Unsupervised detection and clustering of seismic sources with scattering network

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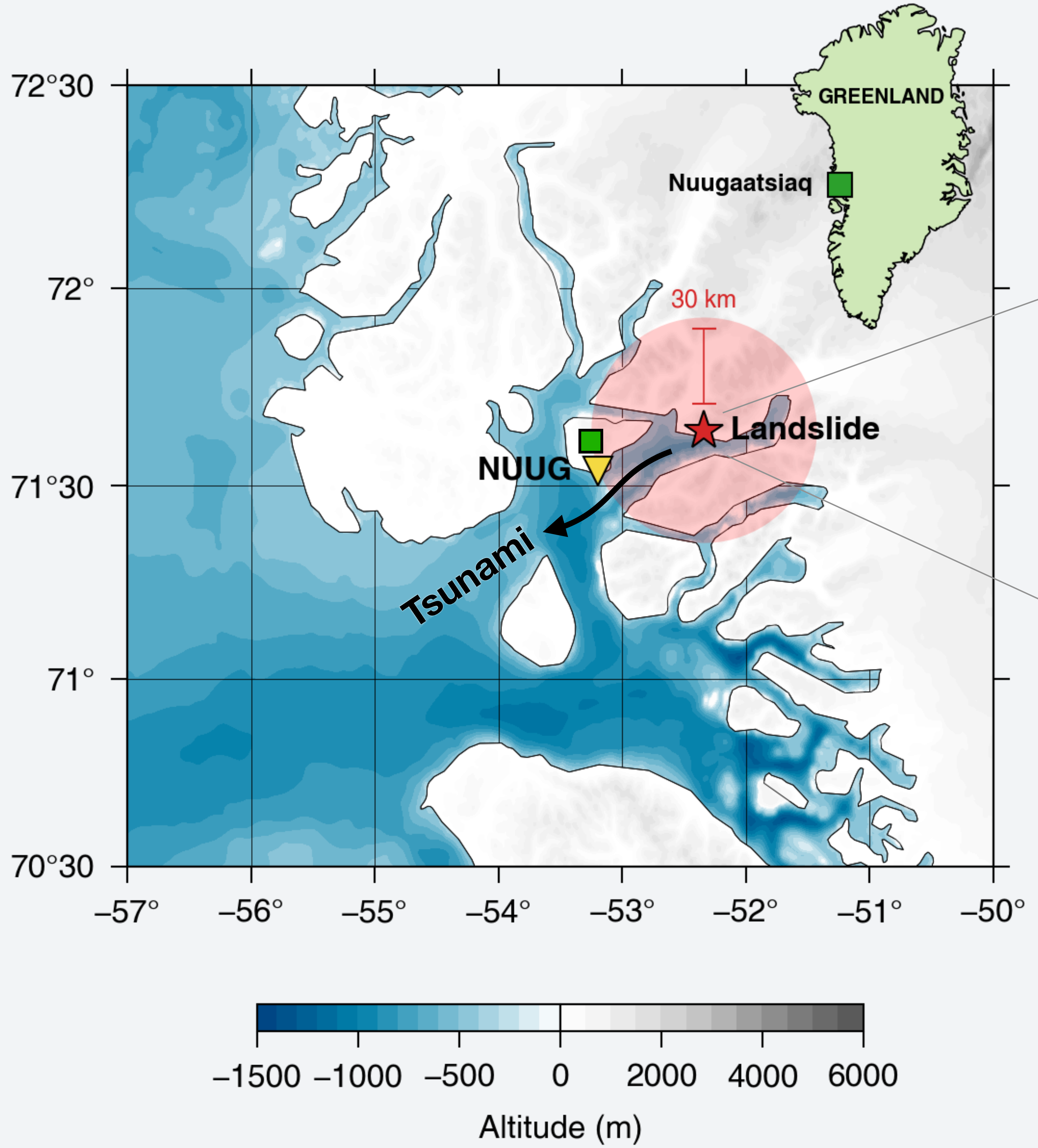
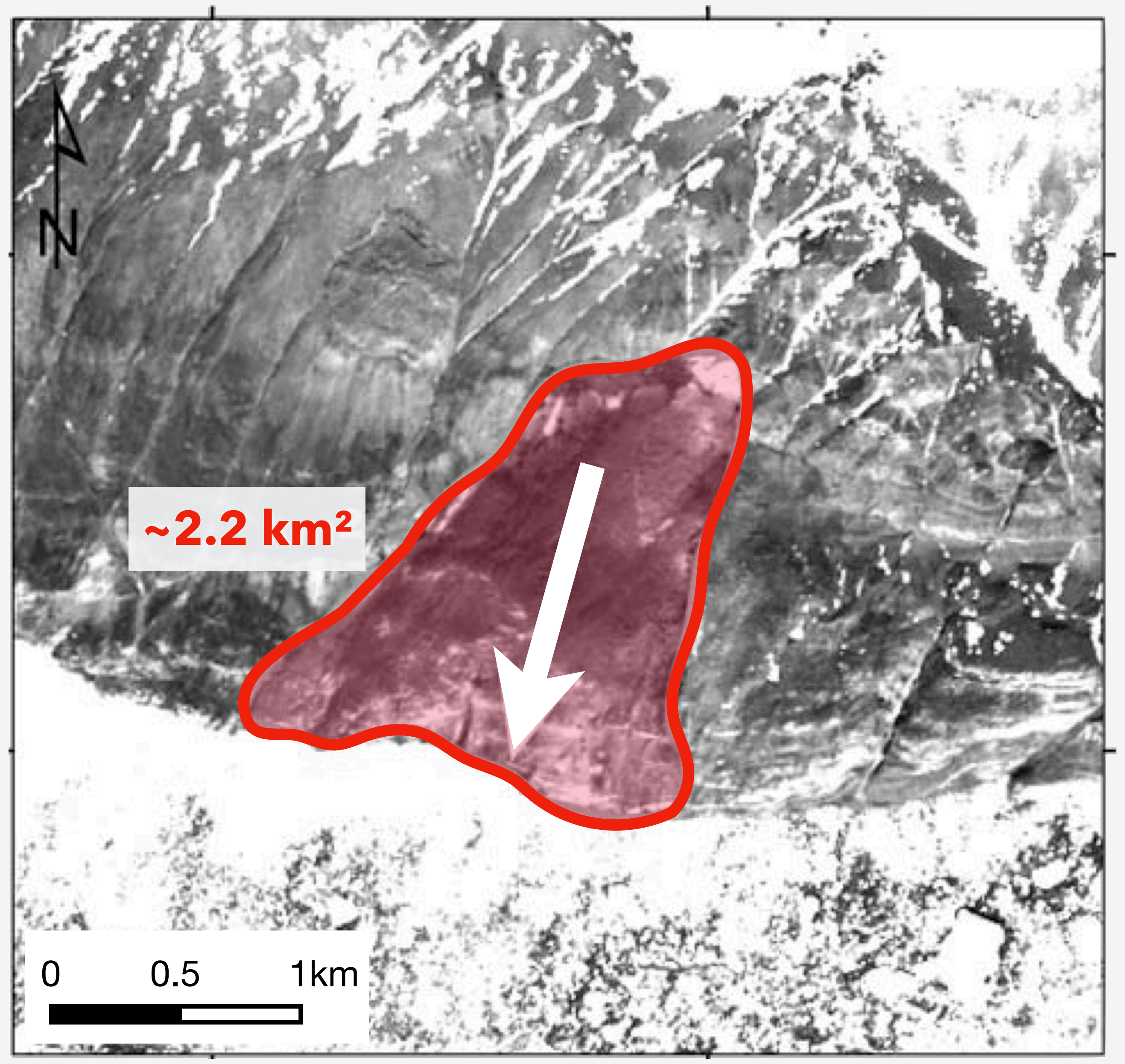
leonard.seydoux@univ-grenoble-alpes.fr

THE 2017 LANDSLIDE OF NUUGAASTIAQ, GREENLAND



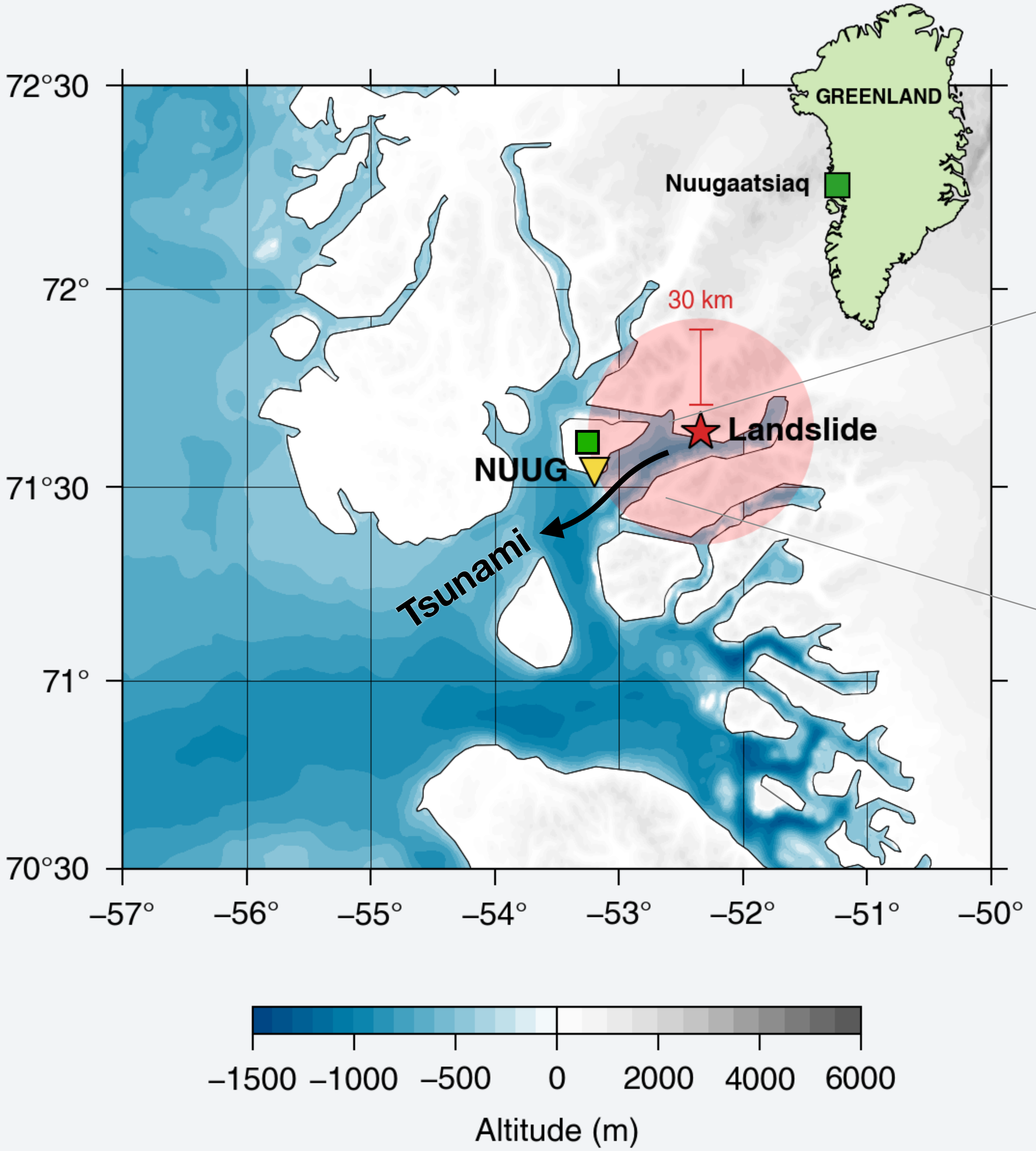
Collapse area

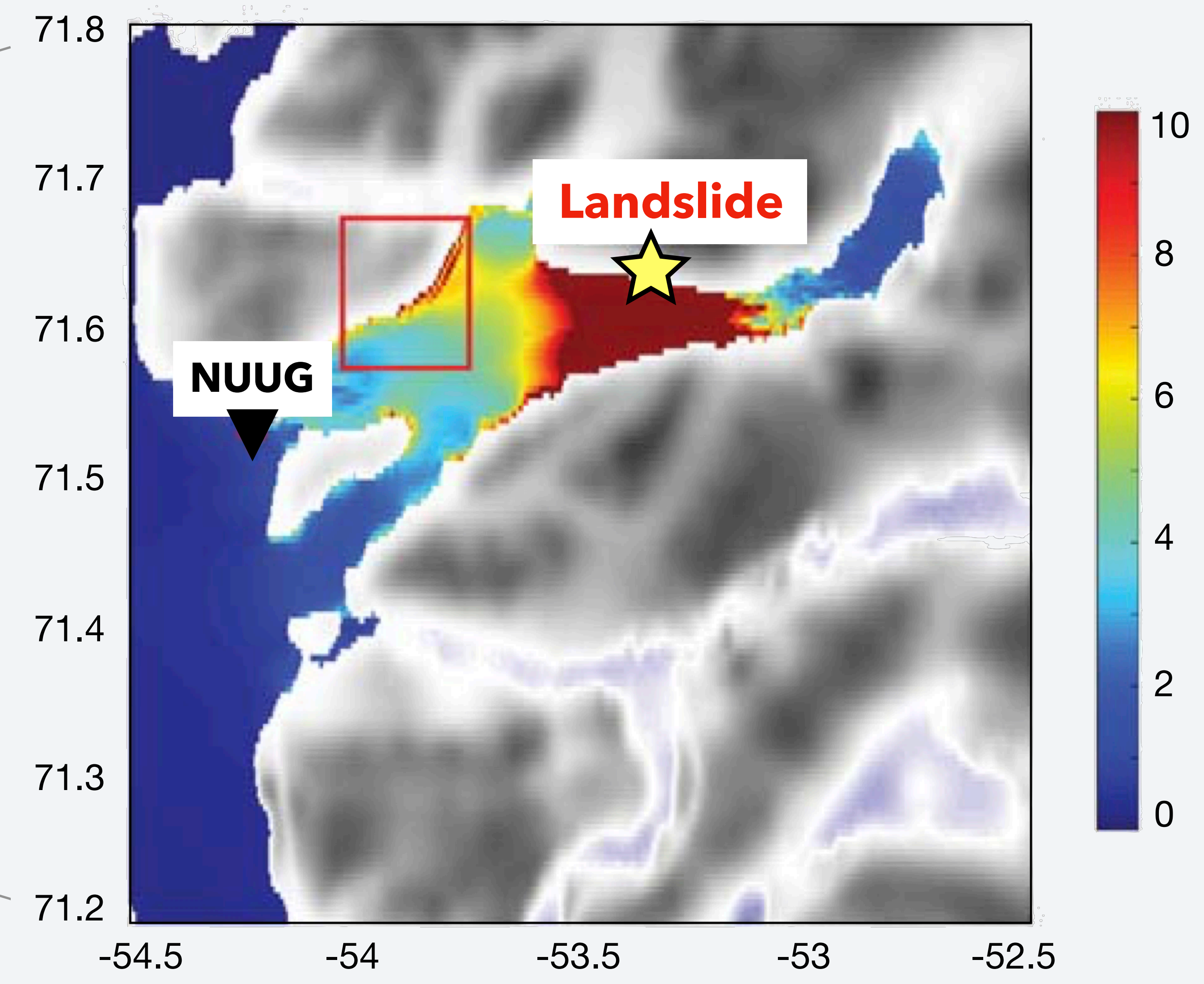


Chao et al. SRL (2017)

