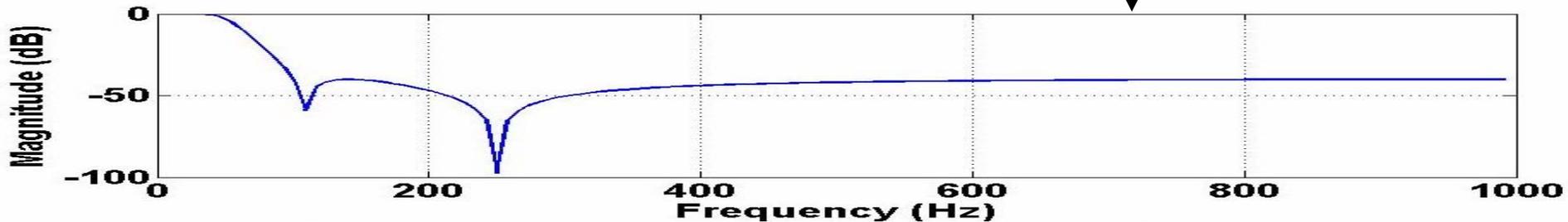
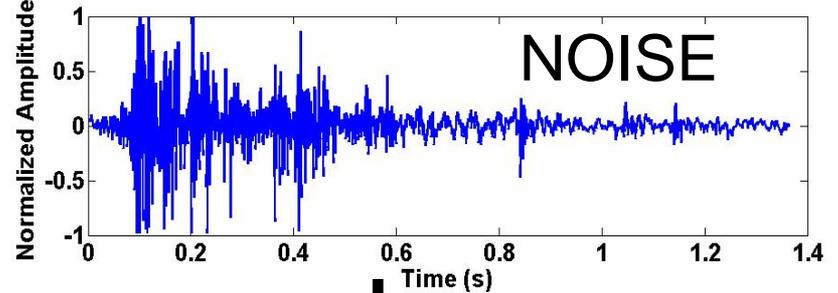
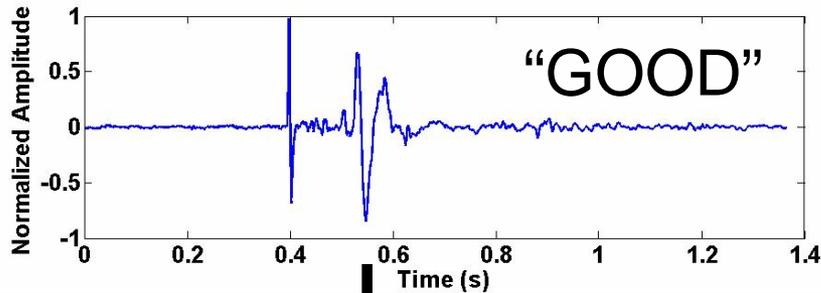
Event length detection: P-wave event lengths of “good” signals are generally shorter than noise event lengths.

Statistical analysis: Noise events are generally more oscillatory than “good” events.



