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# Examples and Analysis of Adaptive Self-Tuning of a Seismic Signal Detector

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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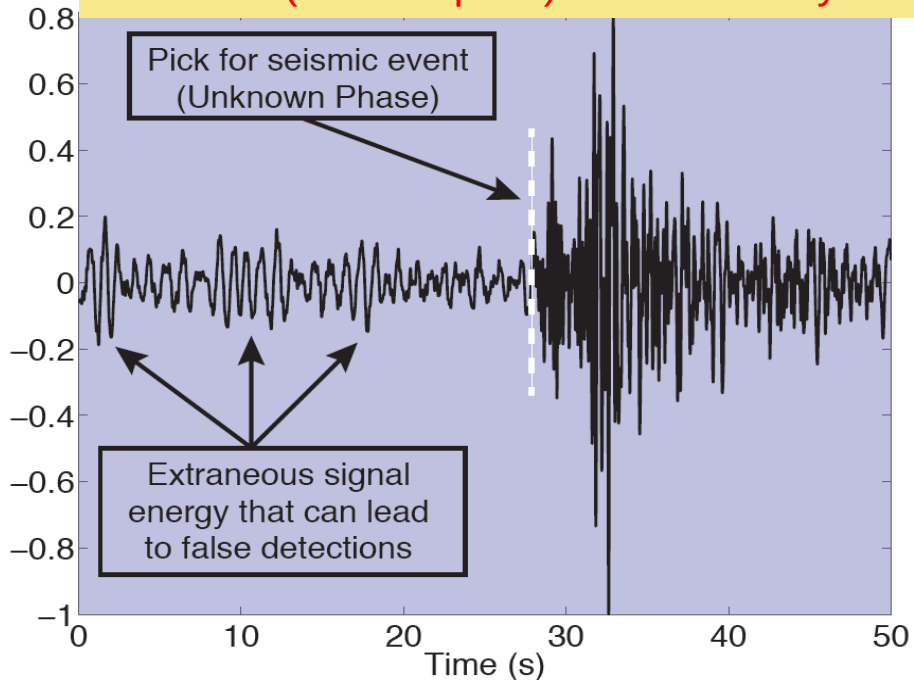
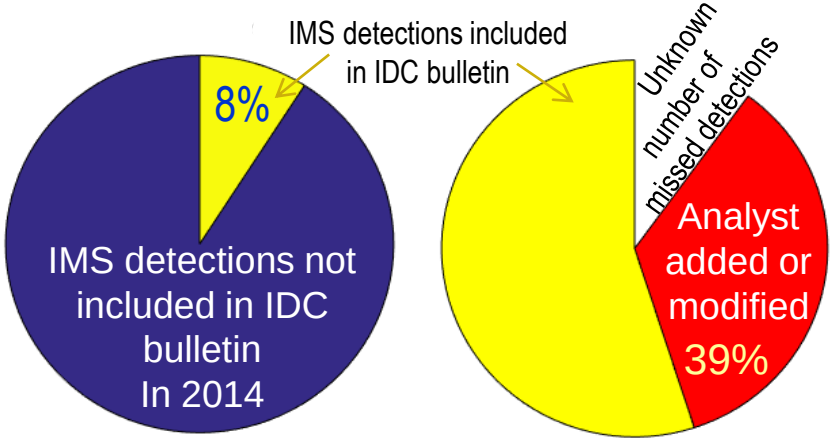
# **Problem**: Too Many False, Missed Detections

- **Goal: *Adaptive self-tuning of sensor parameters***
  - **Superior automatic detection of signals is closely related to parameter settings, but**
  - **Manual identification of effective parameters is painstaking.**
- **Parameters are often chosen to minimize the number of missed signals, resulting in many false signal detections**

Standard (non-adaptive) detectors may falsely trigger on extraneous signal energy




Only 8% of 5,575,923 International Monitoring System seismic station detections were included in the International Data Center (IDC) analyst-reviewed bulletin for 2014.




39% of IDC bulletin detections are found or modified by human analysts



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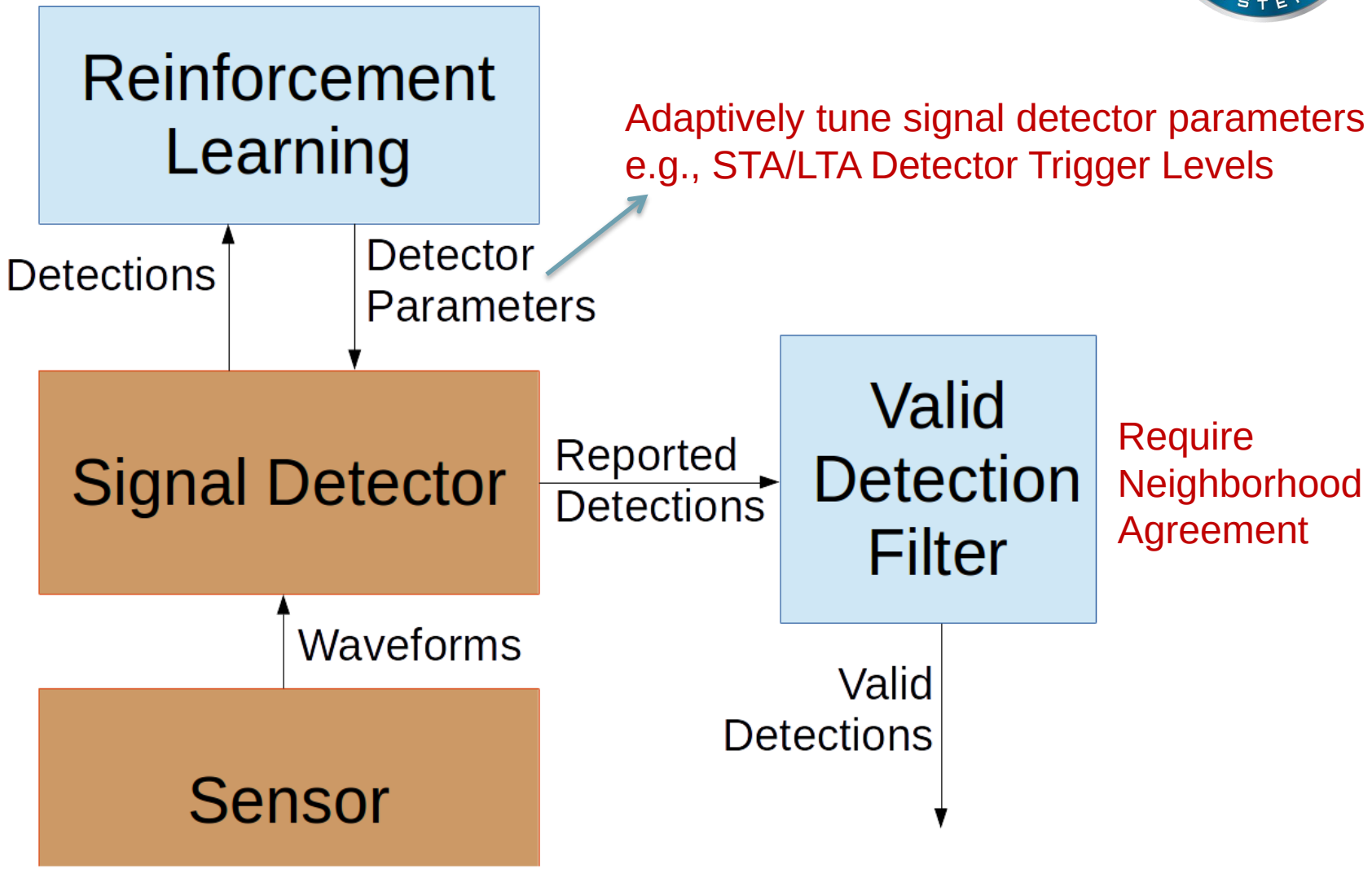
# **Our Approach**: Adaptive Sensor Tuning (**AST**) with Neighborhood Agreement