BETWEEN 35 AND 51 MILLION M³ OF MATERIAL DIVED INTO THE SEA

TSUNAMI WAVES GENERATED BY THE ROCKFALL



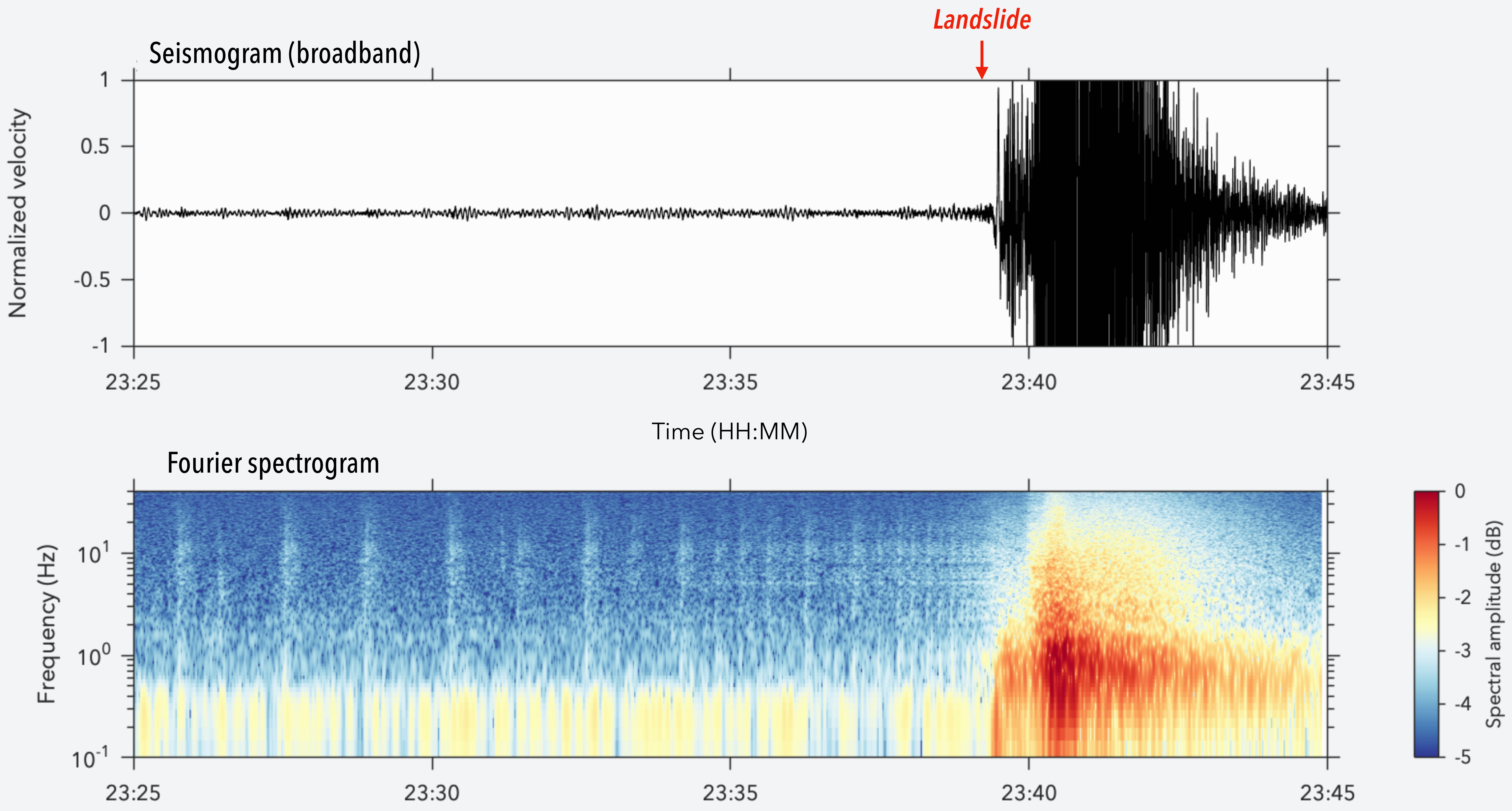


Chao et al. SRL (2017)

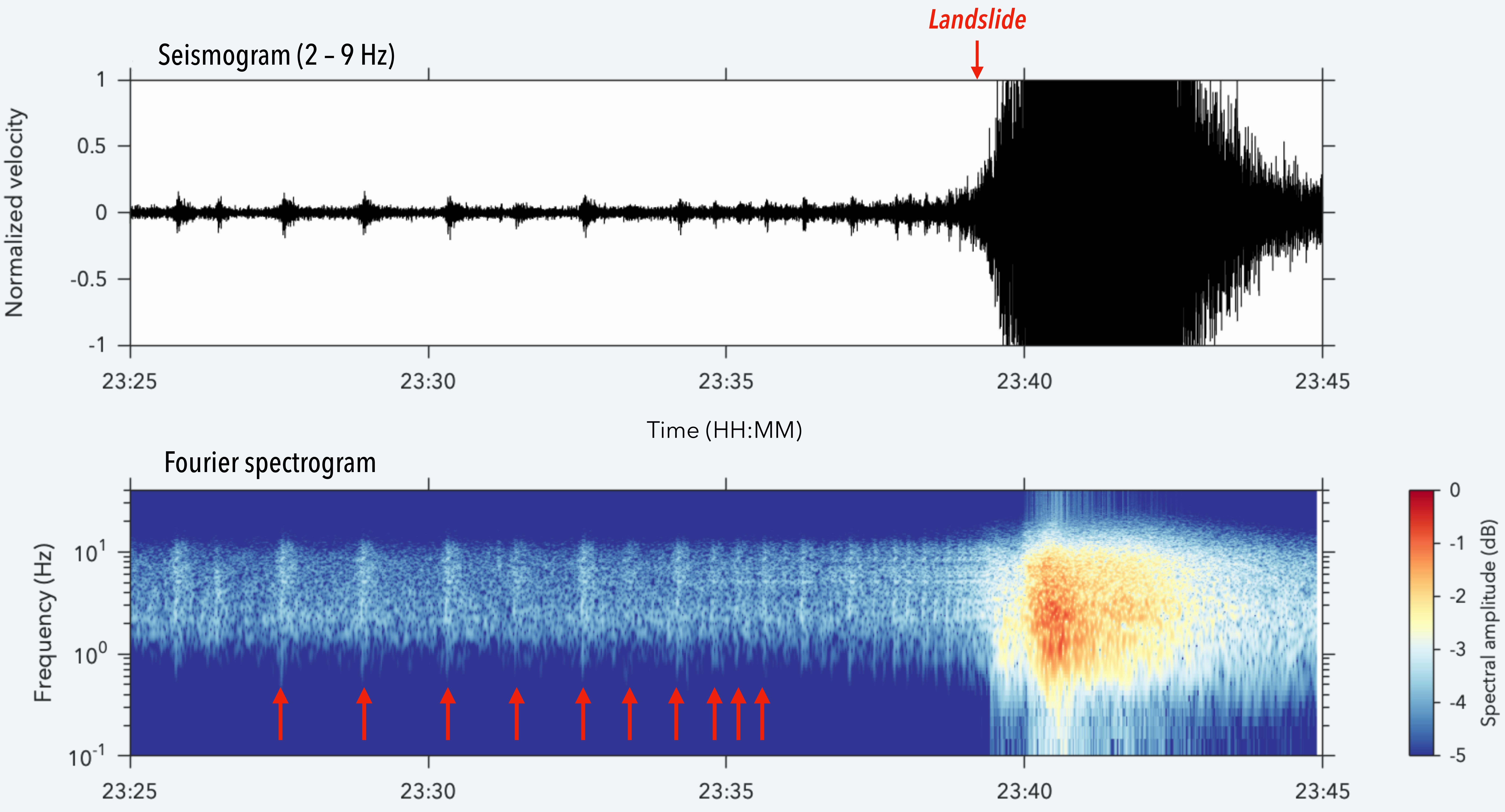
BETWEEN 35 AND 51 MILLION M³ OF MATERIAL DIVED INTO THE SEA