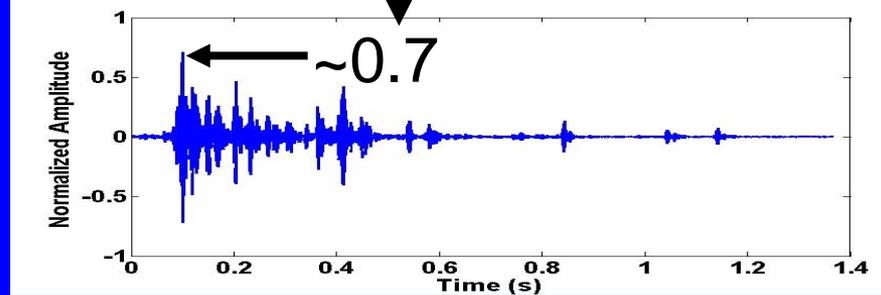
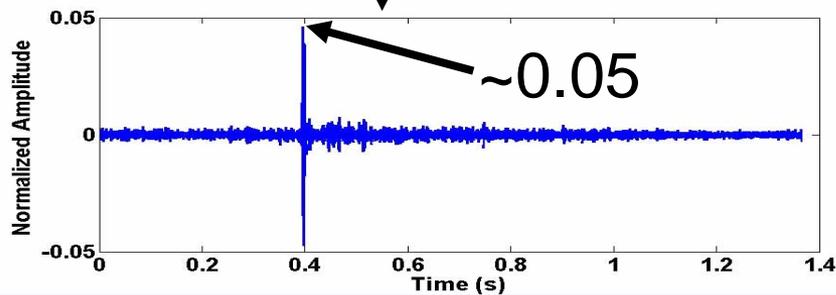
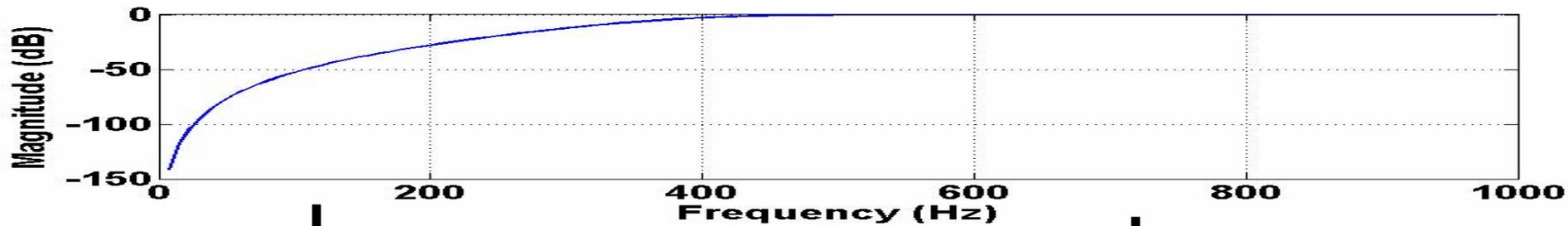
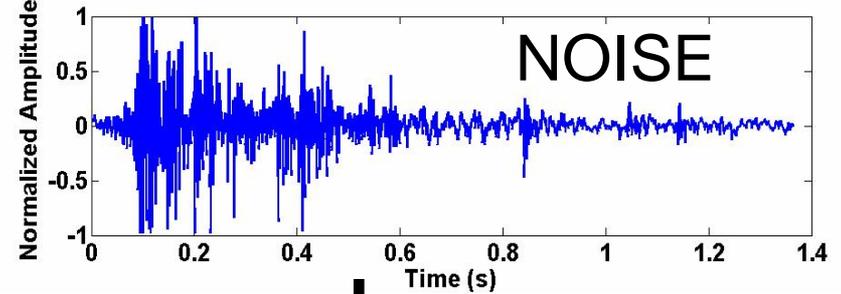
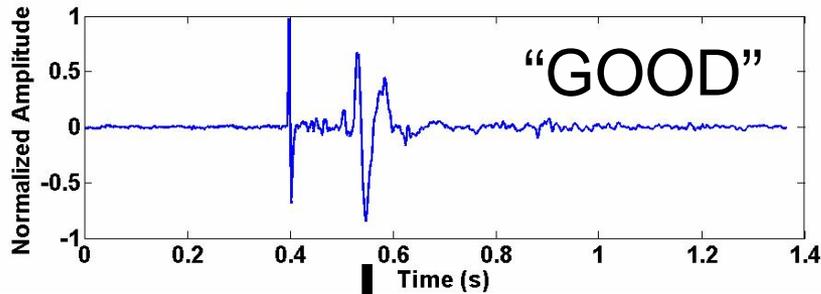
Algorithms Explored: Frequency Filtering

Fourth-order Inverse-Chebyshev low-pass filter.