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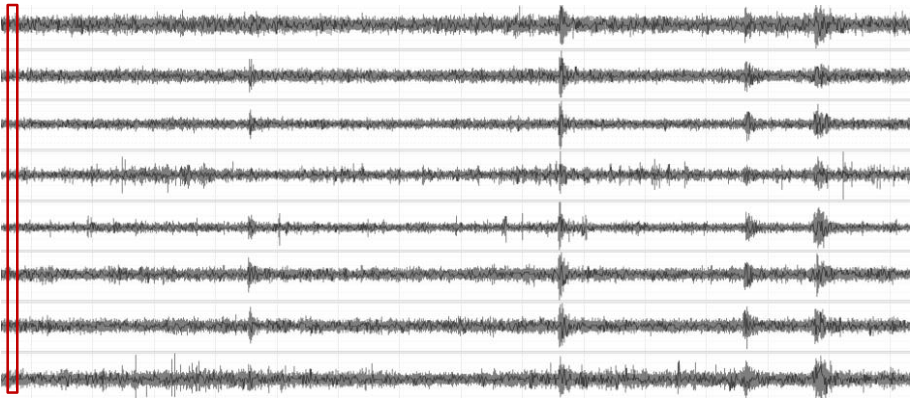
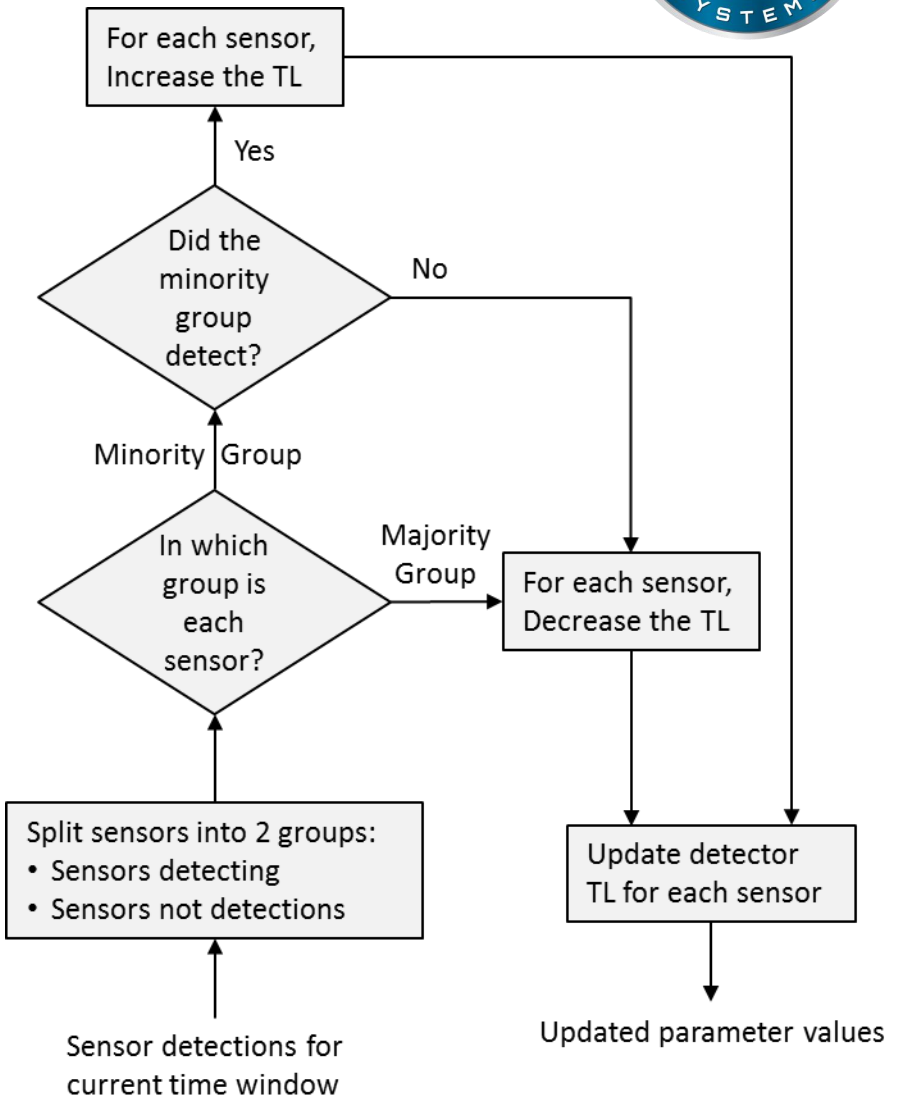
# Majority Rules AST Algorithm

## Dynamically adjust STA/LTA Trigger Levels

- The detector looks for signals in a small time window sliding across waveforms.



- At each time step, all sensors in each neighborhood are split into two groups
  - Those detecting a signal
  - Those not detecting a signal
- Sensors in the majority group
  - Decrease their TLs
- Sensors in the minority group
  - Decrease TLs if they didn't detect
  - Increase TLs if they did detect