TRIGGERING TSUNAMI WAVES > 10 METERS

BAND-LIMITED SEISMIC PRECURSORS REVEALED BY FOURIER SPECTROGRAM

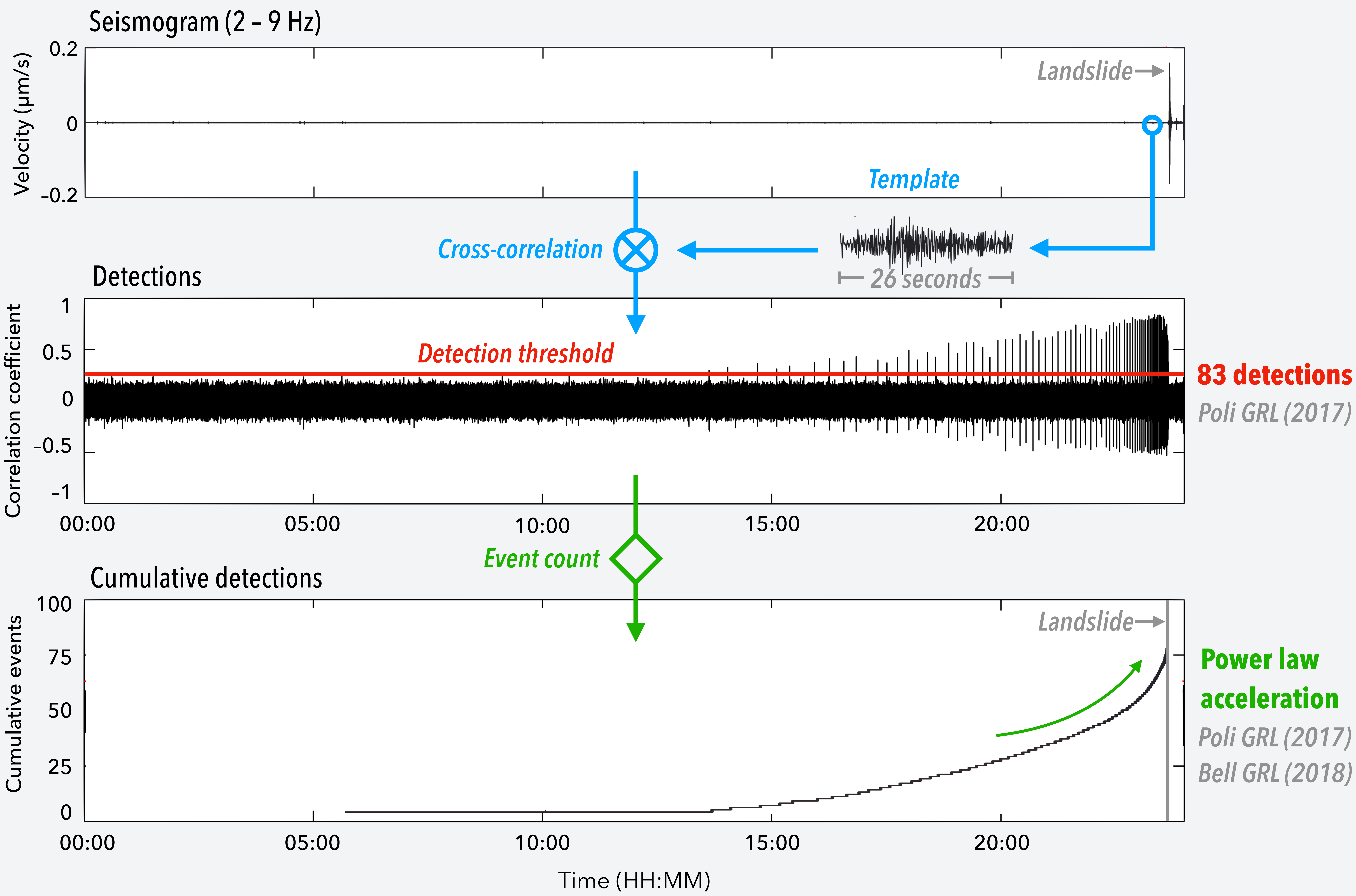


BAND-LIMITED SEISMIC PRECURSORS REVEALED BY FOURIER SPECTROGRAM

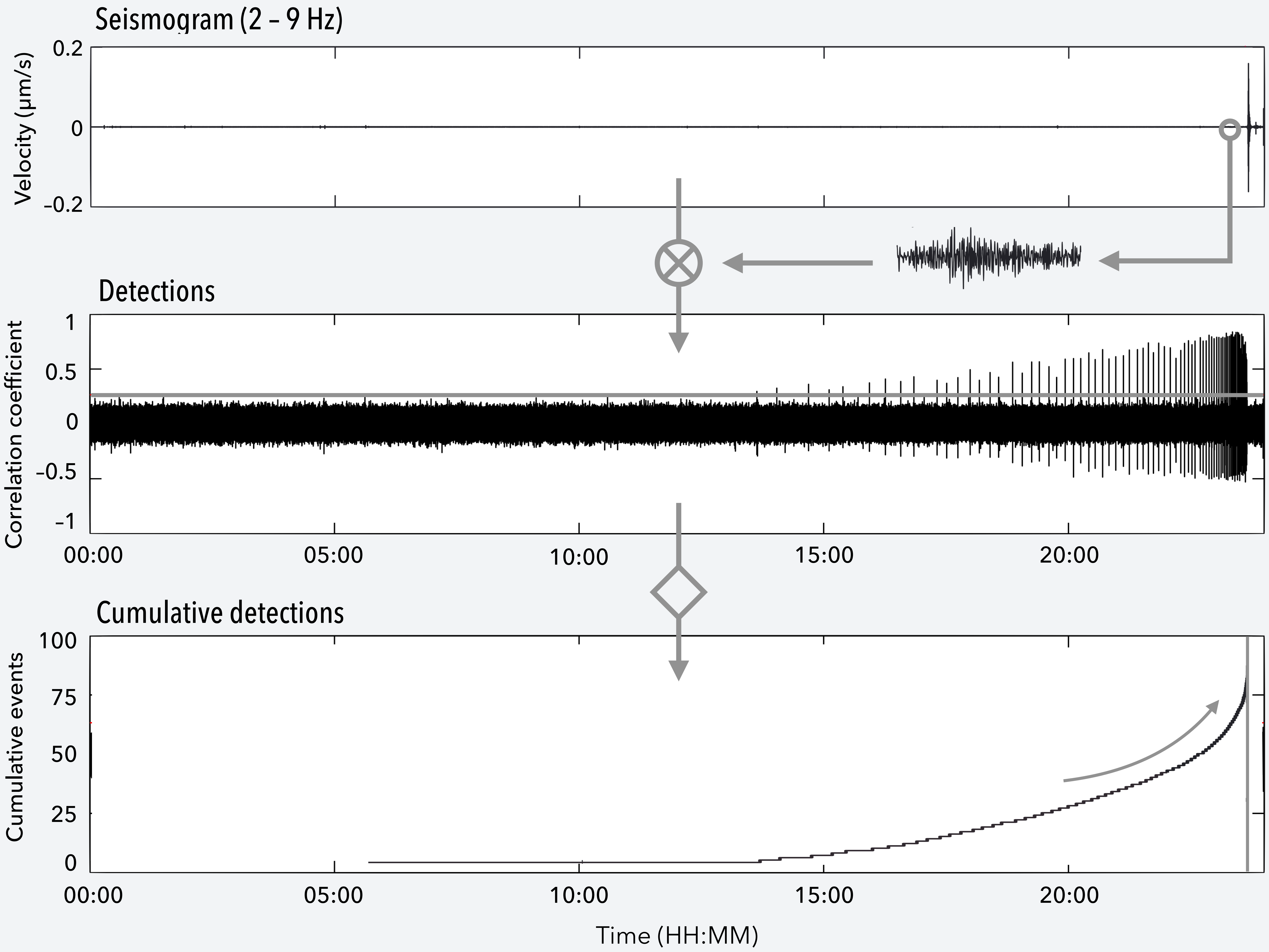


COMPLEX SPECTRAL SHAPE PREVENTS CLUSTERING

THE "SUPERVISED" WAY: TEMPLATE MATCHING DETECTIONS

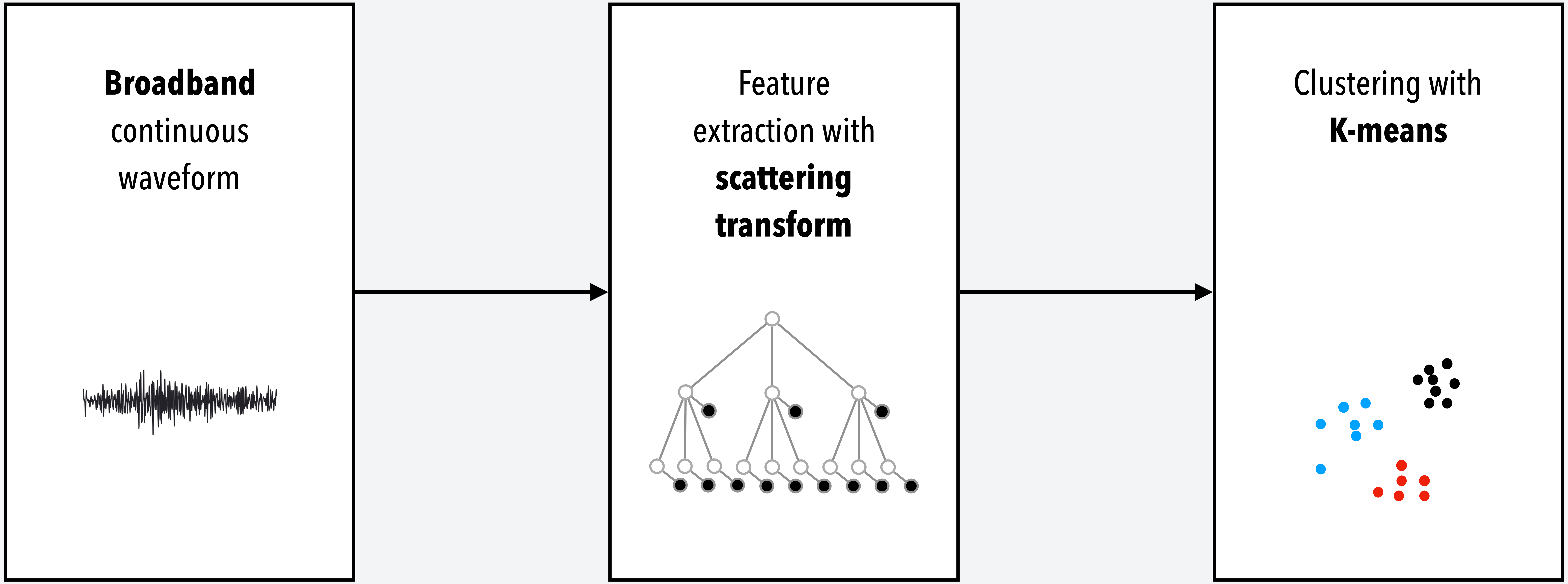


THE "SUPERVISED" WAY: TEMPLATE MATCHING DETECTIONS

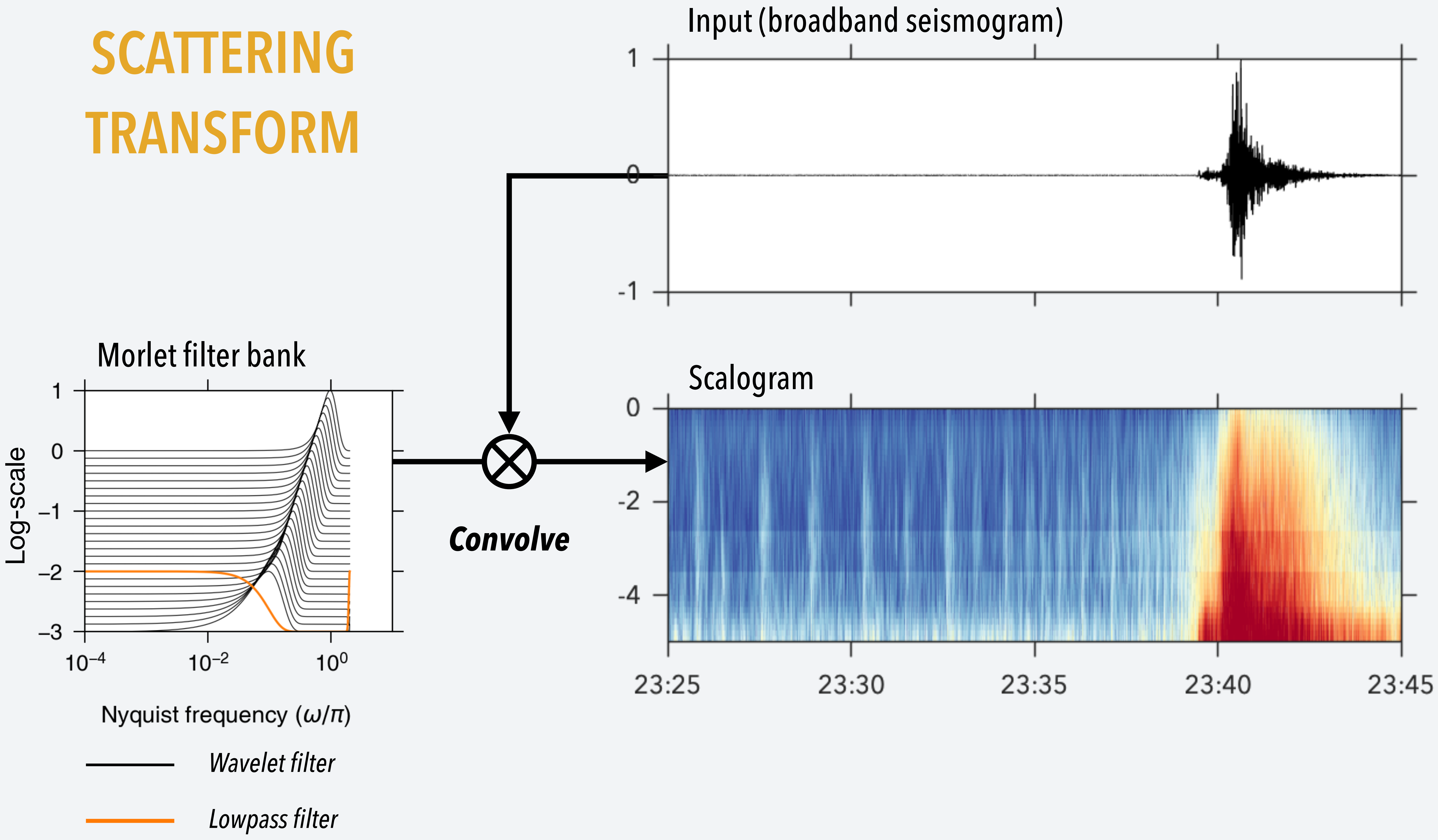


COULD WE RETRIEVE THIS RESULT WITH UNSUPERVISED STRATEGY?

CLUSTERING OF SEISMIC SIGNALS WITH SCATTERING TRANSFORM FEATURES



IDEA OF A SCATTERING TRANSFORM



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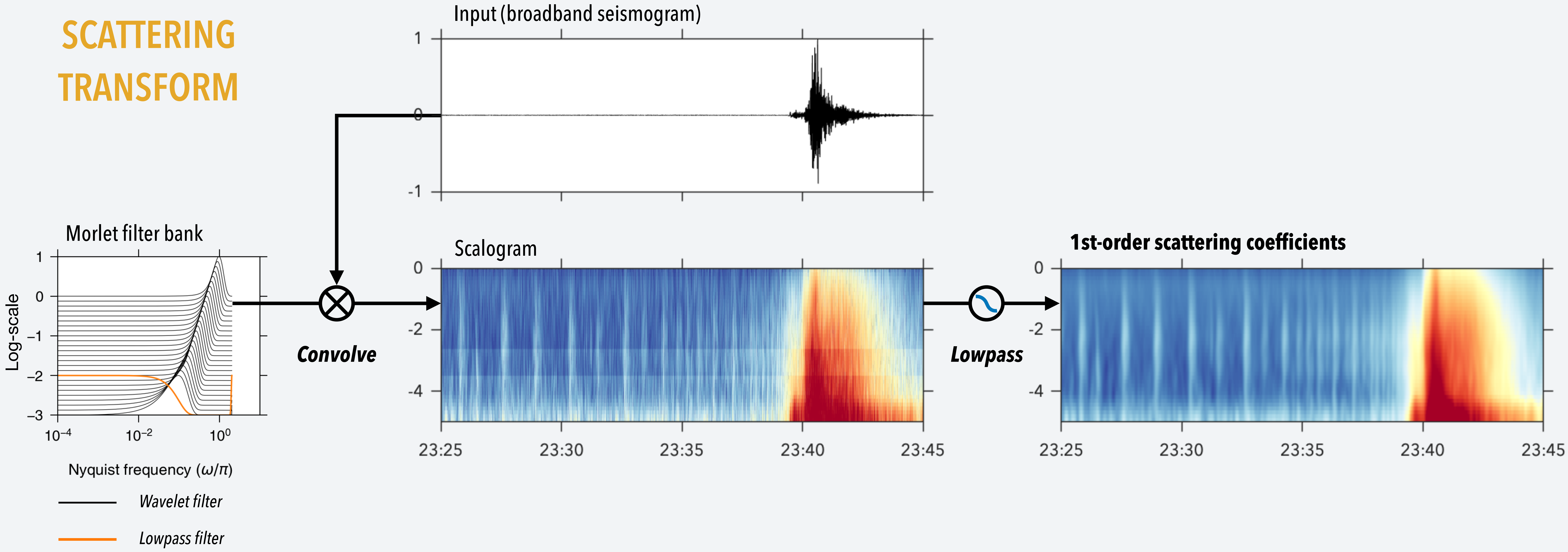
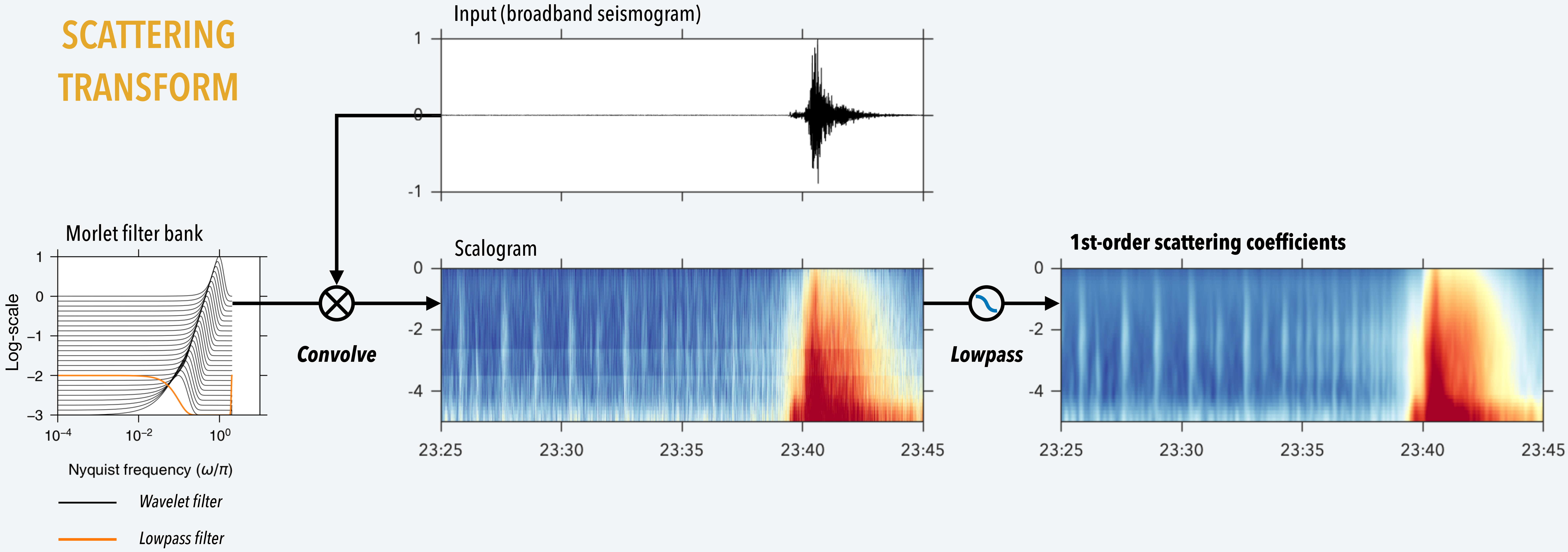