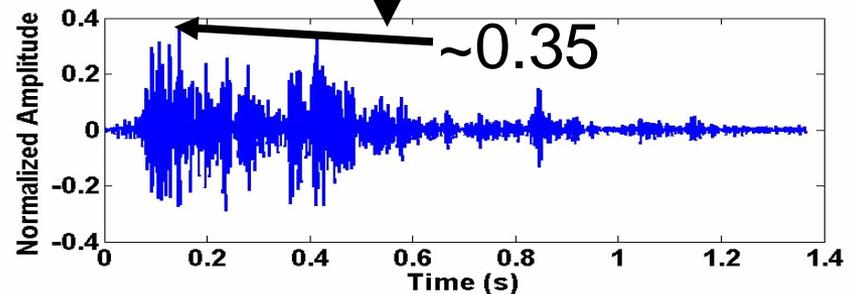
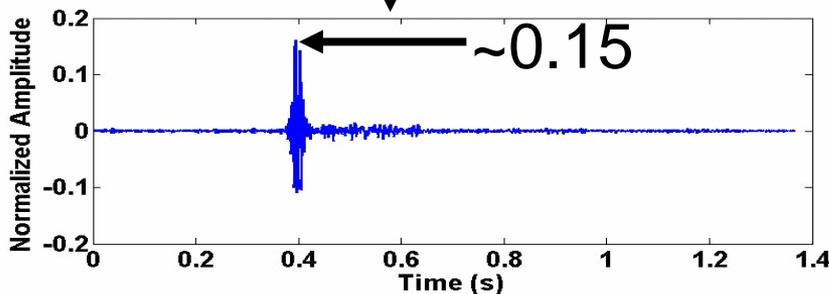
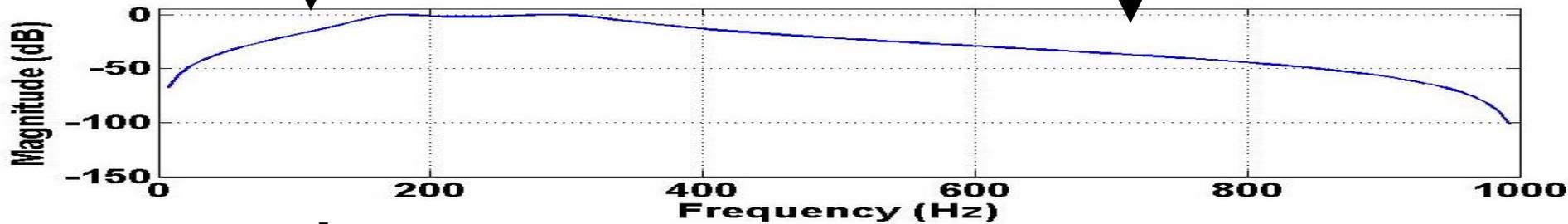
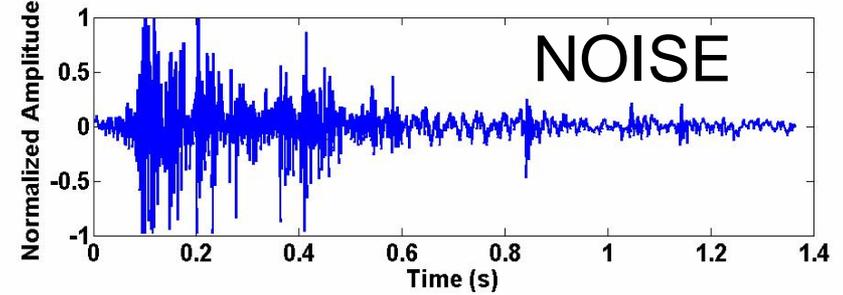
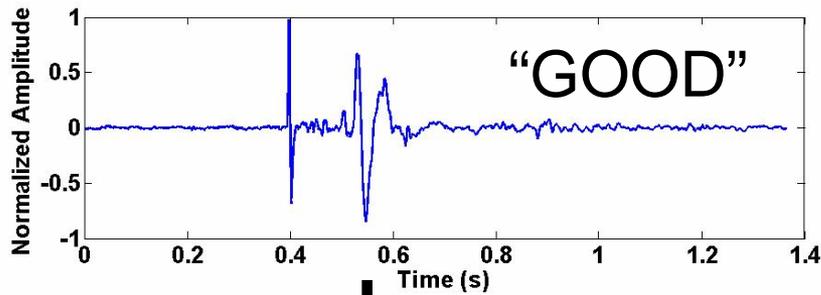
Algorithms Explored: Frequency Filtering

Fourth-order Butterworth high-pass filter.