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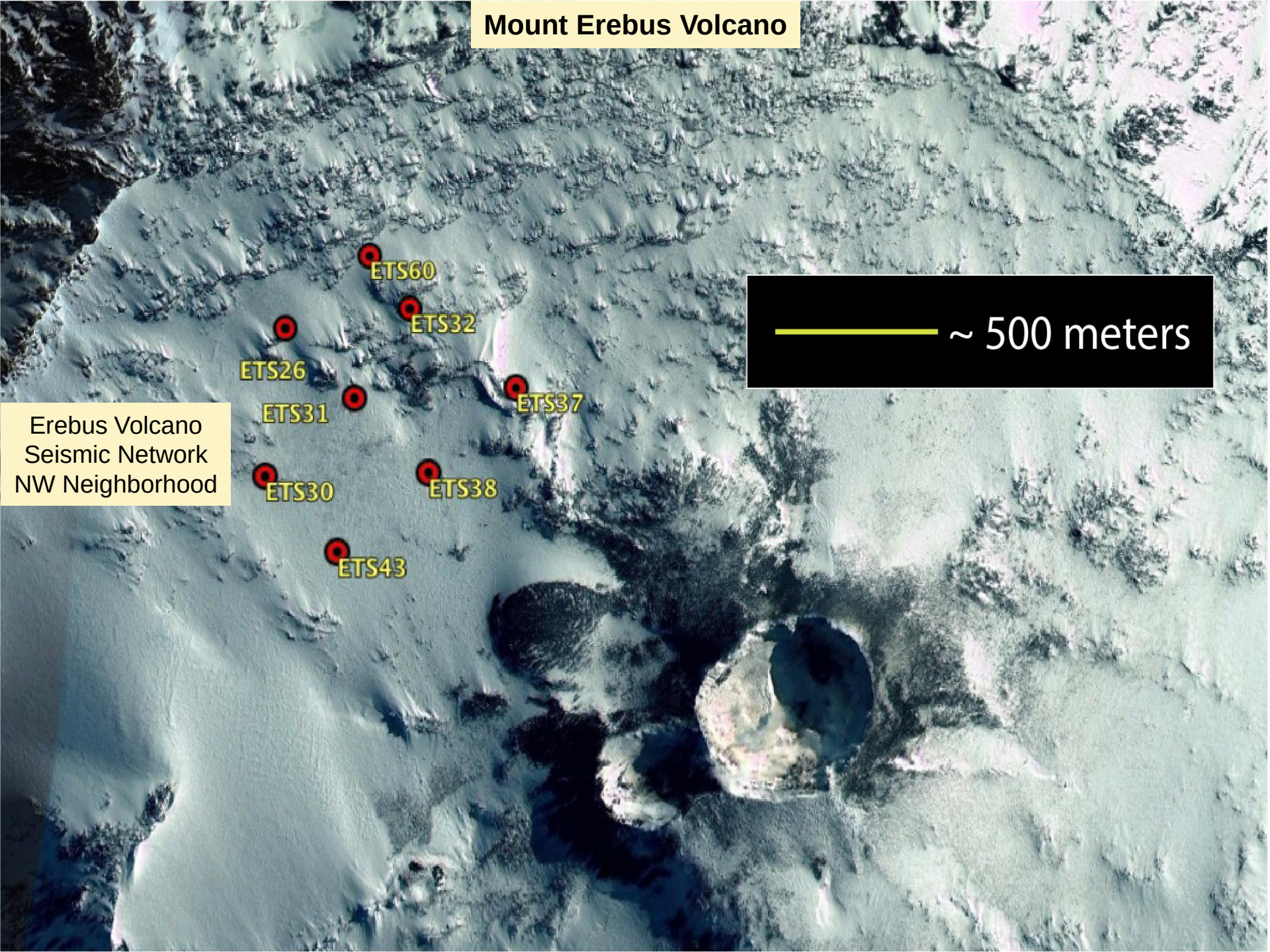