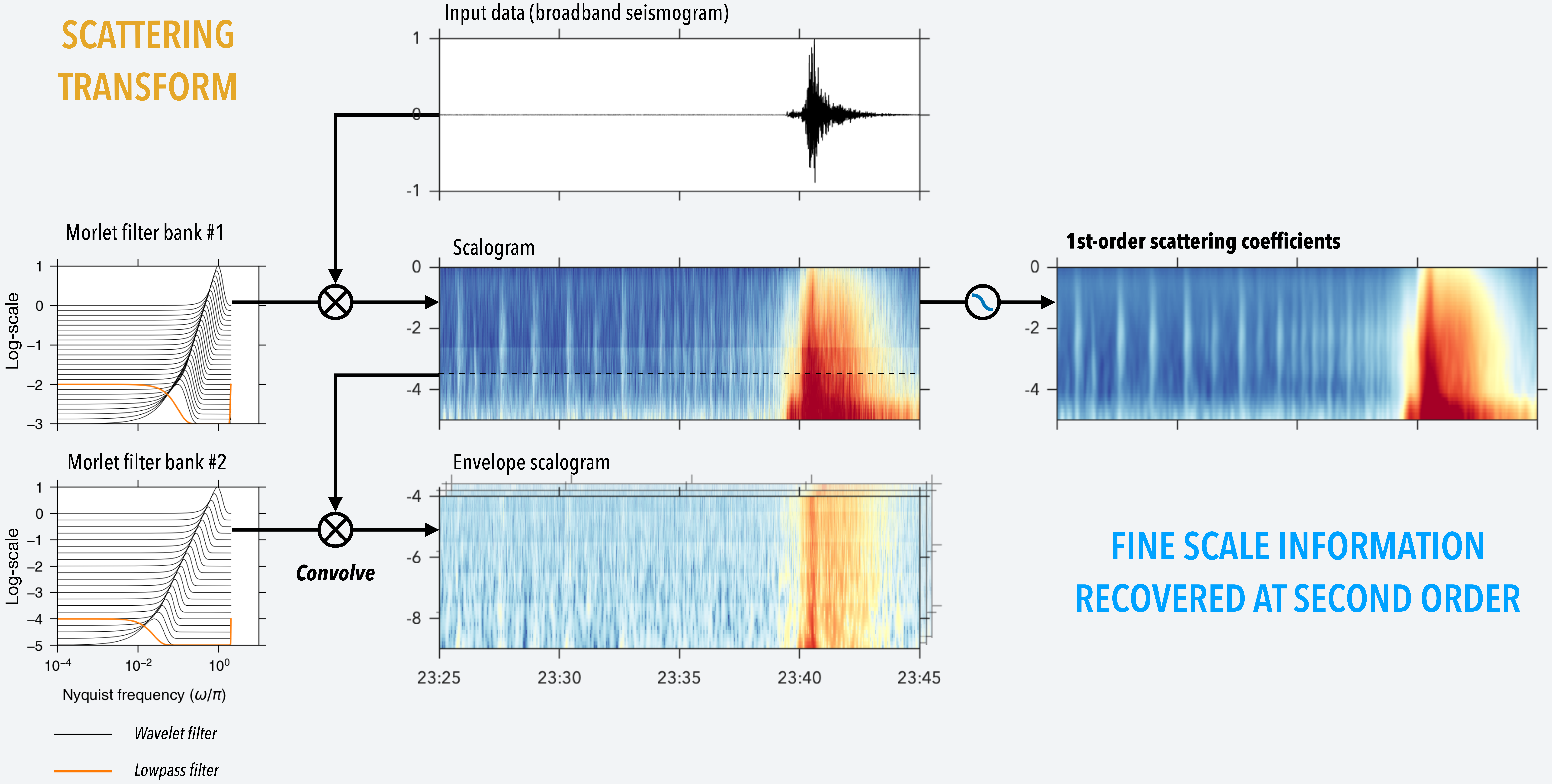
IDEA OF A SCATTERING TRANSFORM



STABLE TO SMALL SIGNAL DEFORMATIONS

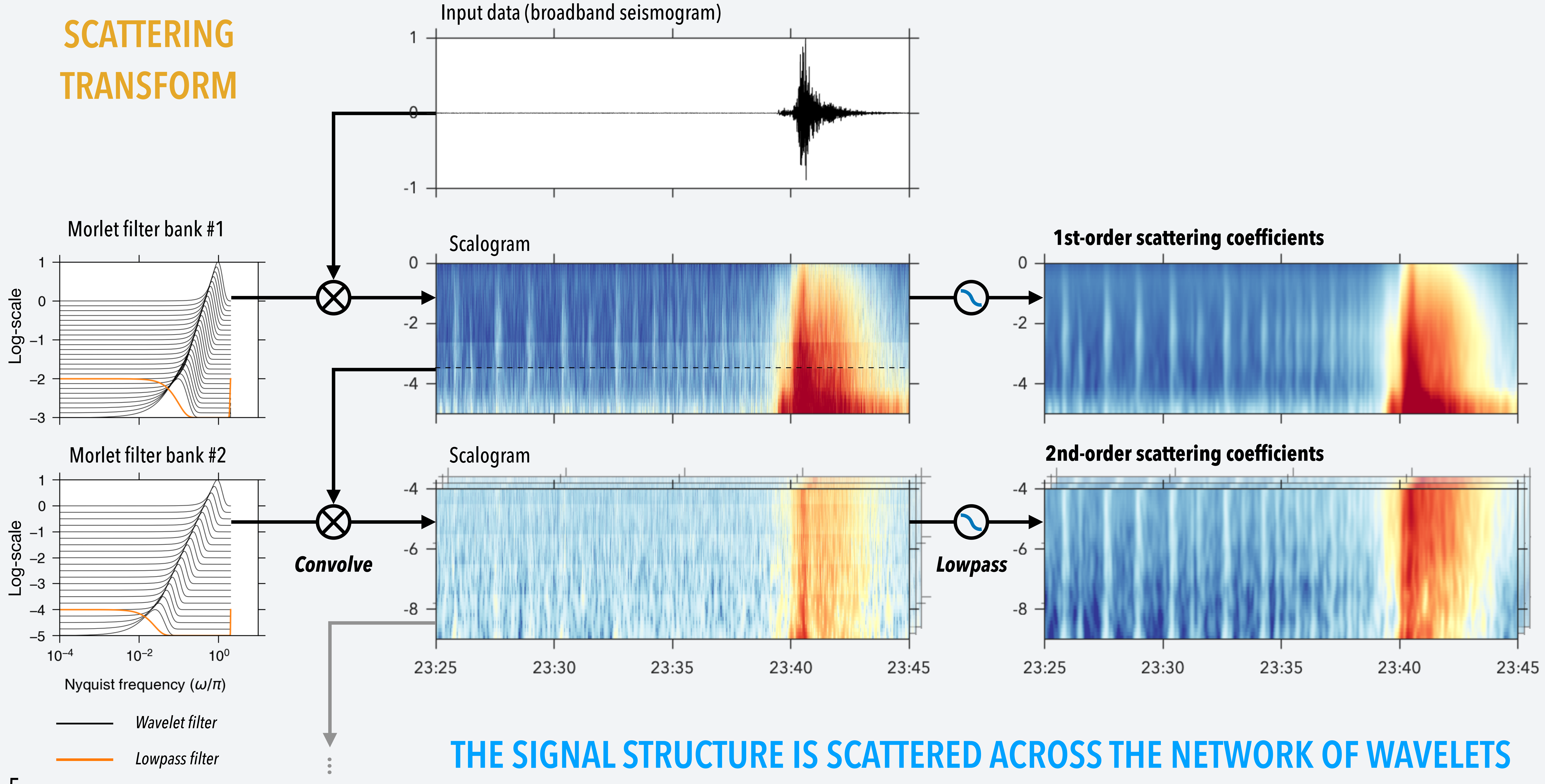
FINE SCALE INFORMATION REMOVED

IDEA OF A SCATTERING TRANSFORM



FINE SCALE INFORMATION RECOVERED AT SECOND ORDER

IDEA OF A SCATTERING TRANSFORM



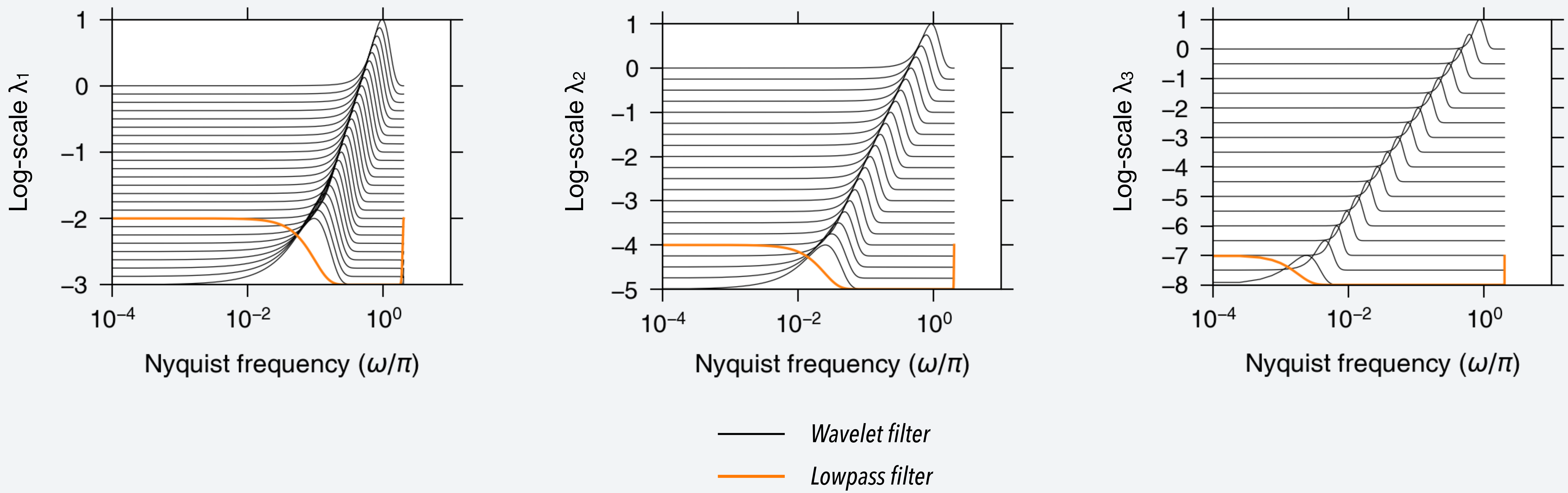
THE SIGNAL STRUCTURE IS SCATTERED ACROSS THE NETWORK OF WAVELETS

SCATTERING NETWORK DESIGN IS STRAIGHTFORWARD

Filter bank #1
Time scale: 2 second

Filter bank #2
Time scale: 8 seconds

Filter bank #3
Time scale: 32 seconds

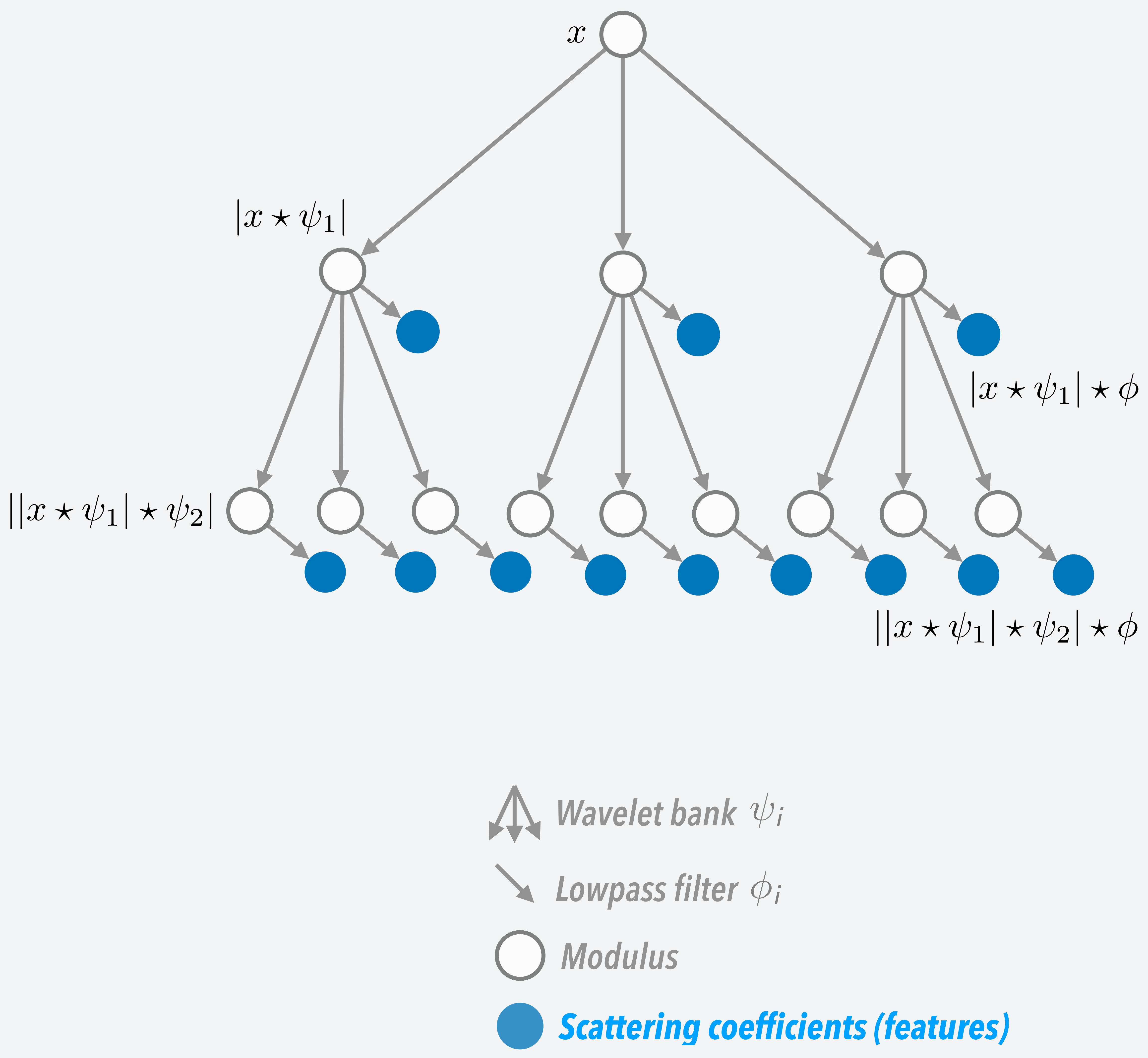


"ACCURACY"

"SPARSITY"

Andén & Mallat IEEE (2014)

SCATTERING NETWORK: AN ANALYTICAL CONVOLUTIONAL NEURAL NETWORK



SCATTERING NETWORK

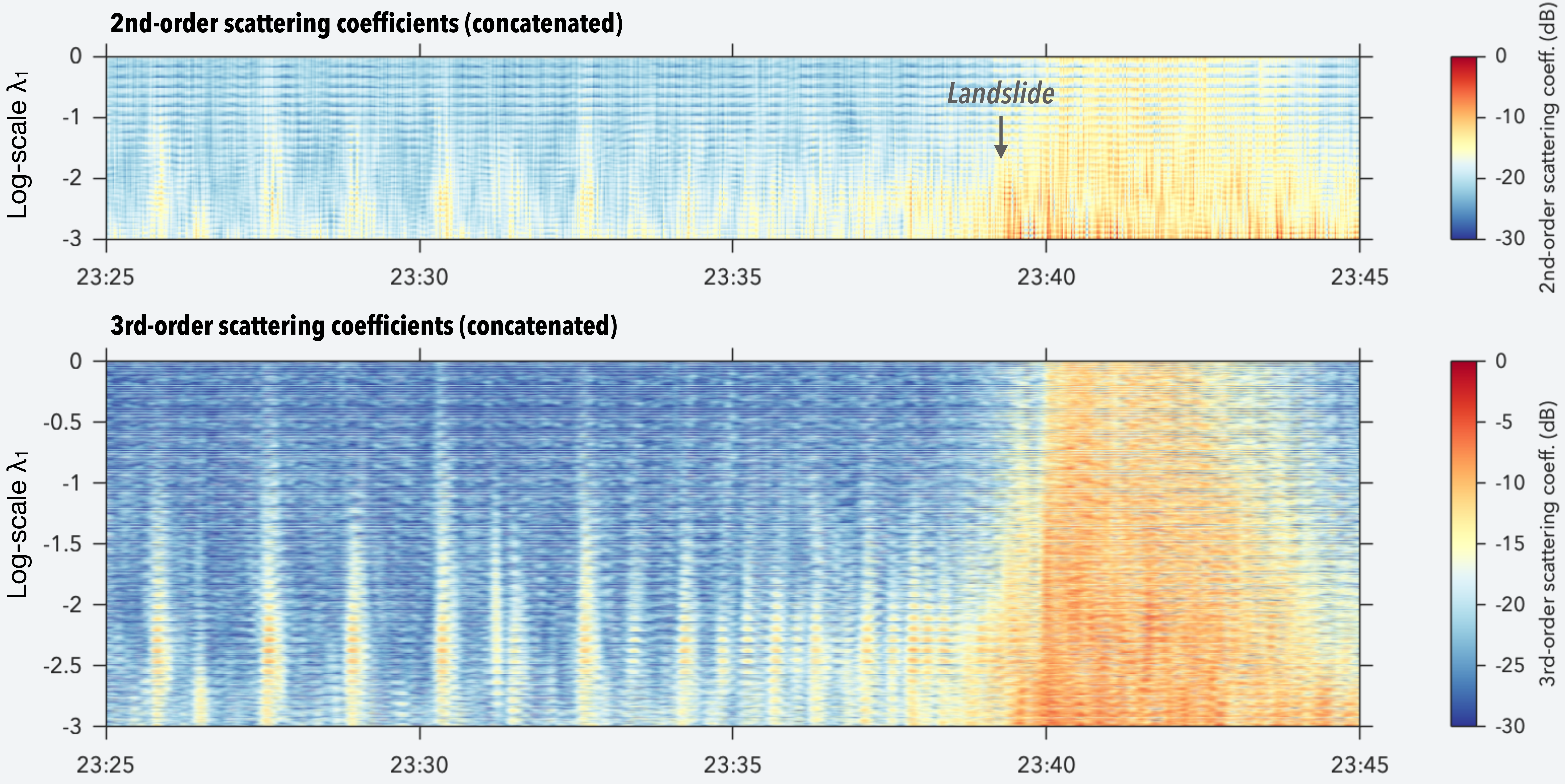
Neural network architecture
No learning
Straightforward design
Stable to small deformations
Multi time scales

STABLE DESCRIPTION OF

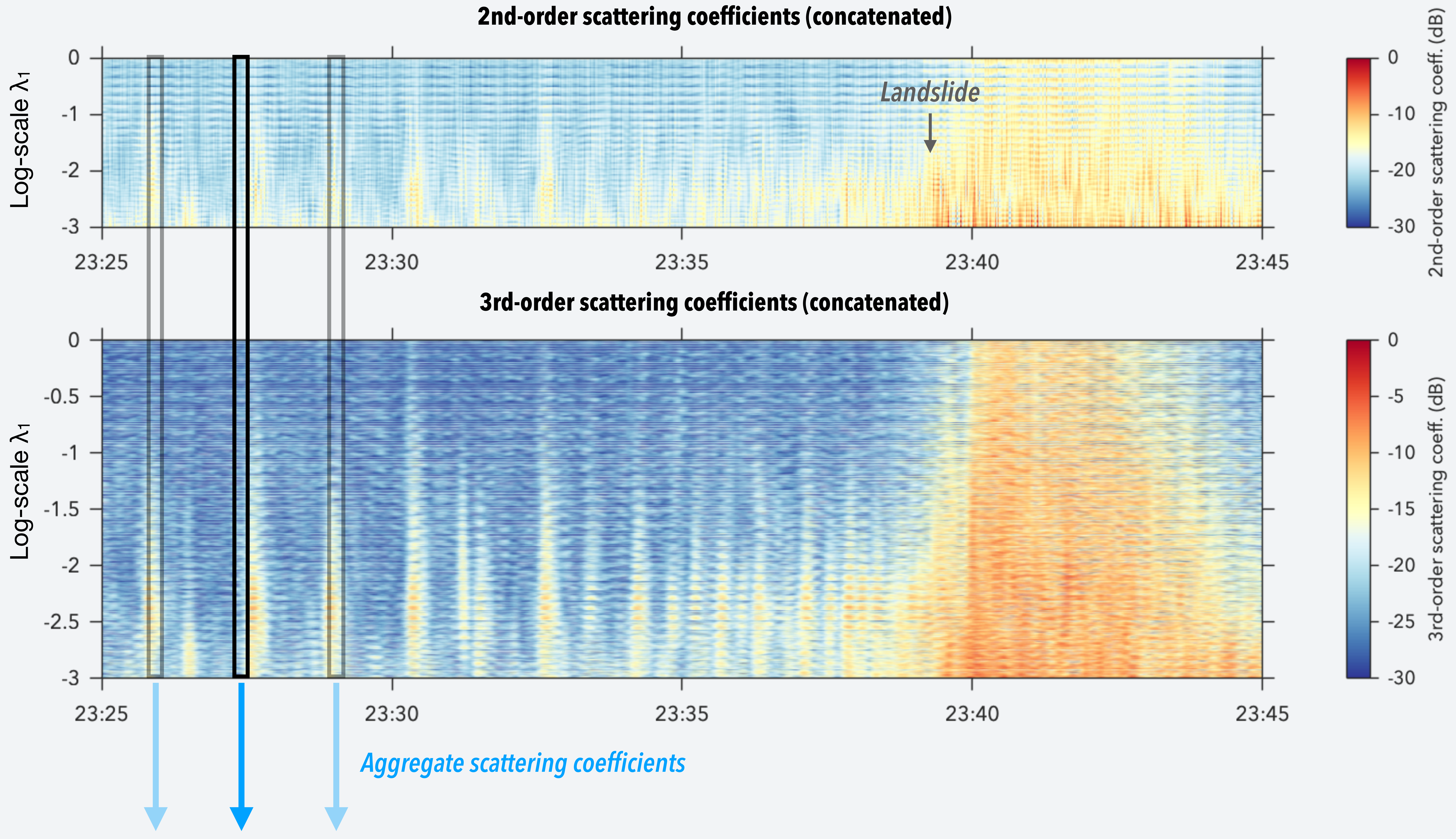
Frequency content
Envelope duration
Envelope shape