Algorithms Explored: Frequency Filtering

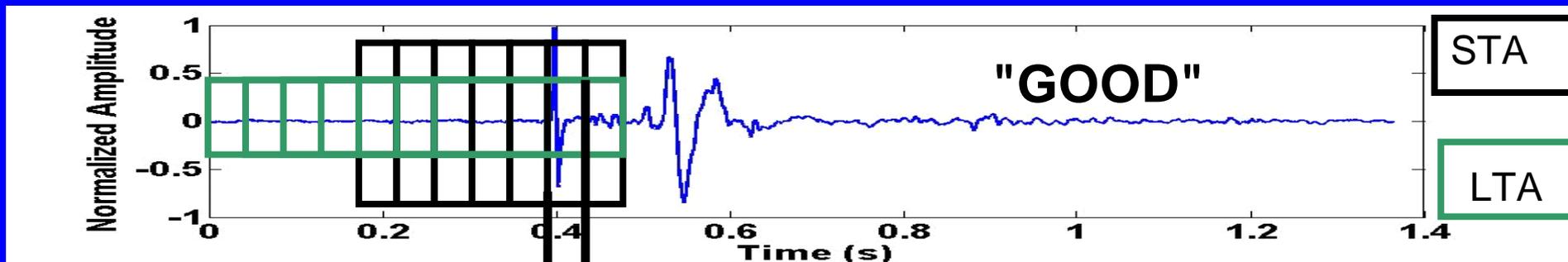
Fourth-order Chebyshev high-frequency band-pass filter.



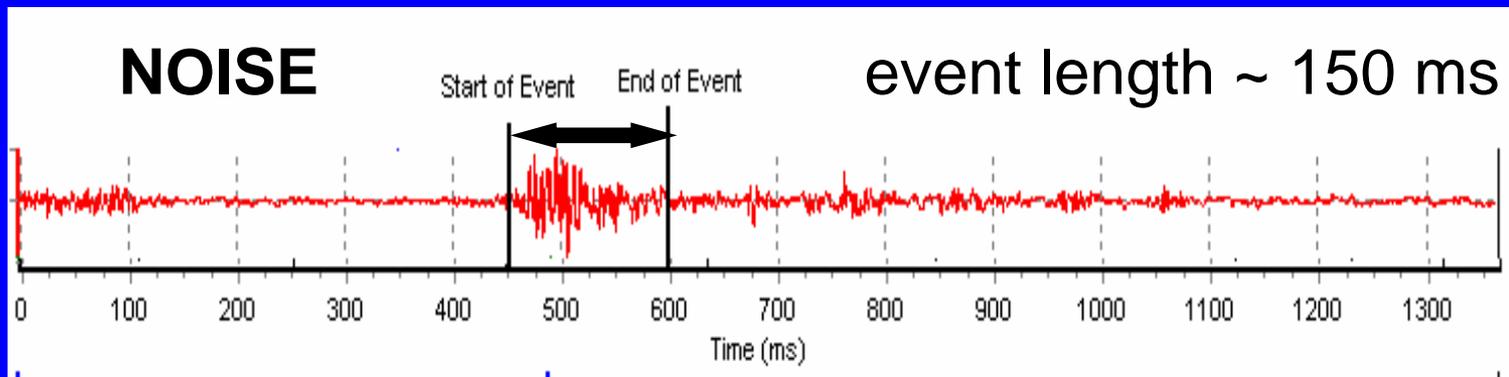
Event length detection: Time-domain

STA/LTA (Ambuter and Solomon, 1974)

- STA / LTA ratio sharply increases at onset of event
- STA / LTA ratio sharply decreases at termination