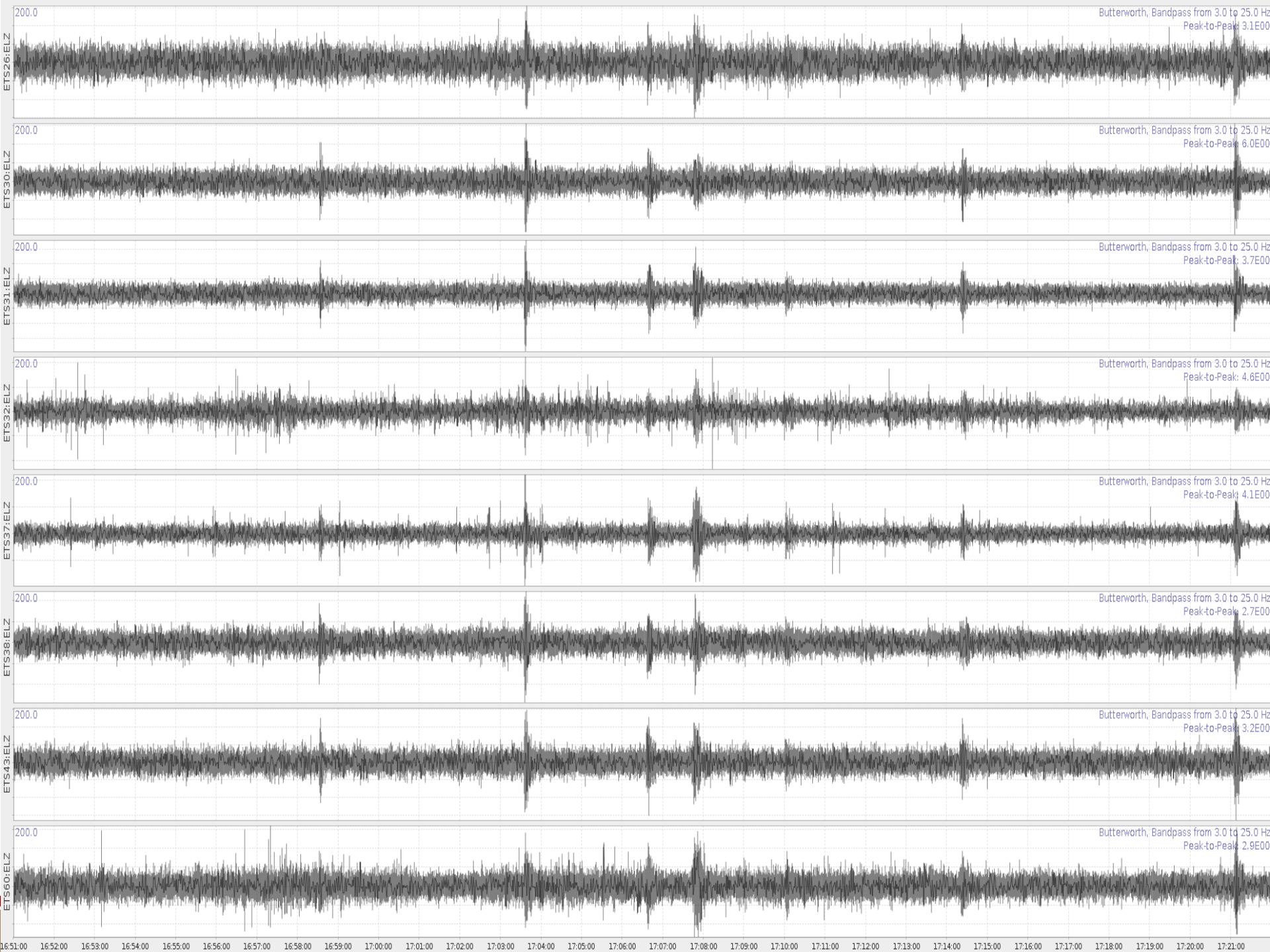
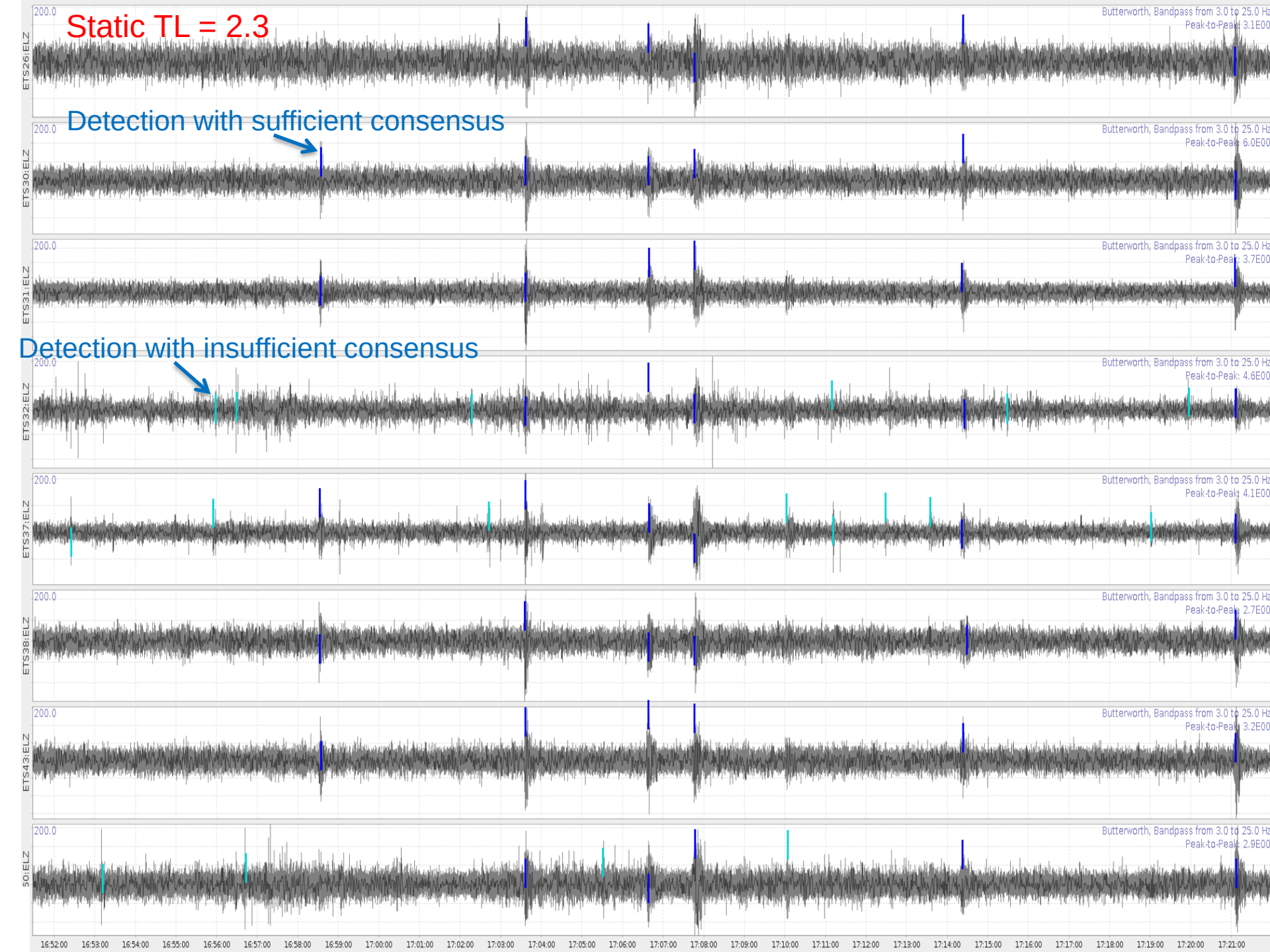
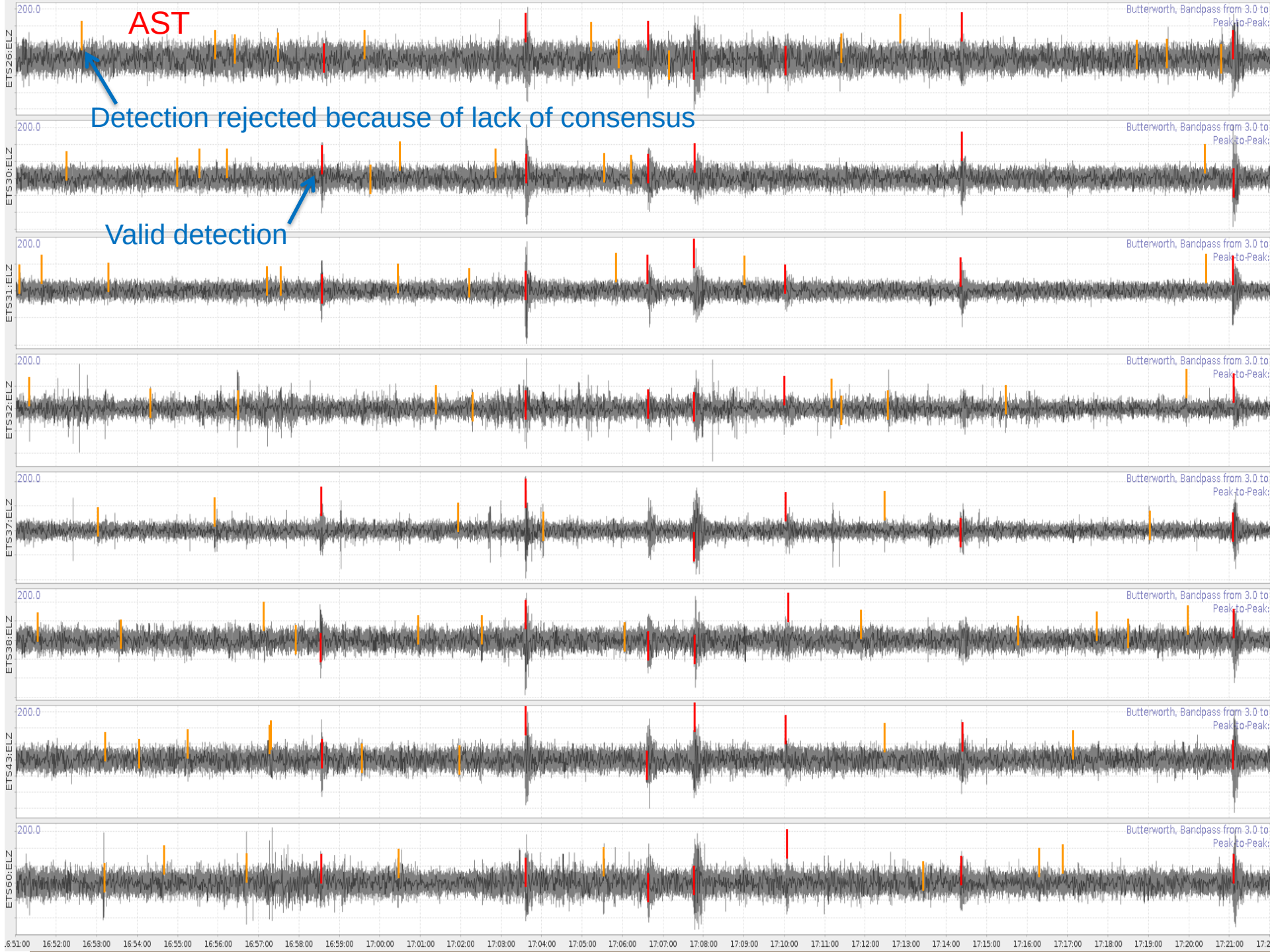