GOOD CANDIDATE FOR SEISMIC SIGNAL FEATURES

EXAMPLE OF SCATTERING COEFFICIENTS

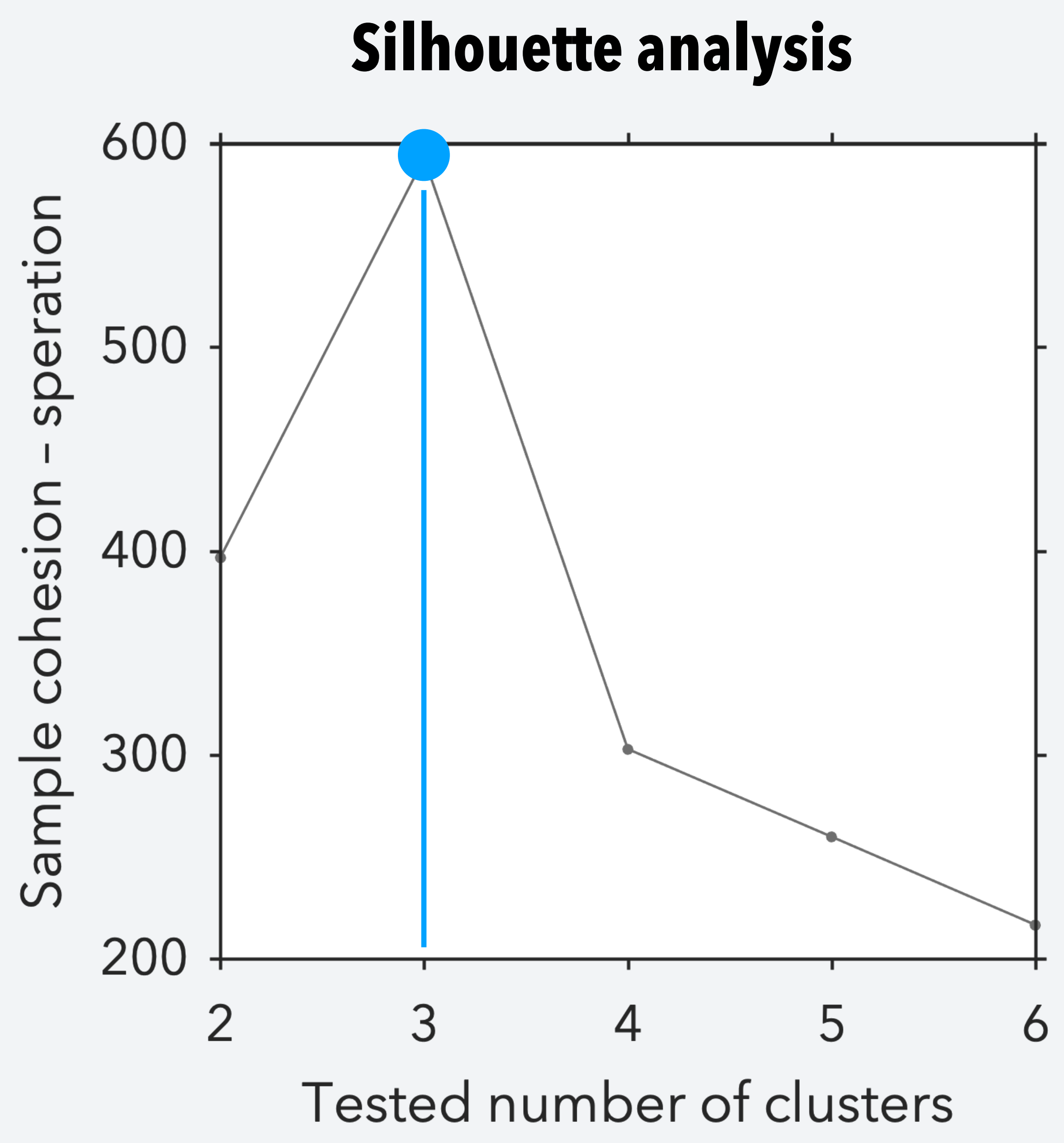


SCATTERING FEATURES EXTRACTION

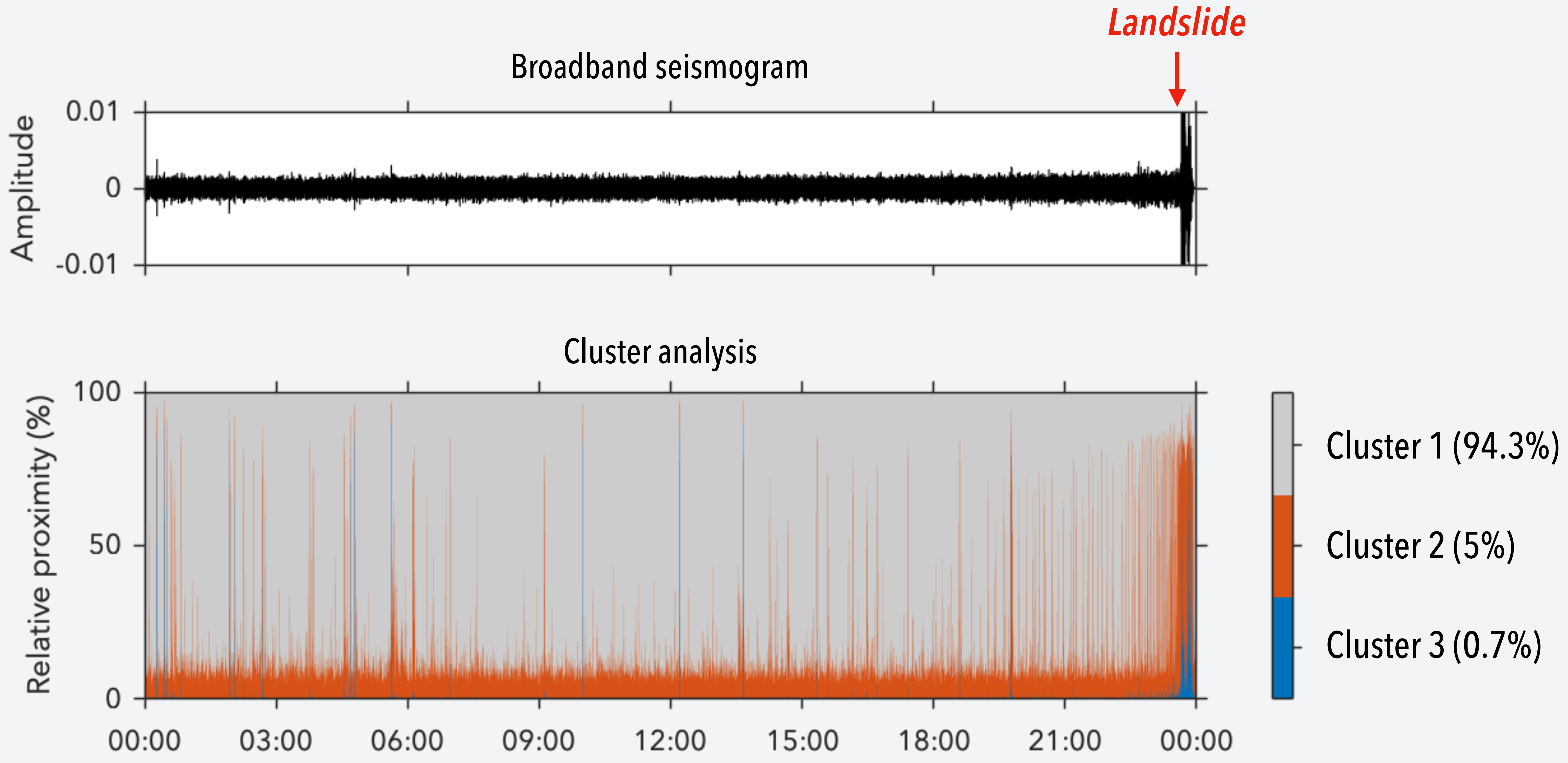


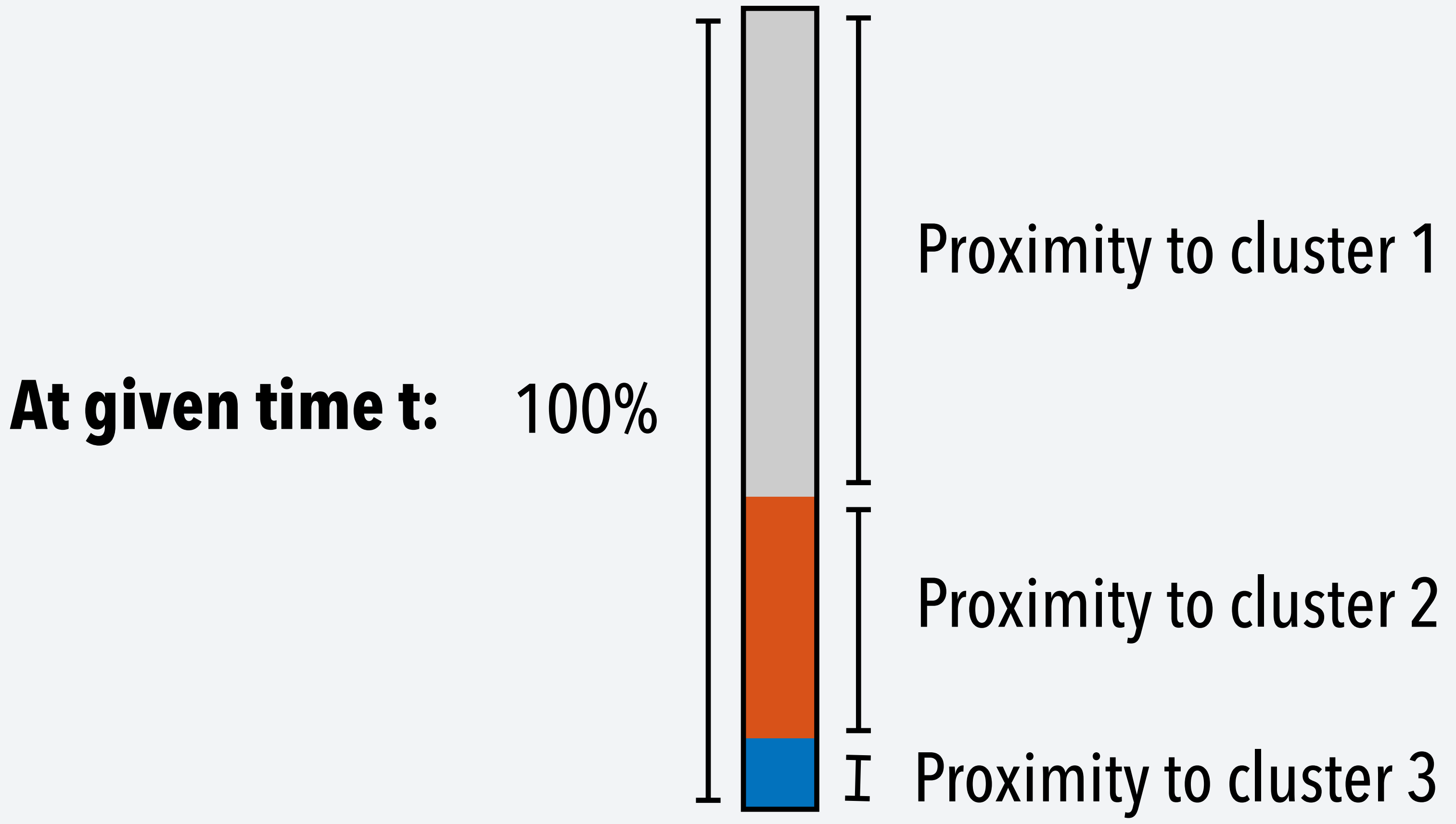
TIME SCATTERING VECTORS → **K-MEANS CLUSTERING**

CLUSTER ANALYSIS OVER THE FULL DAY



OPTIMAL NUMBER OF CLUSTERS = 3





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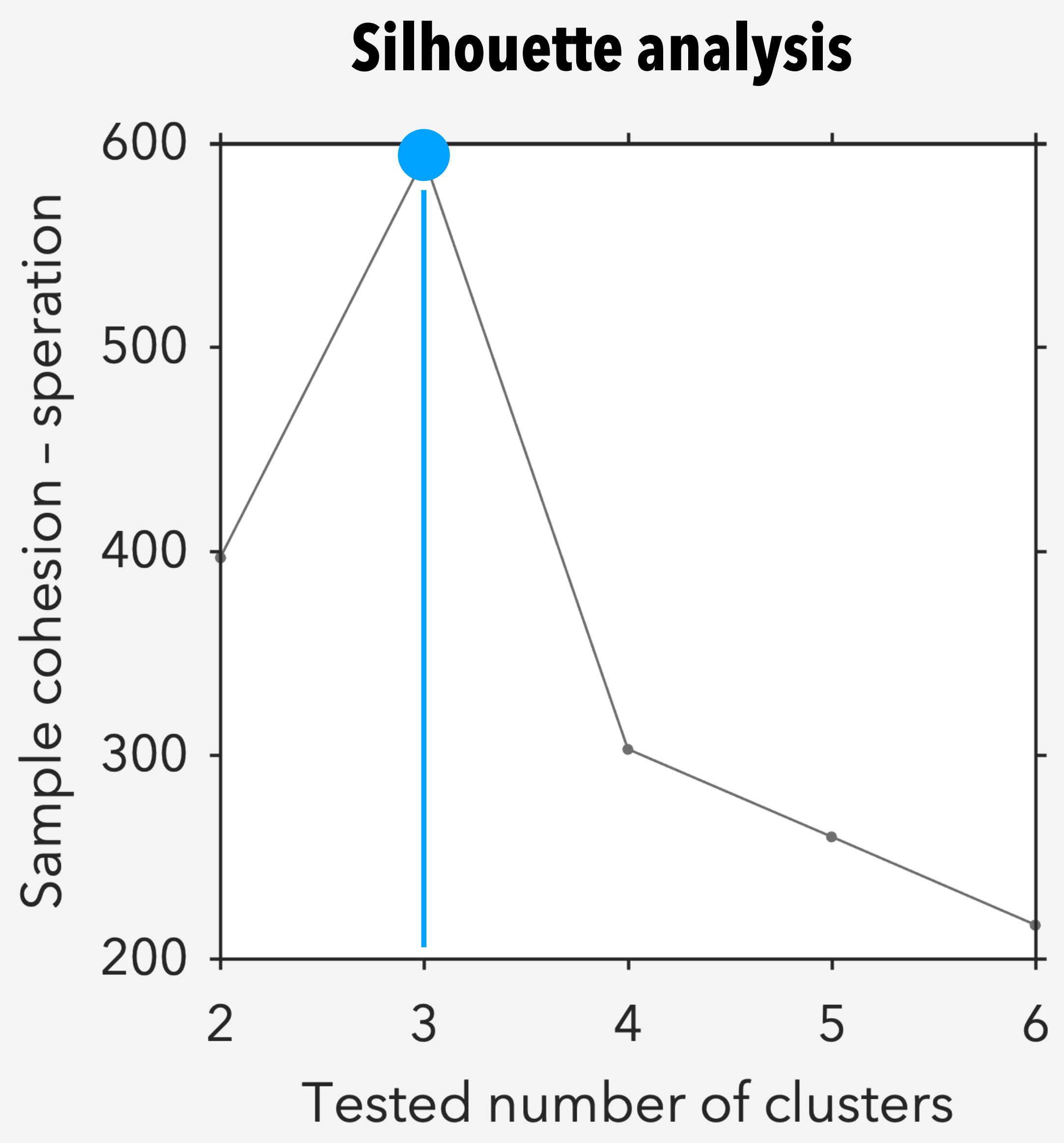
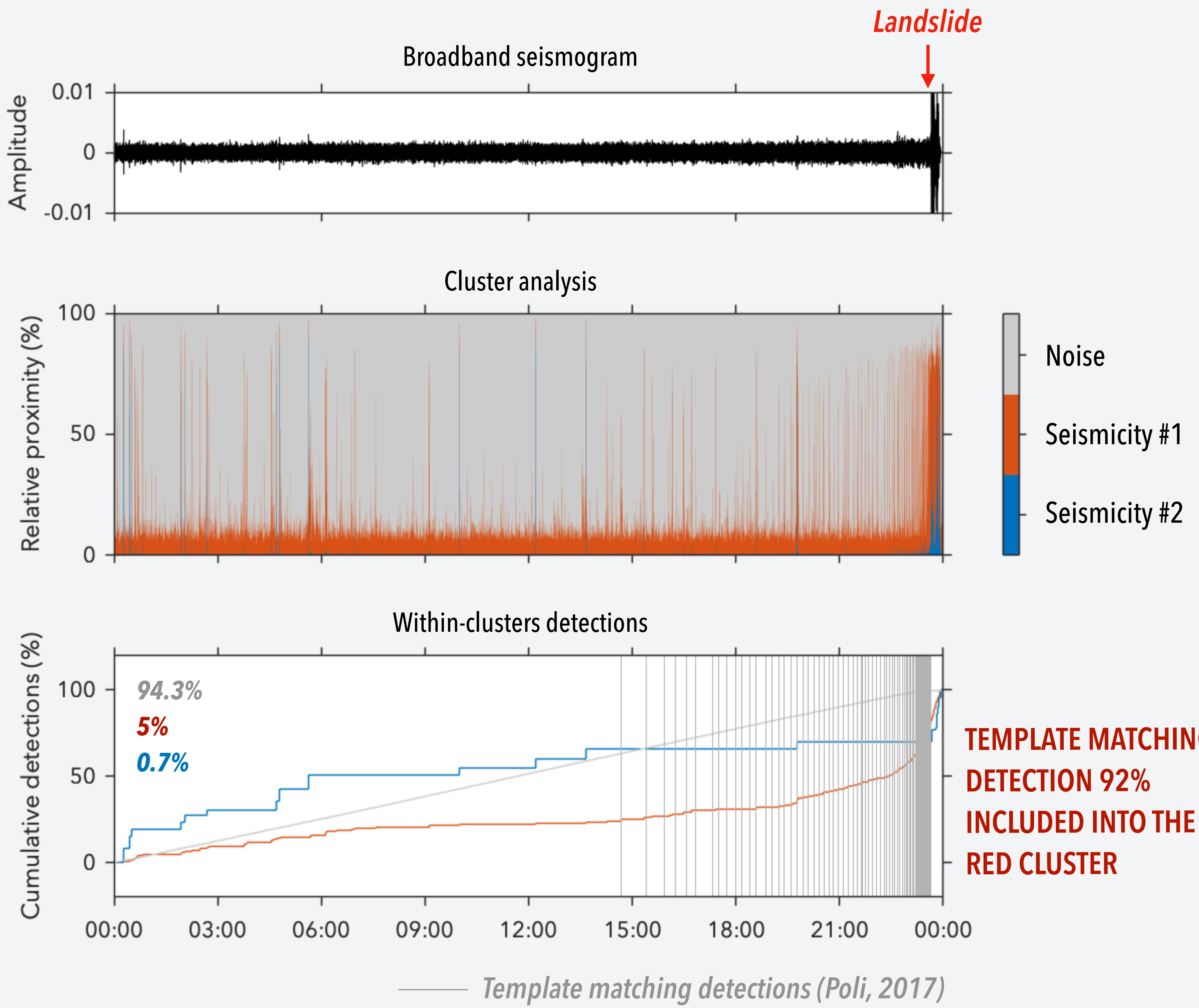