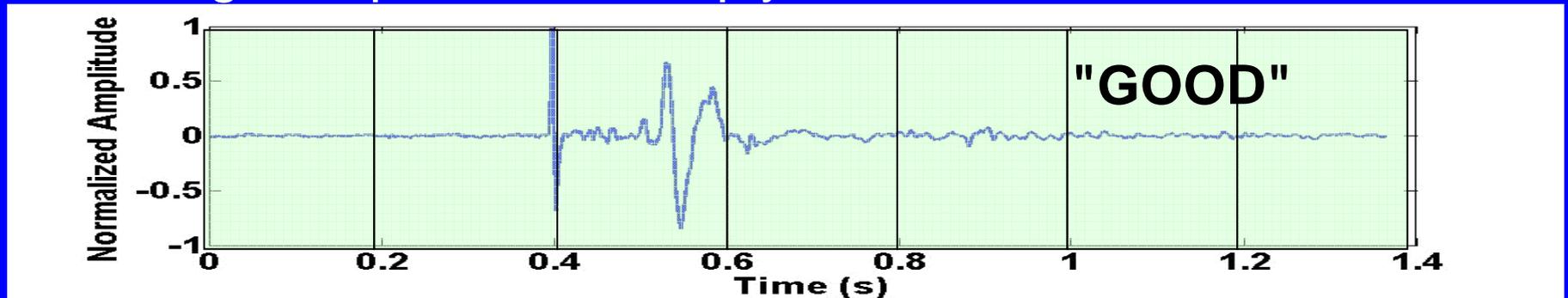
onset termination event length ~ 40 ms



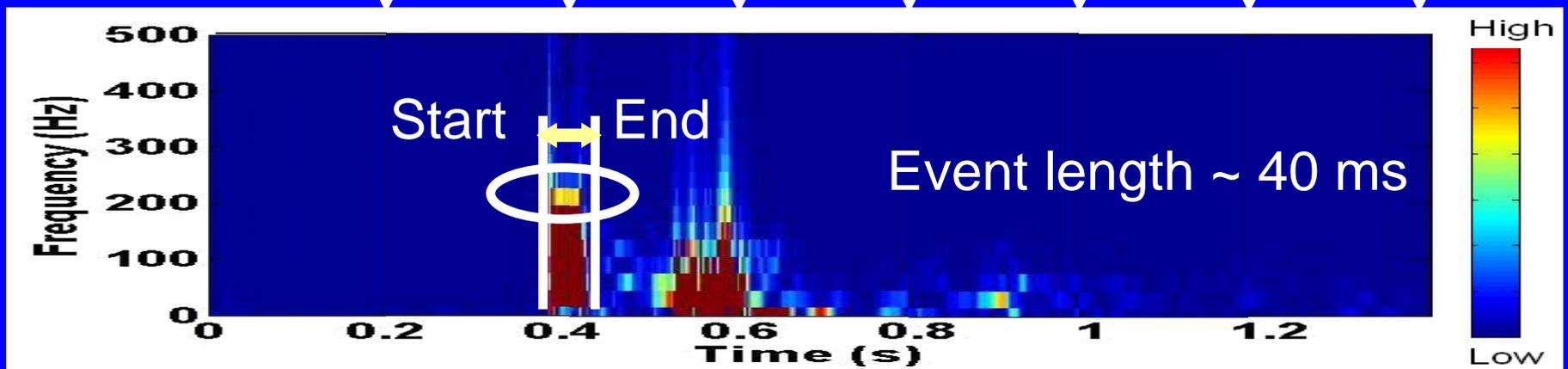
Event length detection: Frequency-domain

Continuous-time Fourier transform:

- High freq. content sharply increases at onset of event
- High freq. content sharply decreases at termination



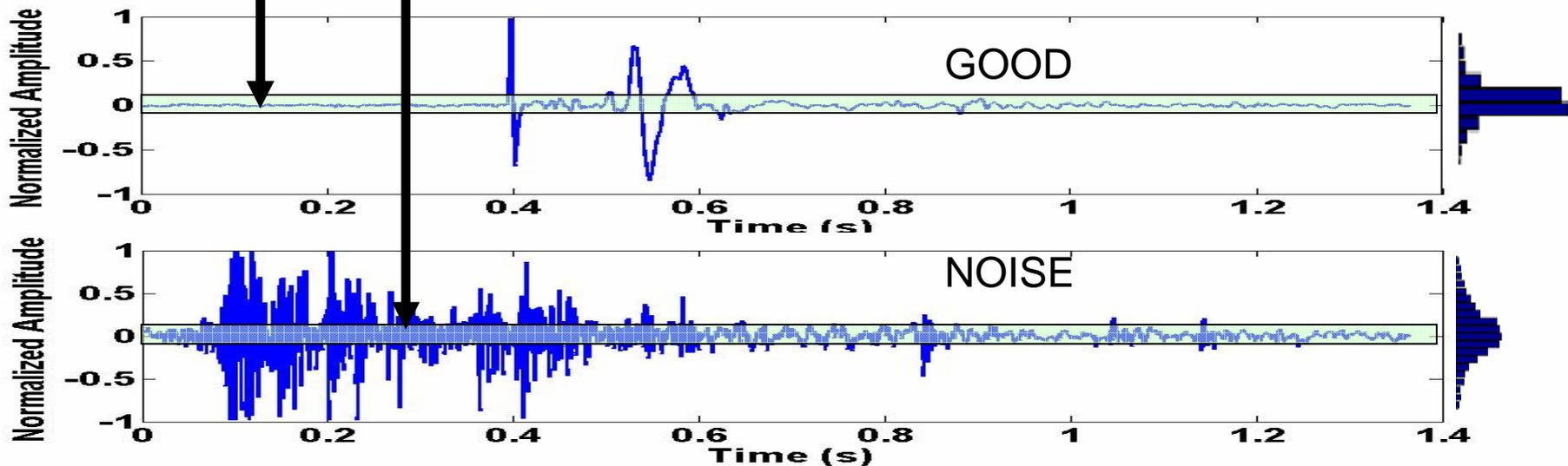
FOURIER TRANSFORM



Statistical analysis: Histogram

99 evenly-spaced bins from -1 to 1, examine # data pts. in 50th.