Mount Erebus Volcano
ETS60
ETS32
ETS26
ETS31
ETS37
ETS30
ETS38
ETS43
~ 500 meters
Erebus Volcano
Seismic Network
NW Neighborhood

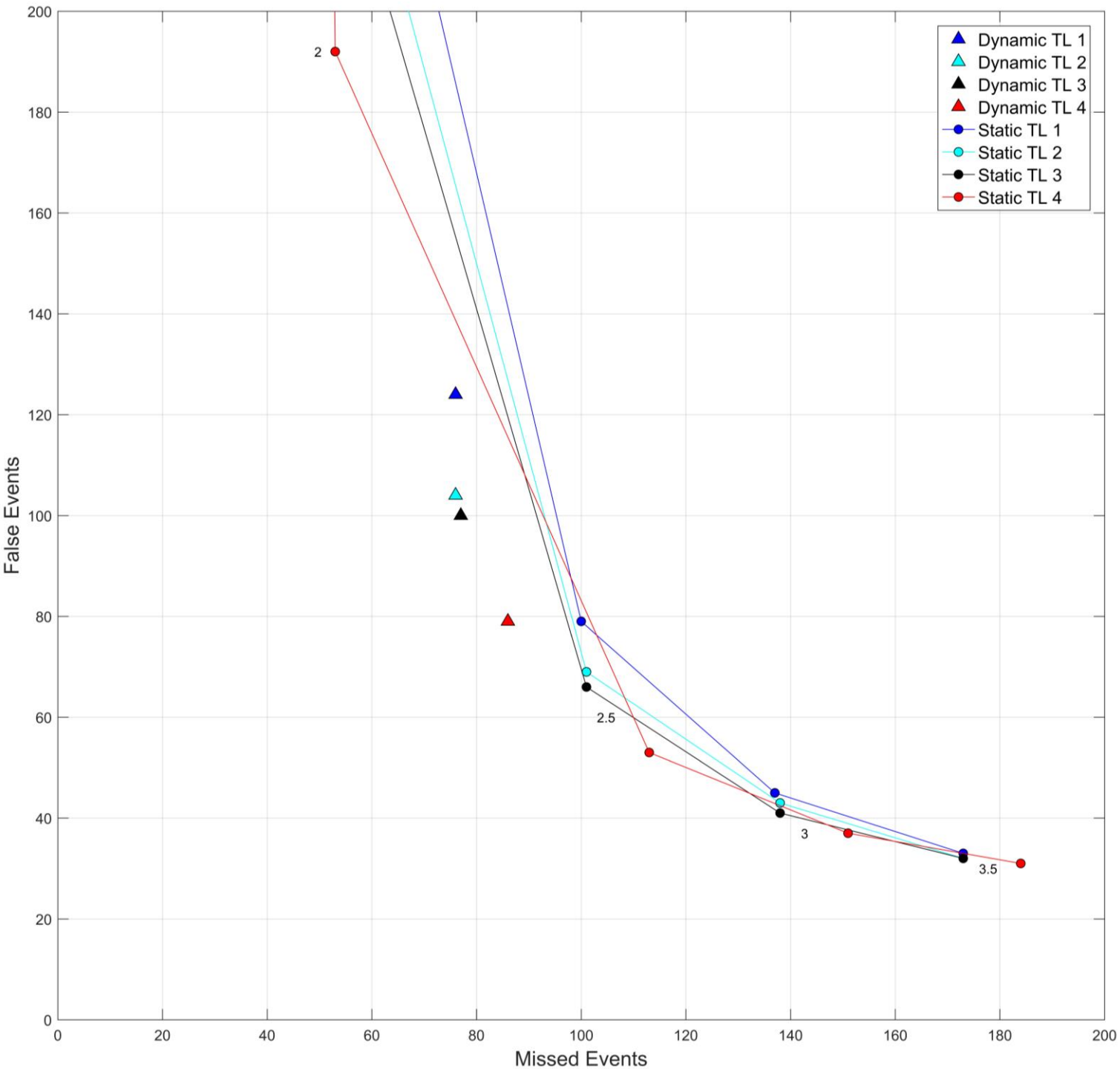

ETS26:ELZ
ETS30:ELZ
ETS31:ELZ
ETS32:ELZ
ETS37:ELZ
ETS38:ELZ
ETS43:ELZ
ETS60:ELZ
200.0
Butterworth, Bandpass from 3.0 to 25.0 Hz
Peak-to-Peak: 3.1E00
Peak-to-Peak: 6.0E00
Peak-to-Peak: 3.7E00
Peak-to-Peak: 4.6E00
Peak-to-Peak: 4.1E00
Peak-to-Peak: 2.7E00
Peak-to-Peak: 3.2E00
Peak-to-Peak: 2.9E00
16:51:00
16:52:00
16:53:00
16:54:00
16:55:00
16:56:00
16:57:00
16:58:00
16:59:00
17:00:00
17:01:00
17:02:00
17:03:00
17:04:00
17:05:00
17:06:00
17:07:00
17:08:00
17:09:00
17:10:00
17:11:00
17:12:00
17:13:00
17:14:00
17:15:00
17:16:00
17:17:00
17:18:00
17:19:00
17:20:00
17:21:00


Static TL = 2.3
Detection with sufficient consensus
Detection with insufficient consensus
ETS26:ELZ
ETS30:ELZ
ETS31:ELZ
ETS32:ELZ
ETS37:ELZ
ETS38:ELZ
ETS43:ELZ
50:ELZ
200.0
Butterworth, Bandpass from 3.0 to 25.0 Hz
16:52:00
16:53:00
16:54:00
16:55:00
16:56:00
16:57:00
16:58:00
16:59:00
17:00:00
17:01:00
17:02:00
17:03:00
17:04:00
17:05:00
17:06:00
17:07:00
17:08:00
17:09:00
17:10:00
17:11:00
17:12:00
17:13:00
17:14:00
17:15:00
17:16:00
17:17:00
17:18:00
17:19:00
17:20:00
17:21:00


AST
Detection rejected because of lack of consensus
Valid detection
ETS26:ELZ
ETS30:ELZ
ETS31:ELZ
ETS32:ELZ
ETS37:ELZ
ETS38:ELZ
ETS43:ELZ
ETS60:ELZ
200.0
Butterworth, Bandpass from 3.0 to
Peak-to-Peak:
16:51:00
16:52:00
16:53:00
16:54:00
16:55:00
16:56:00
16:57:00
16:58:00
16:59:00
17:00:00
17:01:00
17:02:00
17:03:00
17:04:00
17:05:00
17:06:00
17:07:00
17:08:00
17:09:00
17:10:00
17:11:00
17:12:00
17:13:00
17:14:00
17:15:00
17:16:00
17:17:00
17:18:00
17:19:00
17:20:00
17:21:00