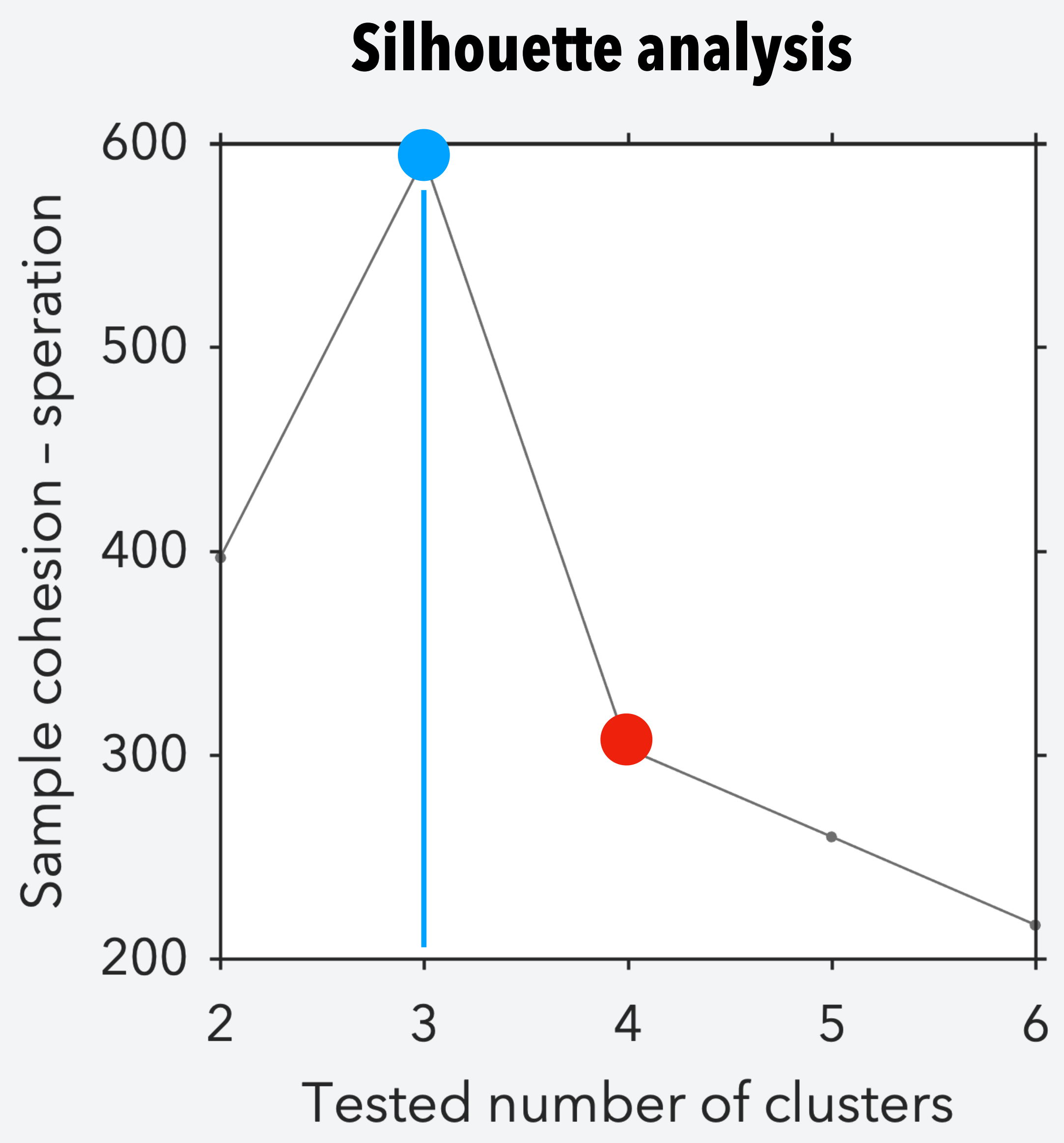
OPTIMAL NUMBER OF CLUSTERS = 3

TWO TYPES OF SEISMICITY REVEALED



TEMPLATE MATCHING DETECTION 92% INCLUDED INTO THE RED CLUSTER

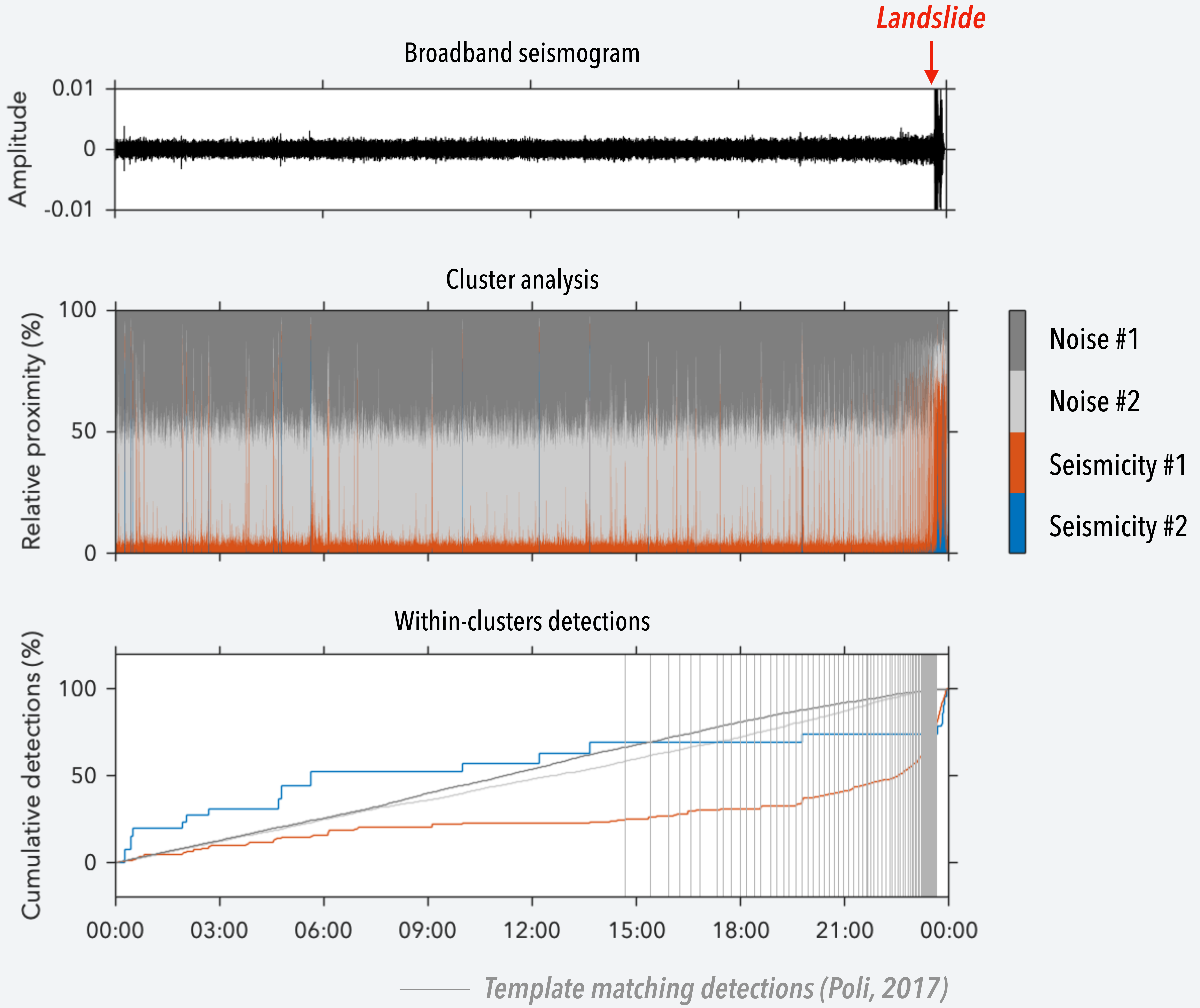
CLUSTER ANALYSIS WITH HIGHER NUMBER OF CLUSTERS