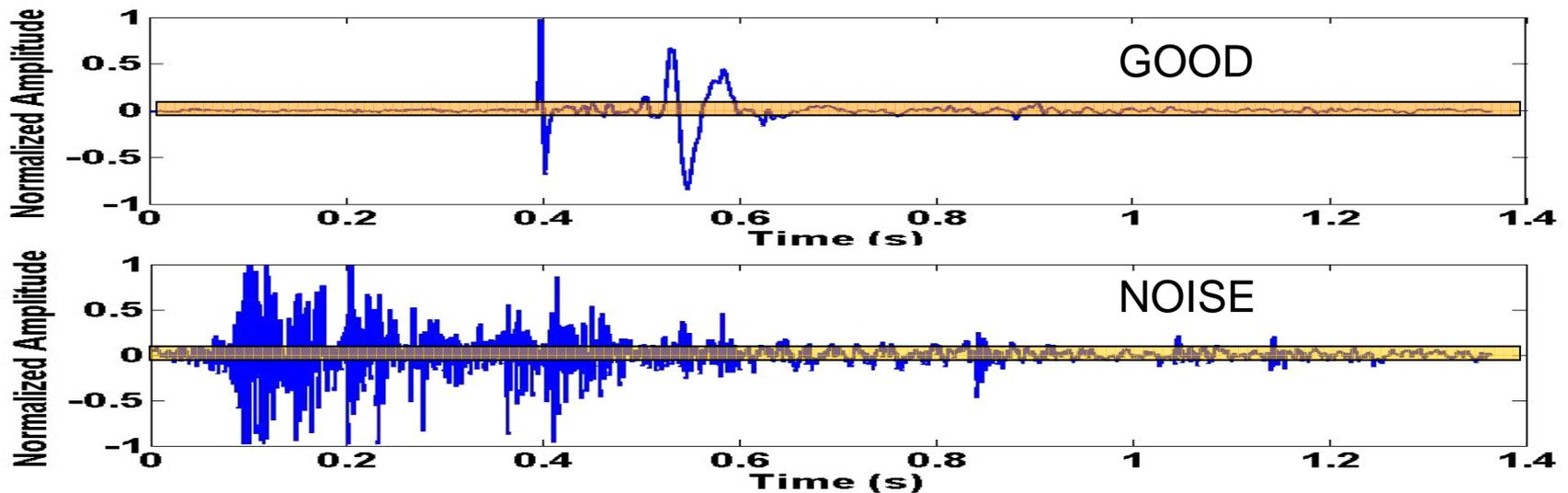
50th bin (width exaggerated for visual clarity)



Signal shown	# pts in B. 50	Tot. Pts.	% pts in B. 50
Good	1416	4096	34.6%
Noise	438	4096	10.7%

Statistical analysis: Threshold window

Example: Set a threshold window between -0.03 and 0.03 and count all data points that lie *outside* this window.



Signal shown	#Pts. Outside	Tot. Pts	% Pts. Outside
Good	850	4096	20.8%
Noise	2795	4096	68.2 %

MATLAB GUI: Many algorithms combined into self-contained Graphical User Interface (GUI) application and tested.