# False vs. Missed Plots

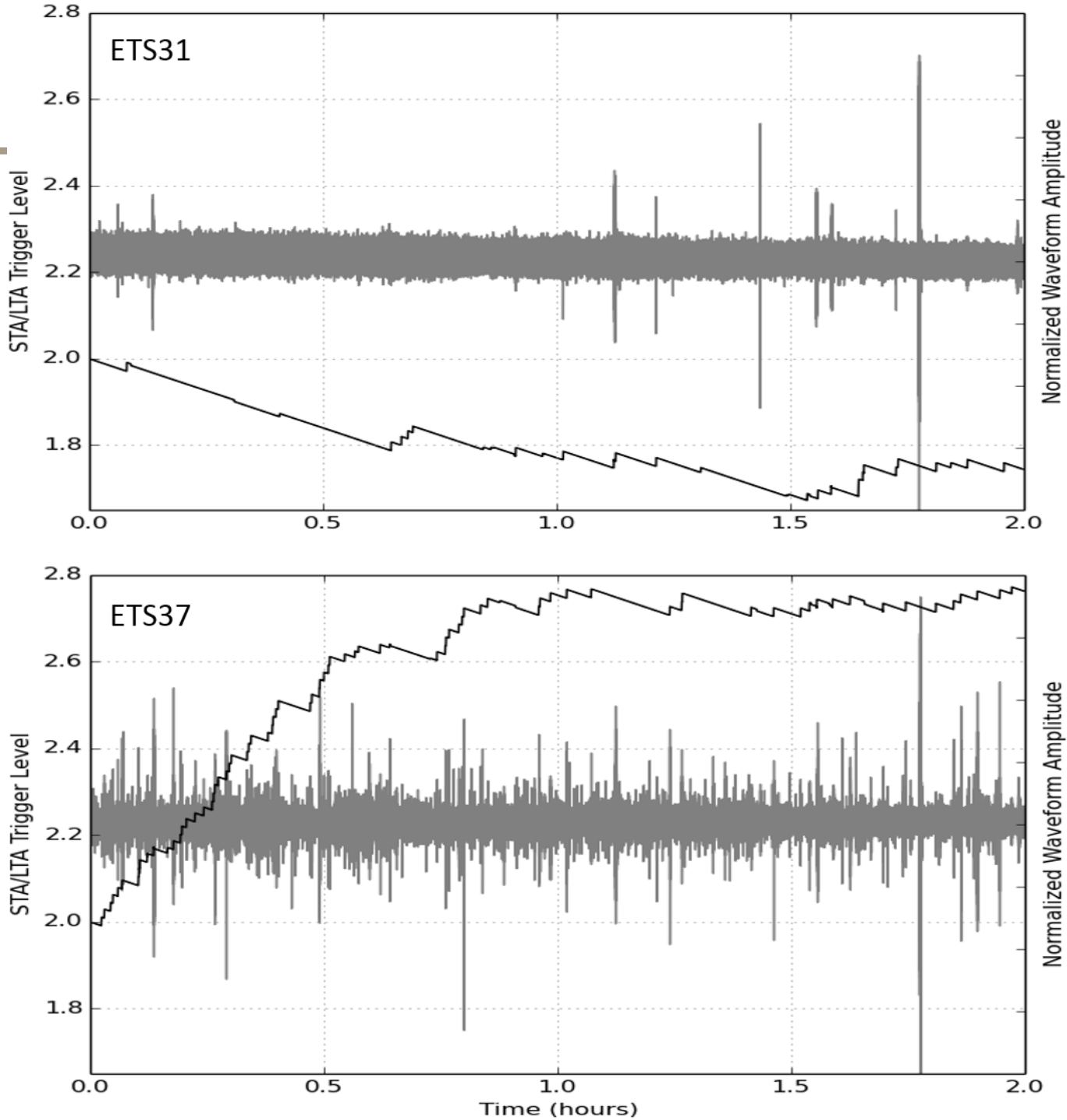
Cumulative statistics over a 22-hour scoring period



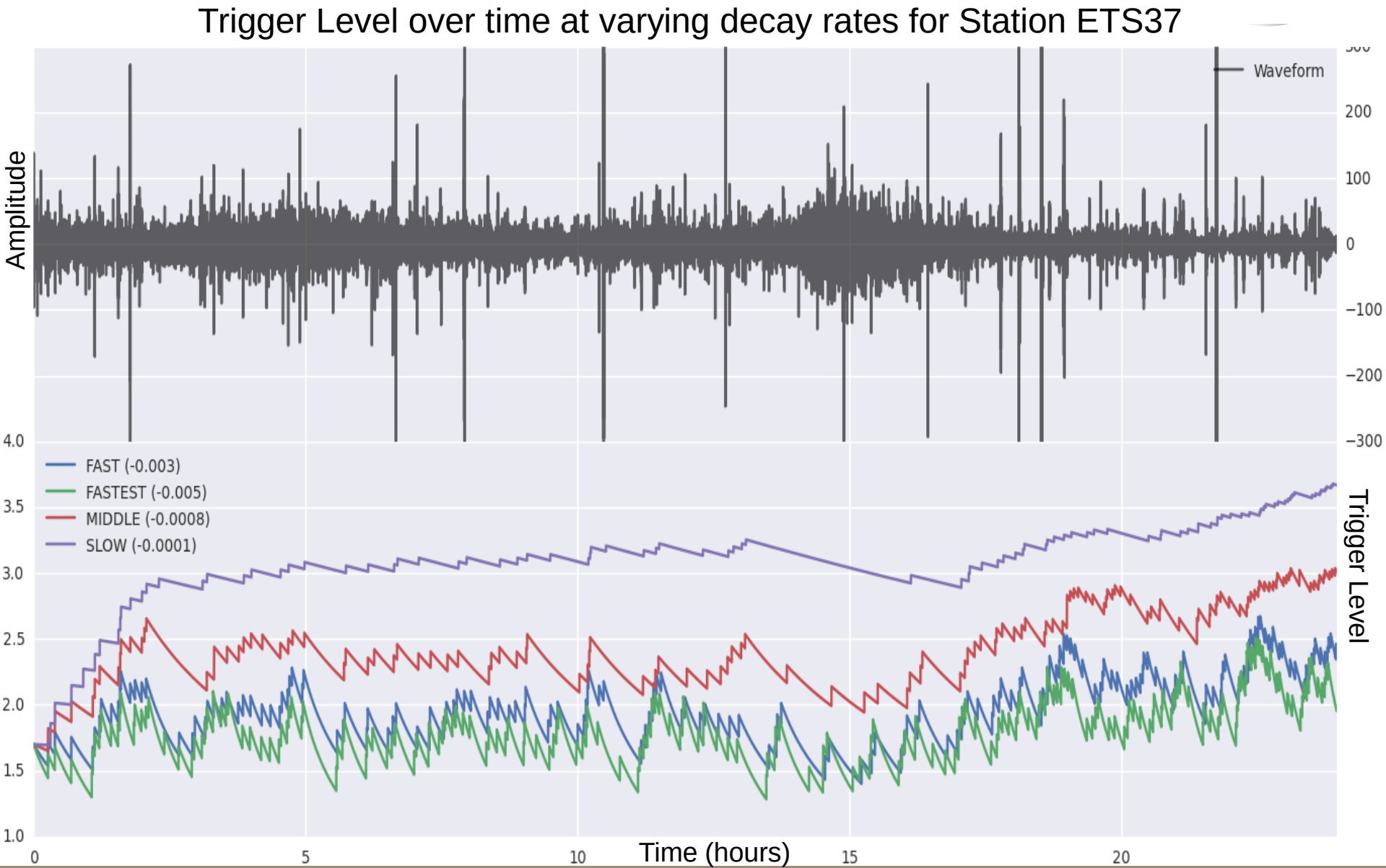
# AST Trigger Level Dynamics

AST pushes TL low on a station with few “false alarms”