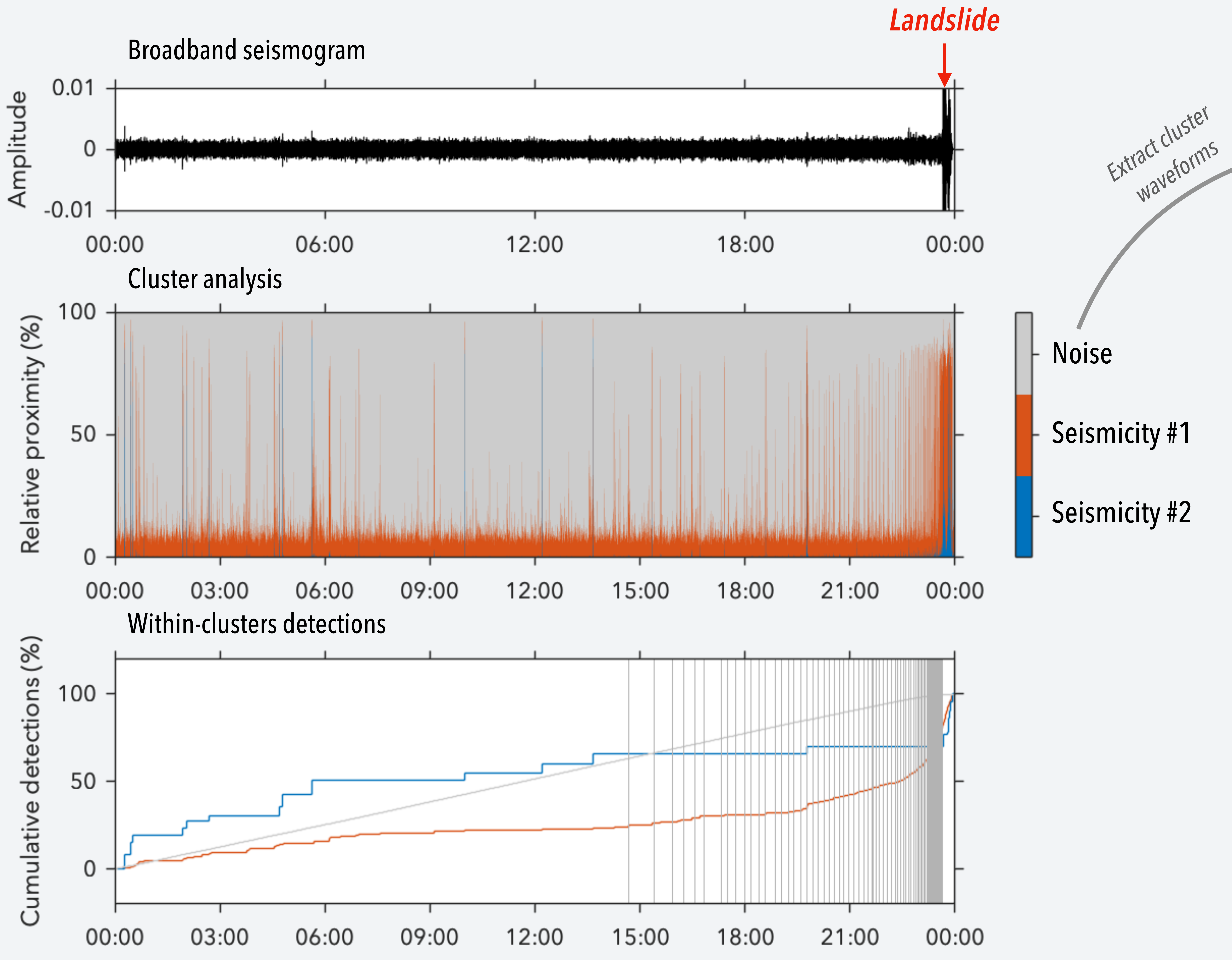
OPTIMAL NUMBER OF CLUSTERS = 3

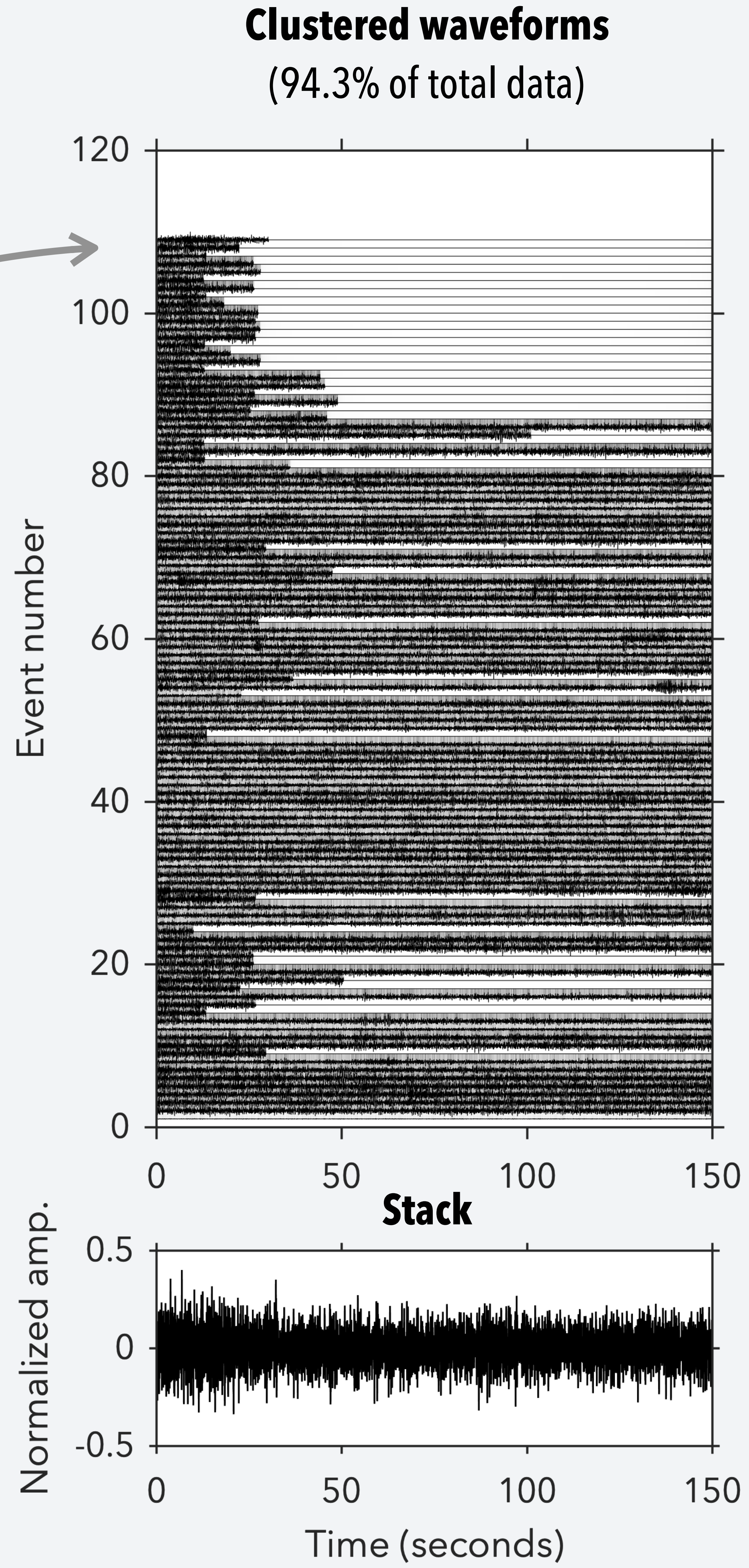
TWO TYPES OF SEISMICITY REVEALED

LOOKING FOR MORE CLUSTERS
ONLY SPLITS THE NOISE CLUSTER

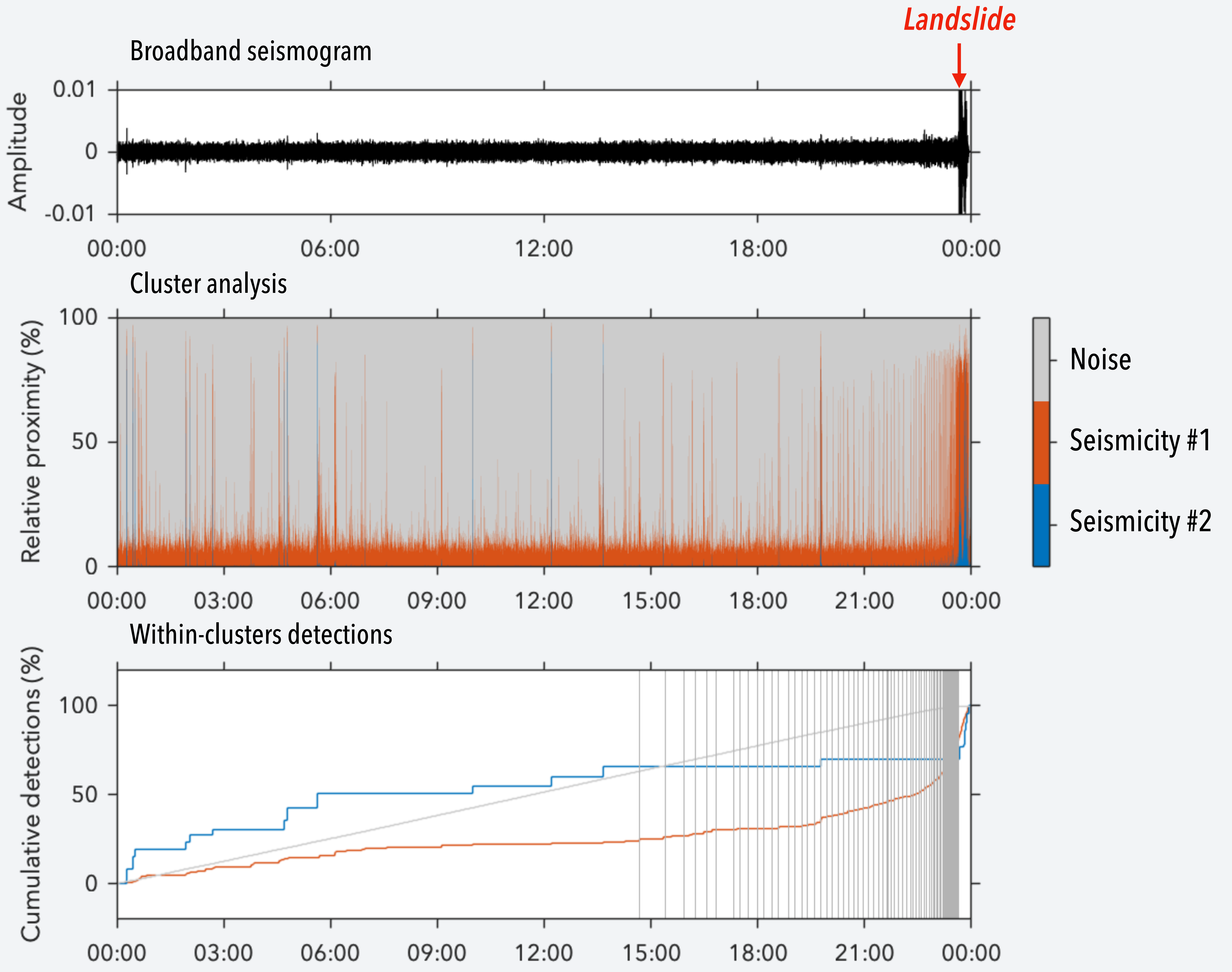


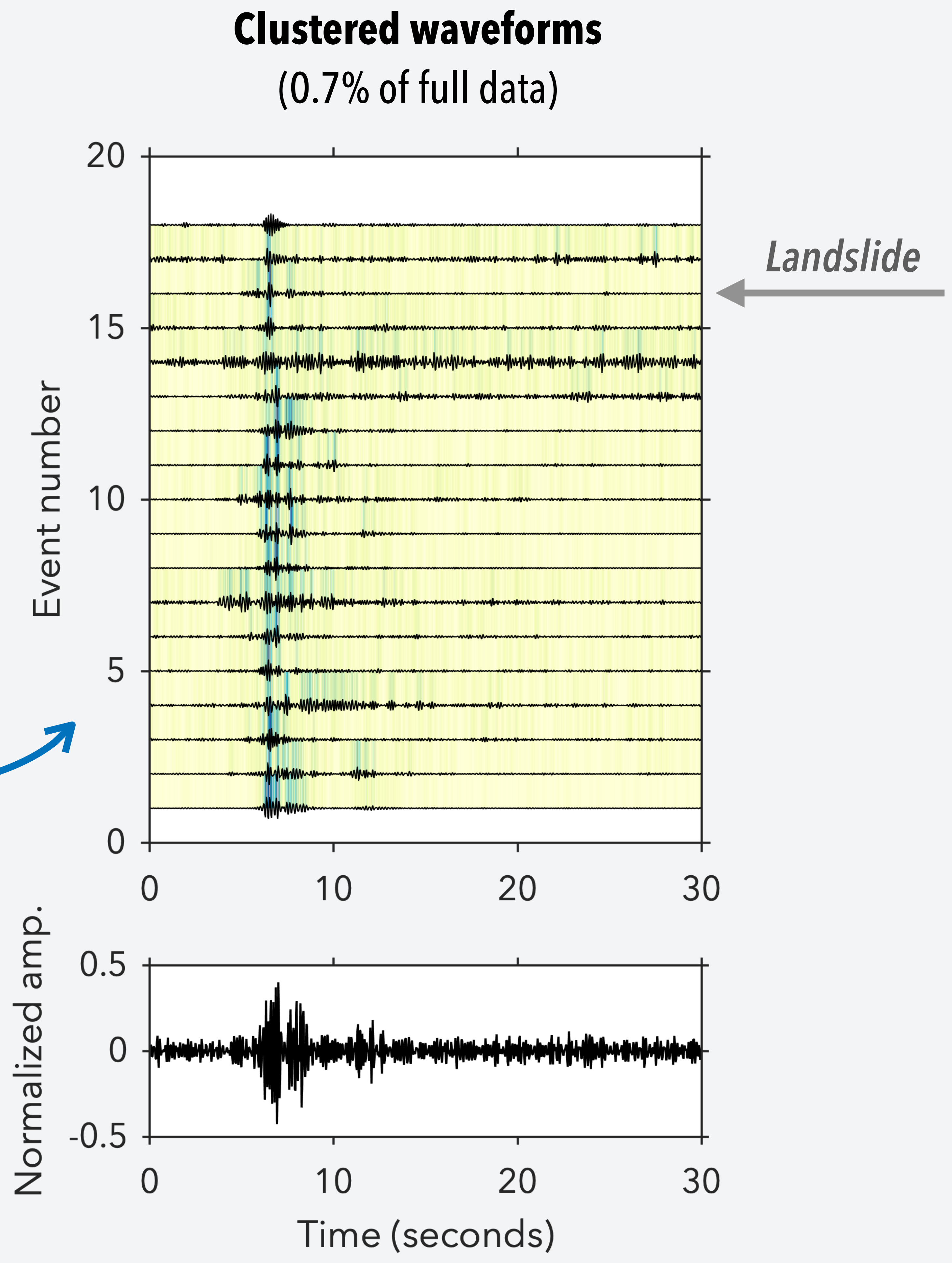
BACKGROUND NOISE CLUSTER





SHORT-DURATION LOCAL SEISMICITY



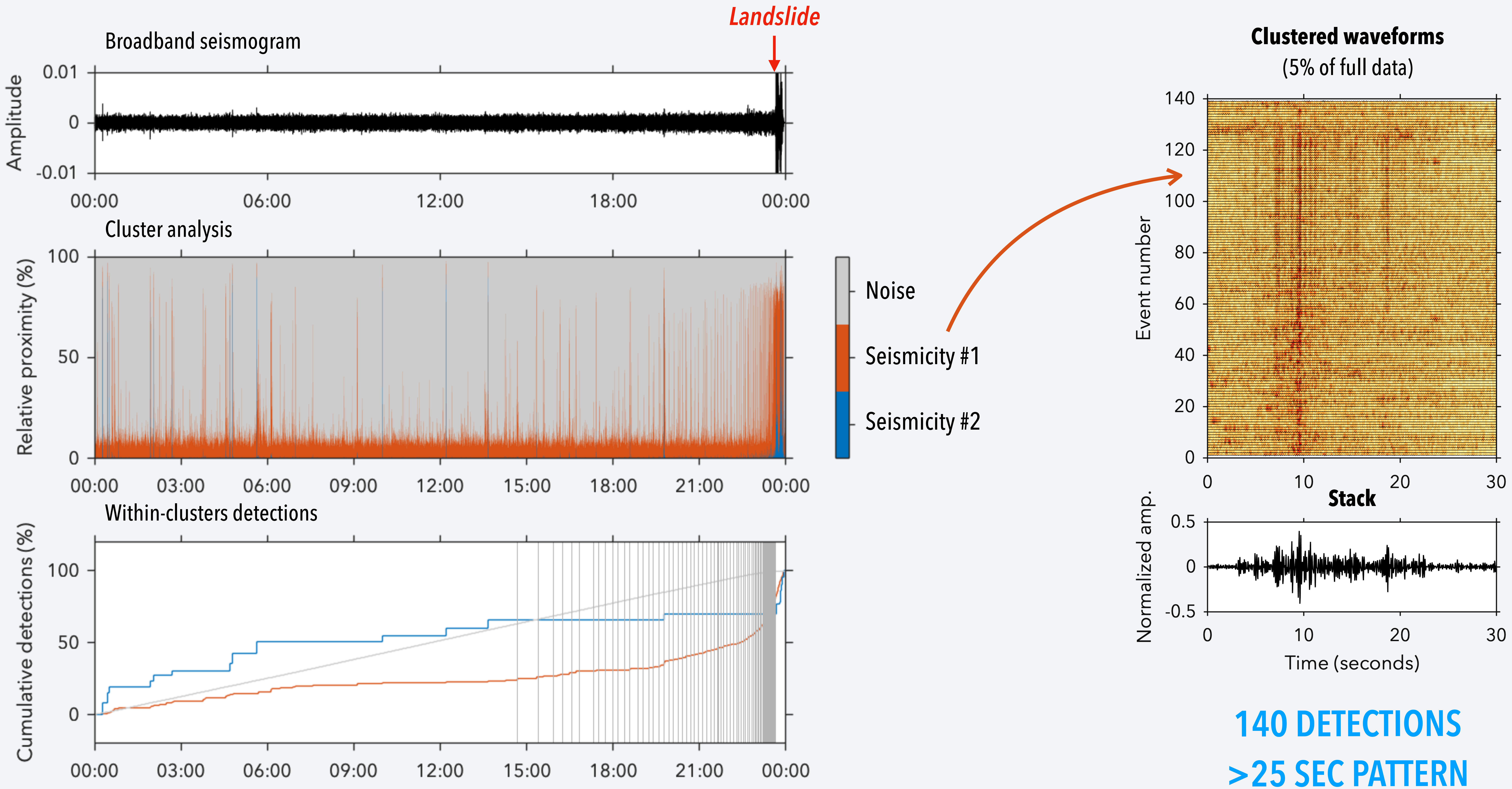


18 DETECTIONS

< 10 SEC EVENTS

SHARP ENVELOPE

SEISMICITY #1: LONG-DURATION SEISMIC REPEATORS



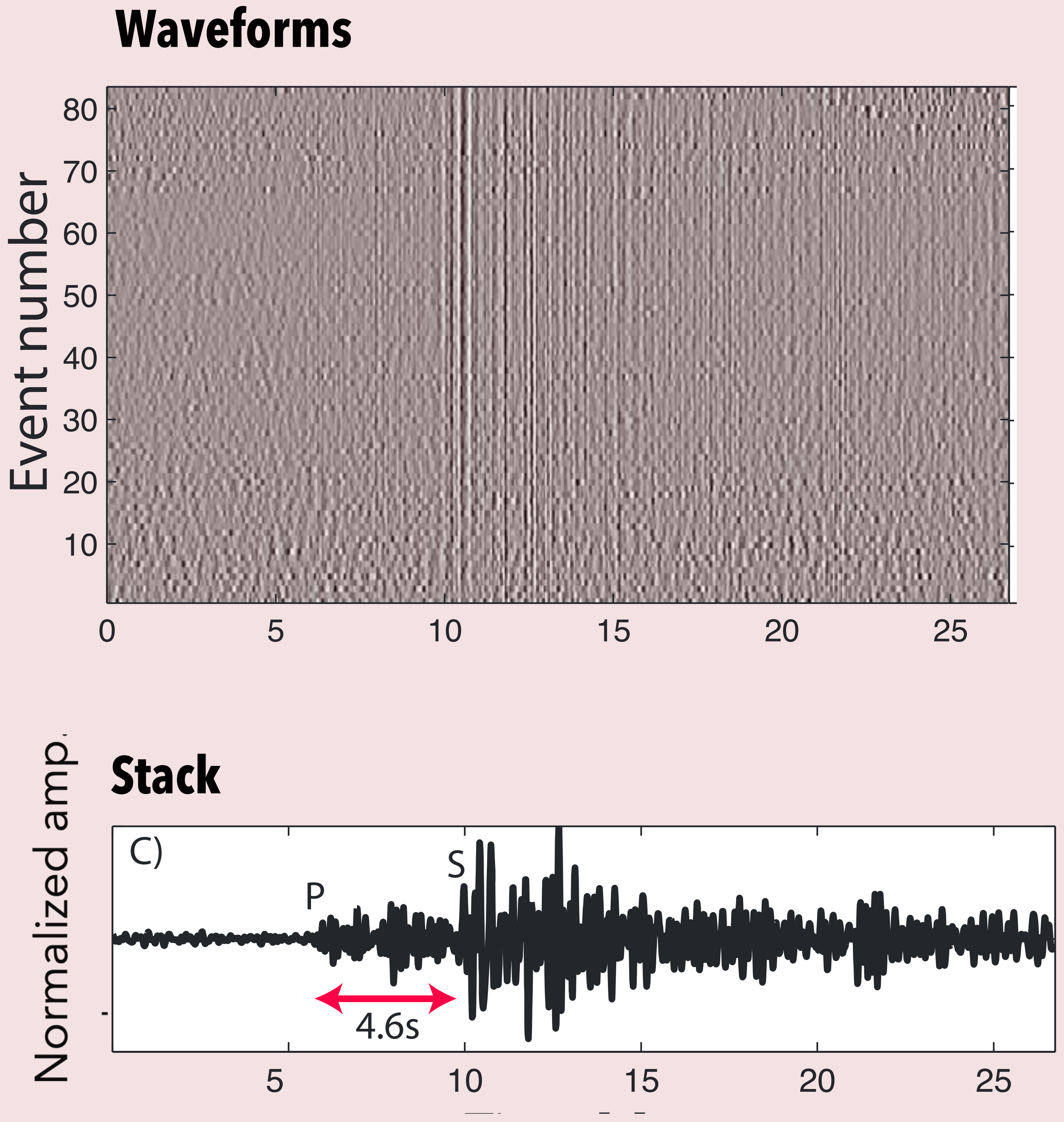
140 DETECTIONS

>25 SEC PATTERN

HIGH SIMILARITY

PRECURSORY SIGNAL DETECTIONS COMPARISON

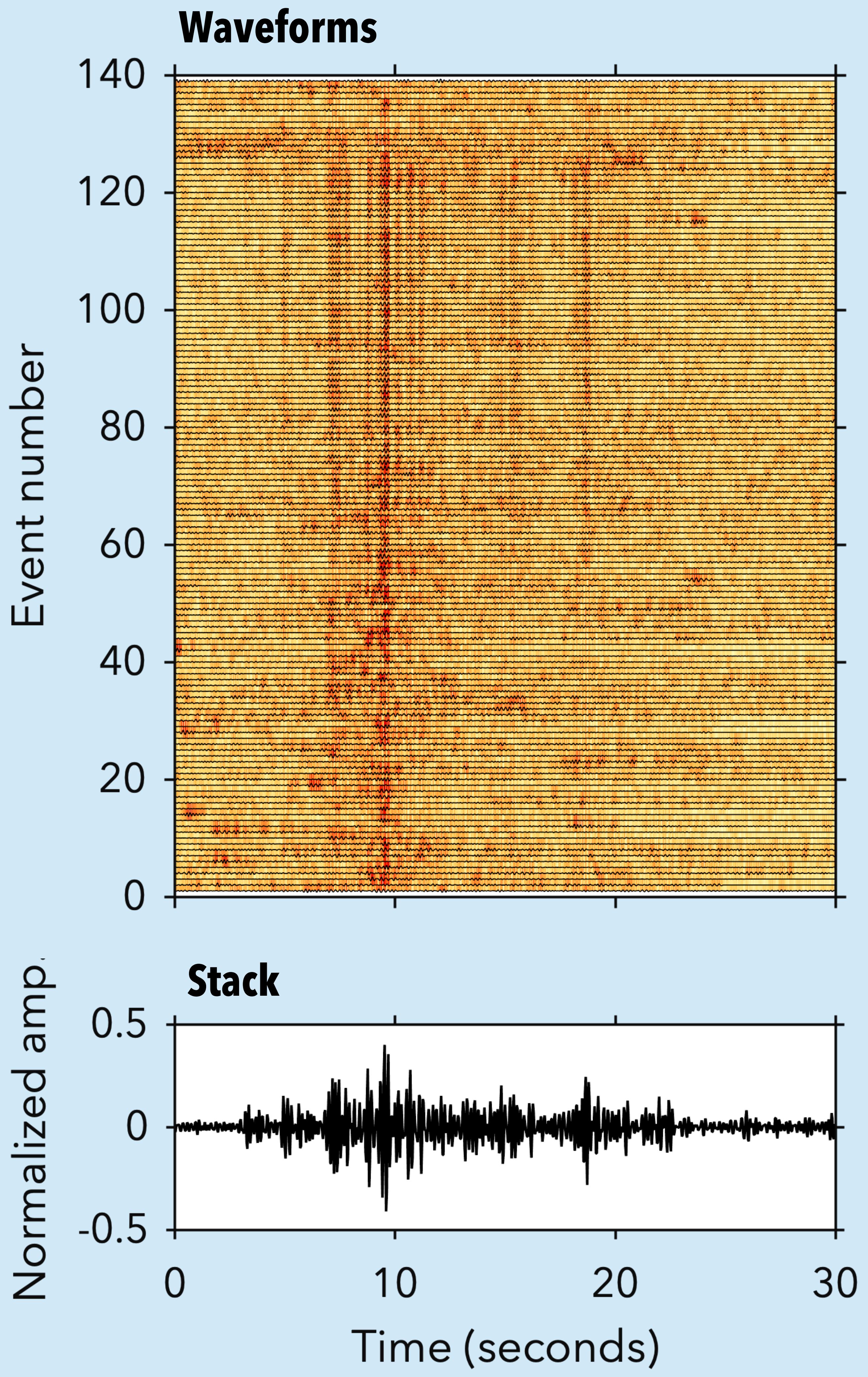
"SUPERVISED"
TEMPLATE MATCHING
DETECTIONS