The screenshot displays the MATLAB GUI for 'Event_Analyzer', Version 1.42, developed by Jeffrey F. Tan in 2006 at CREWES, University of Calgary. The interface is divided into several functional areas:

- Header:** Version and author information.
- Analysis Quantity:** Includes a text input for '(Set # of Files to "1" to view all files)', a numeric input for '# Of Files to Analyze' (set to 0), and radio buttons for 'All Files' and 'Continuous Run'.
- File Selection:** Multiple dropdown menus for 'Choose Start File...', 'Files to be Analyzed...', 'Choose Spectrogram Type...', 'Choose Geophone...', and 'Choose Channel...'.
- Decision Settings:** A vertical panel on the right with checkboxes and numeric inputs for 'LPF' (0.55), 'HPF' (0.1), 'BPF' (0.15), 'Thresh' (0.6), 'SR' (0.097128), 'Hist' (0.15), and 'FDM' (0.1). It also includes checkboxes for '#G/C (1-7)' and '#G/C/F (1-10)', both set to 4.
- Histogram Plot Settings:** A table for setting plot parameters:

	Min	Max
	0	0.8
	0	0.8
	0	0.8
	0.5	1
	0	0.15
	0	0.2
	0	1
	0	7
	0	8

- Control Panel:** 'Choose Mode...' dropdown, 'Start', 'Stop', and 'Reset' buttons, and an 'Enable Time Interval Function Below' checkbox with a 'Time Intervals Between Events (seconds)...' dropdown.
- Status:** A red bar indicating 'Ready'.
- File Management:** 'All Files Analyzed (in Chronological Order)' section with dropdowns for 'Good Files...', 'Noise Files...', and 'Deleted Files...'. Below it, 'Most Recent Files Analyzed' section shows three empty boxes for 'Good Files (0)', 'Noise Files (0)', and 'Deleted Files (0)'. A 'Most Recent F' label and a 'Good' button are also present.
- Geophone Components:** 'Geophone Components to Analyze' dropdown set to 'Components to Examine...' with a 'Default = All (Recommended)' note.
- File/Channel Tracker:** A table at the bottom showing file analysis details:

File Locator/Identifier	#Channels/File	Seq. Channel #	File #	Ch# in File
File Locator...	15	1	---	---

Adjustable settings, plots

Setting Guide
A Lower Limit An Upper Limit
For "Good" Classification
Click Boxes on left for Histogram Plots
Click Boxes on right for Sequential Plots

File/Channel Tracker

Preliminary Results:

Preliminary, specific dataset: 7031 of 7032 files correctly classified (99.99% accuracy for this very specific dataset).

Currently, testing on various datasets.

Much testing remains, but initial results are encouraging.

Current Question: Is there a certain combination of algorithm threshold settings that will distinctly and accurately separate "good" and "noise" files for all types of datasets?

Issues:

- Data variability and uncertainty as datasets change from pad to pad
- Program speed vs. accuracy

Future Work:

- Does one set of algorithms perform better than the rest?
- Testing, optimization, and more testing.

Conclusions:

- Passive seismic event classification algorithms developed.
- MATLAB GUI application created, tested, optimized.
- Initial results encouraging, more testing and optimization remains.
- If program is implemented at Cold Lake in the future (our goal), much time and money would likely be saved during production. Focus could potentially shift to other pertinent production issues.

Acknowledgements:

- CREWES sponsors
- CREWES staff and students
- Sophia Follick, Colum Keith, and Richard Smith from Imperial Oil Ltd.

Presentation References:

Ambuter, B.P. and Solomon, S.C., 1974, An event-recording system for monitoring small earthquakes: Bulletin of the Seismological Society of America, Vol. 64, No. 4, 1181-1188.

Imperial Oil Ltd, 2006, Disclosure document for Cold Lake expansion project:

http://www.limperiale.ca/Canada-English/Investors/Operating/Natural_Resources/I_O_NaturalOilSandsDisclosure05.asp
internet web page.

Imperial Oil Ltd, 2006, Disclosure document for Cold Lake expansion project:

http://www.limperiale.ca/Canada-English/Investors/Operating/Natural_Resources/I_O_NaturalOilSandsDisclosure04.asp
internet web page.

Imperial Oil Ltd, 2006, Alberta's Oil Sands:

http://www.limperiale.ca/Canada-English/Investors/Operating/Natural_Resources/I_O_NaturalResourcesFig1.asp,
internet web page.

Imperial Oil Ltd, 2006, Proposed Development Areas - Mahihkan North and Nabiye :

http://www.limperiale.ca/Canada-English/Investors/Operating/Natural_Resources/I_O_NaturalResourcesFig4.asp,
internet web page

Imperial Oil Ltd, 2006, Cyclic Steam Stimulation - not to scale:

http://www.limperiale.ca/Canada-English/Investors/Operating/Natural_Resources/I_O_NaturalResourcesFig5.asp,
internet web page.