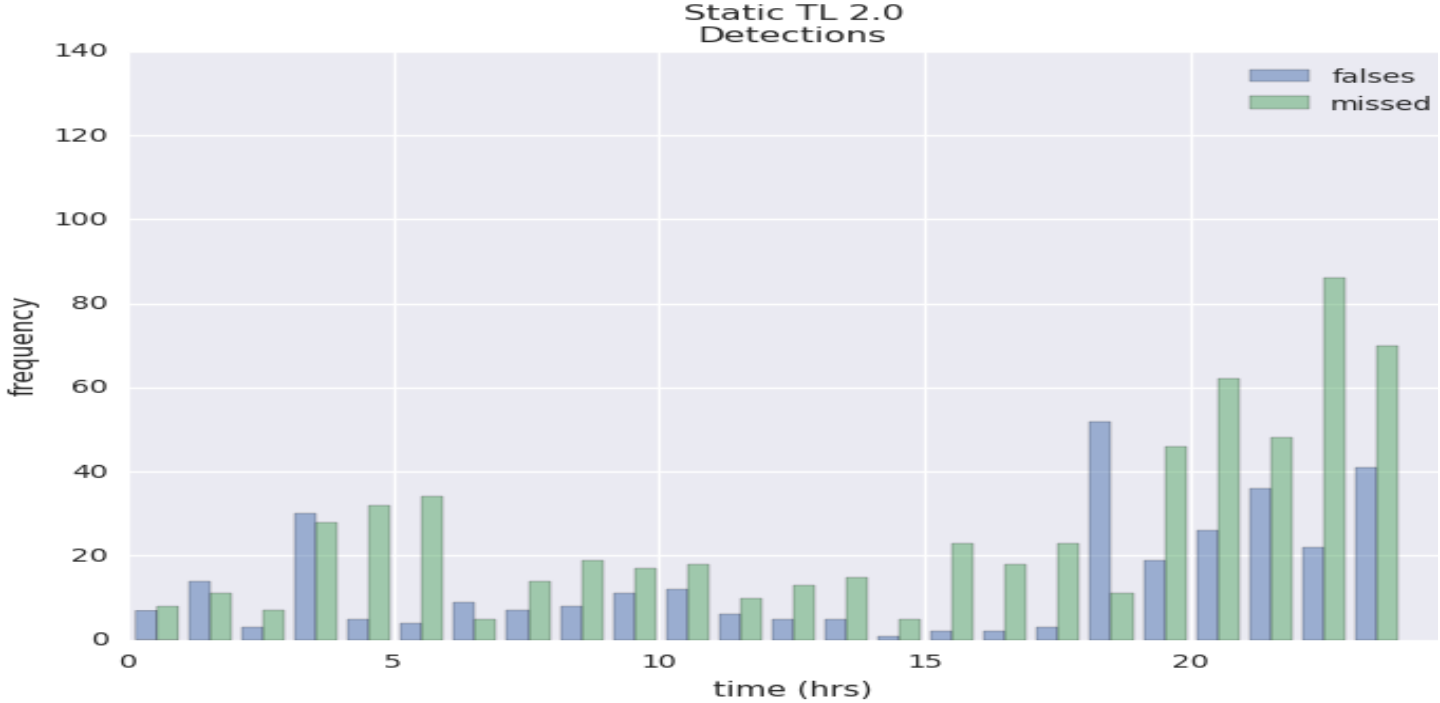
AST tries to push TL low, but each “false alarm” pushes it higher

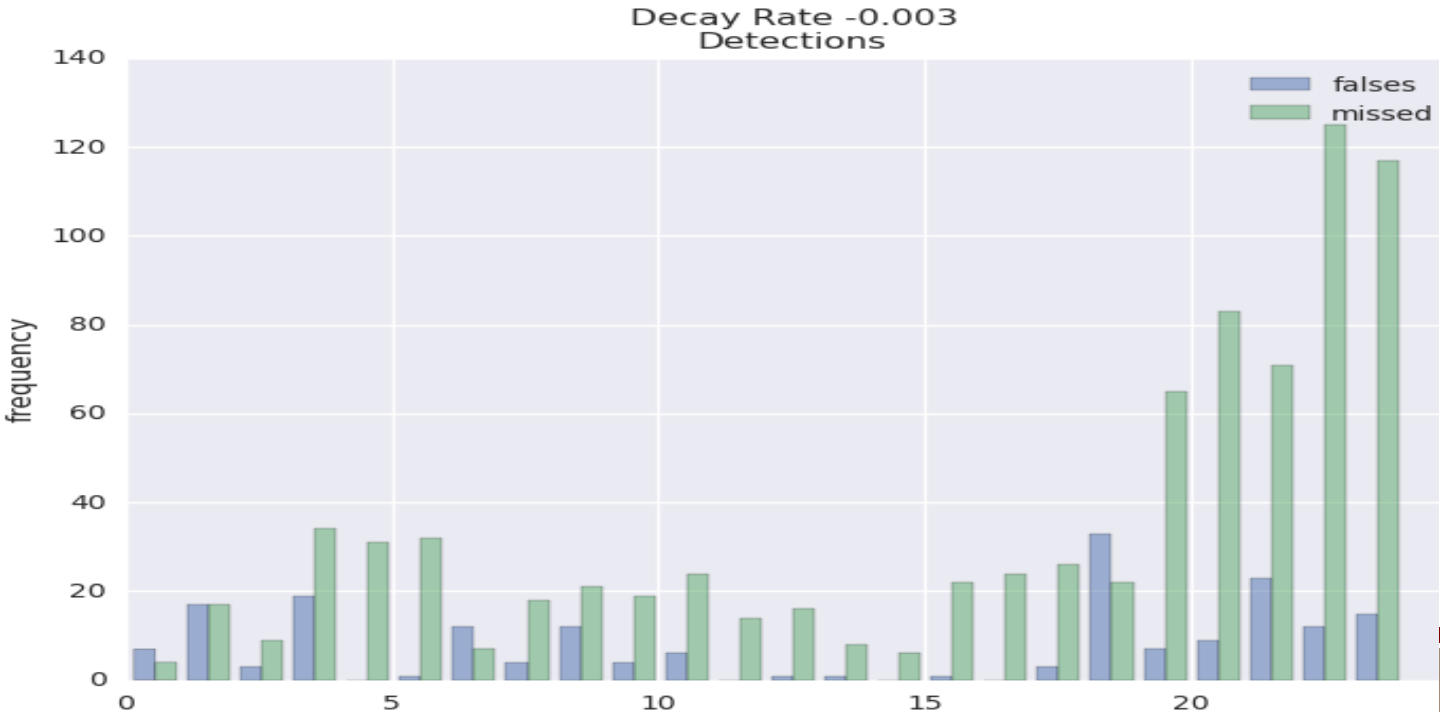


# AST Trigger Level Dynamics at Different Decay Rates

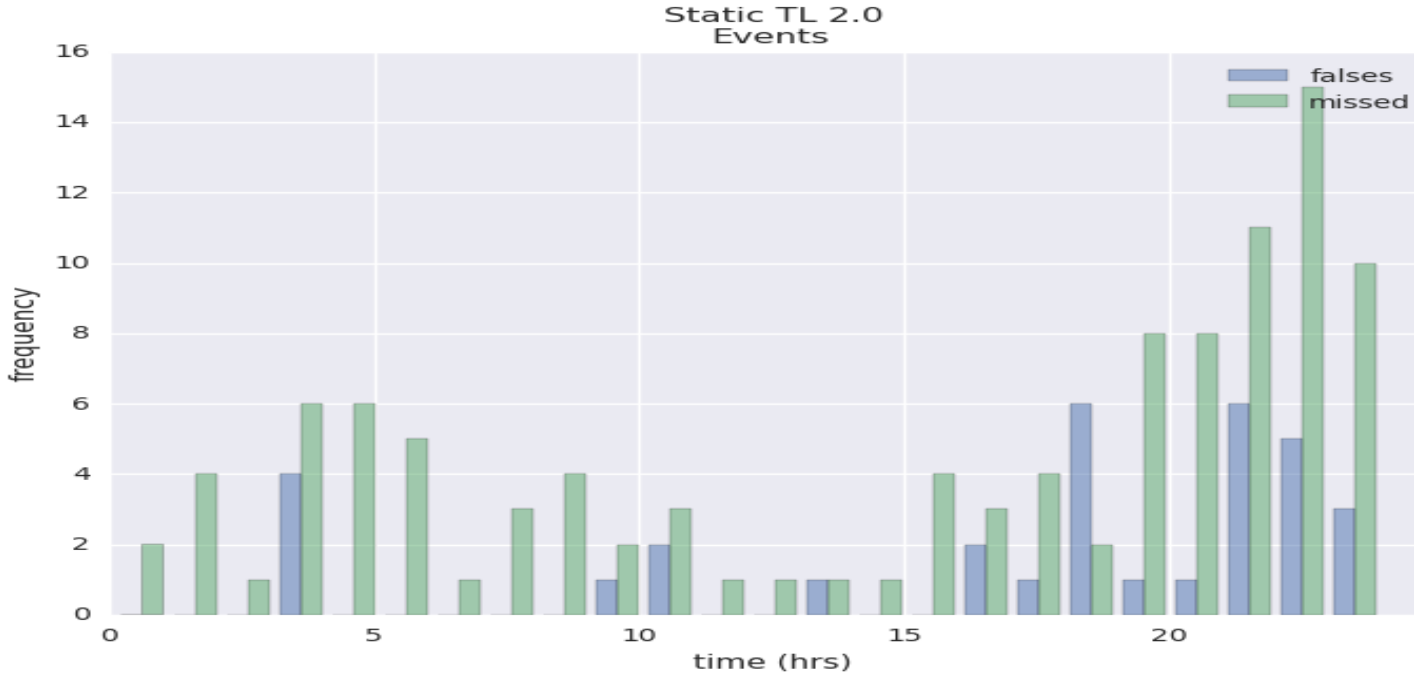


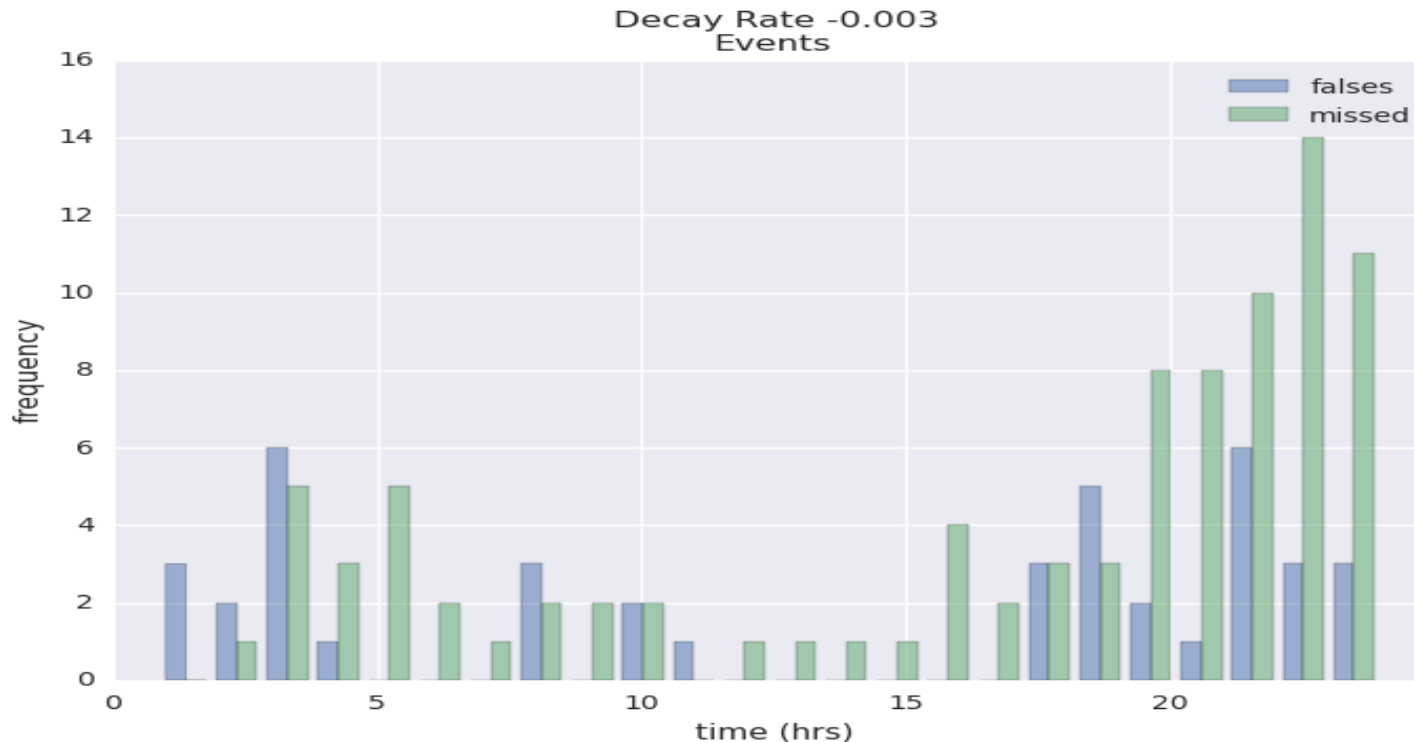
# Detections Comparison (Static vs. Dynamic) TL over Time



# Events Comparison (Static vs. Dynamic) TL over Time



# Summary

- Conclusions
  - Can improve detection performance of systems with tunable parameters and multiple sensors with overlapping coverage
    1. Majority Rules parameter adjustment
    2. Event-driven detection filtering
  - AST Algorithm can be tuned to favor less missed or false detections/events
    - Provides stable performance in unknown environments
- Future R&D
  - Tune multiple parameters simultaneously
    - Other STA/LTA parameters, Filtering parameters, etc.
- Explore new applications
  - Nuclear explosion, induced seismicity monitoring
  - Chemical concentration, Surveillance