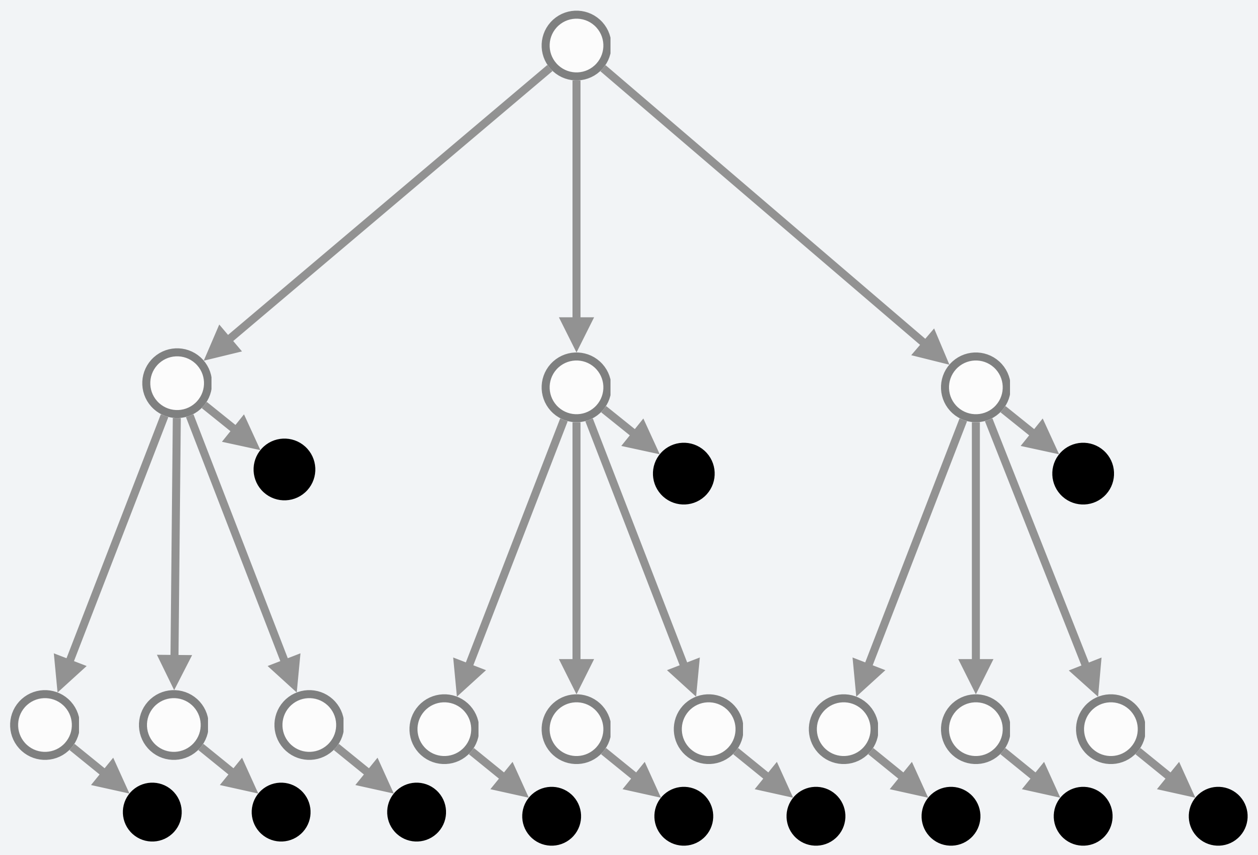
Poli (2017)

WHAT WE NEED:
FREQUENCY BAND
WAVEFORM HISTORY

UNSUPERVISED
SCATTERING TRANSFORM
DETECTIONS



WHAT WE LEARN:
FREQUENCY BAND
WAVEFORM HISTORY

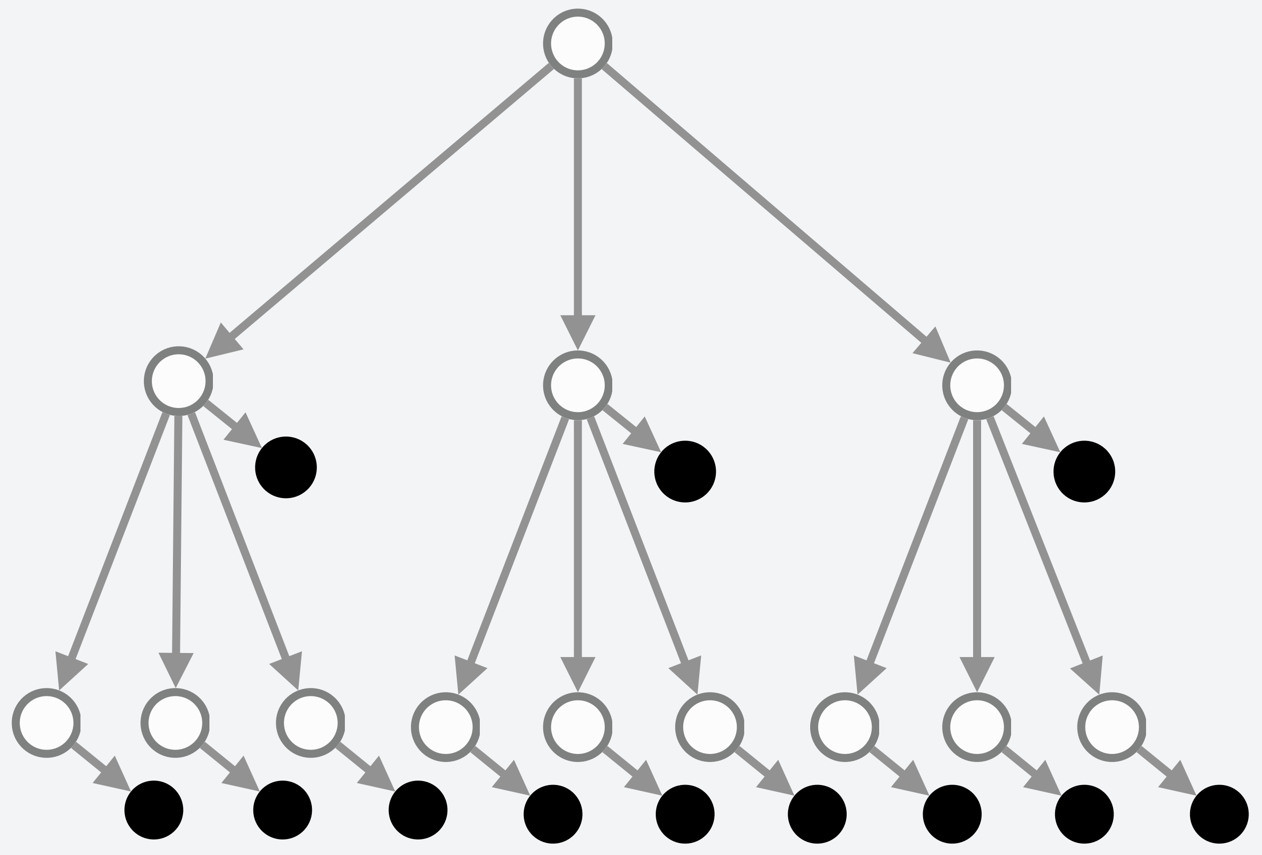


CONCLUSIONS

- **Scattering network**
  - provides stable features of seismic waveforms
  - describes frequency content, envelope duration and shape
  - architecture is straightforward
- **Unsupervised detections and clustering revealed**
  - Background noise cluster
  - Long-duration seismicity including previous template matching detections
  - Short-duration local seismicity

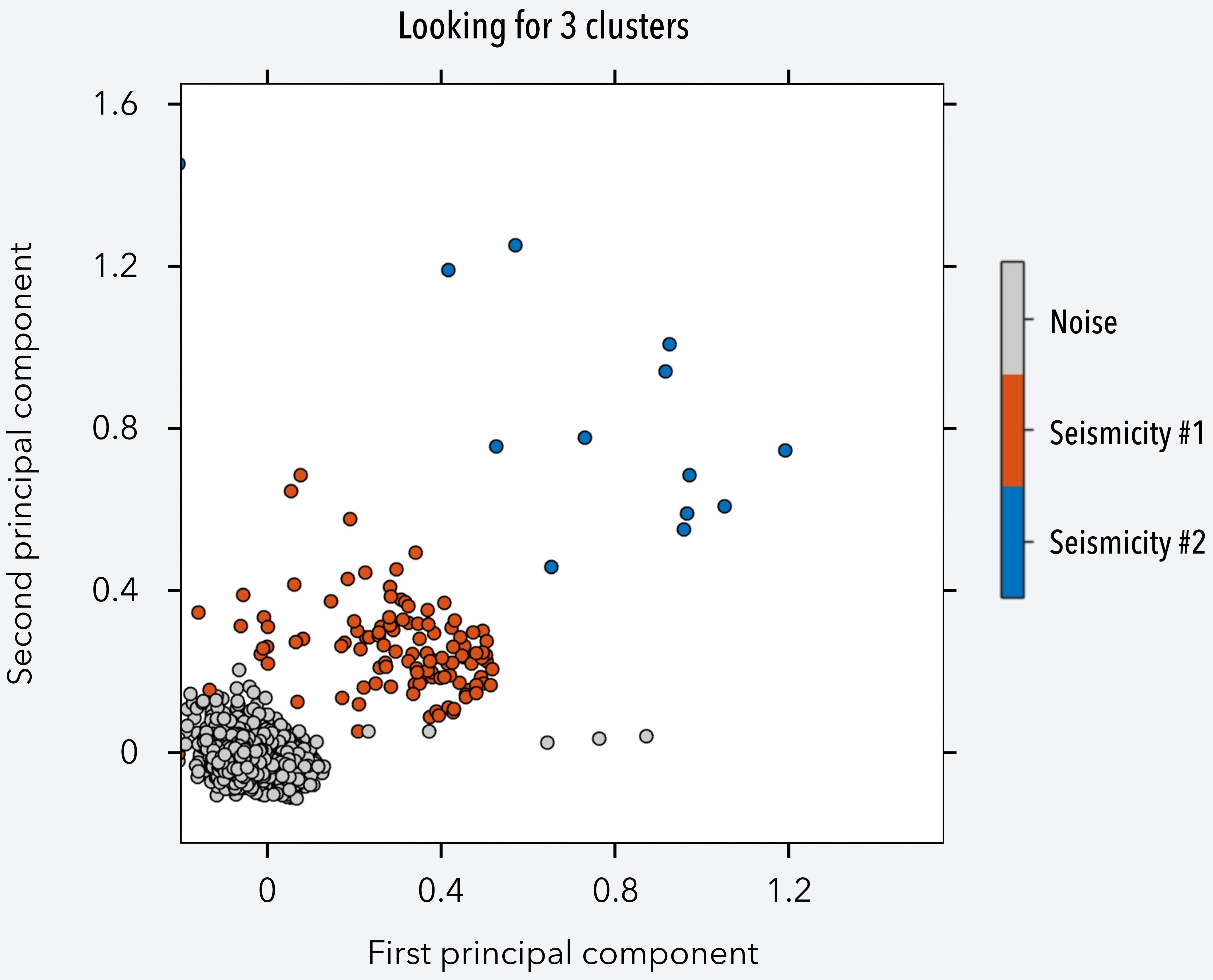
PERSPECTIVES & ONGOING WORK

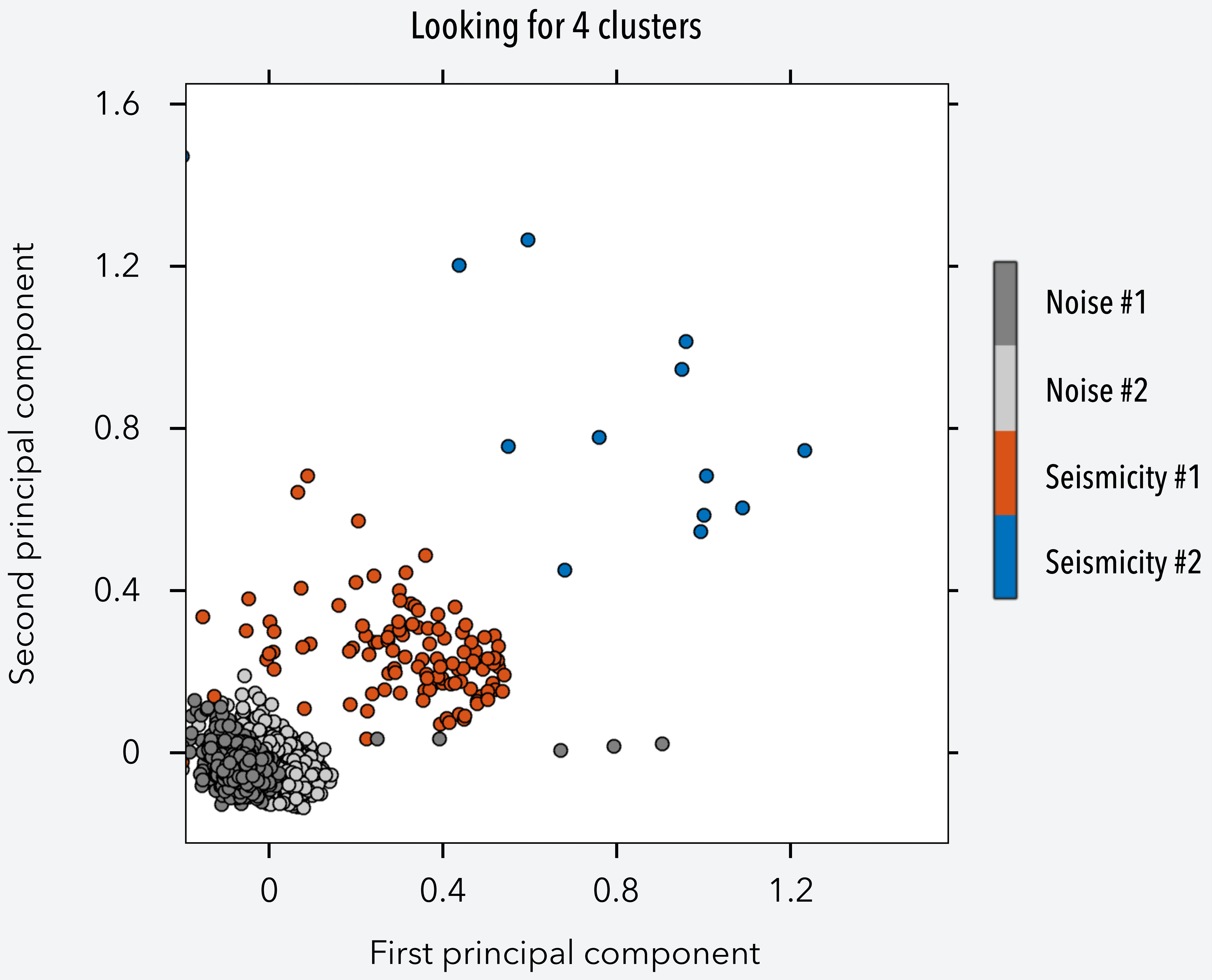
- **Move to array scattering transform (belief propagation)**
- **Application to other kind of seismic activity (e.g. tremors, LFE, ...)**



THANK YOU!

PRINCIPAL COMPONENT VIEW OF THE CLUSTERS





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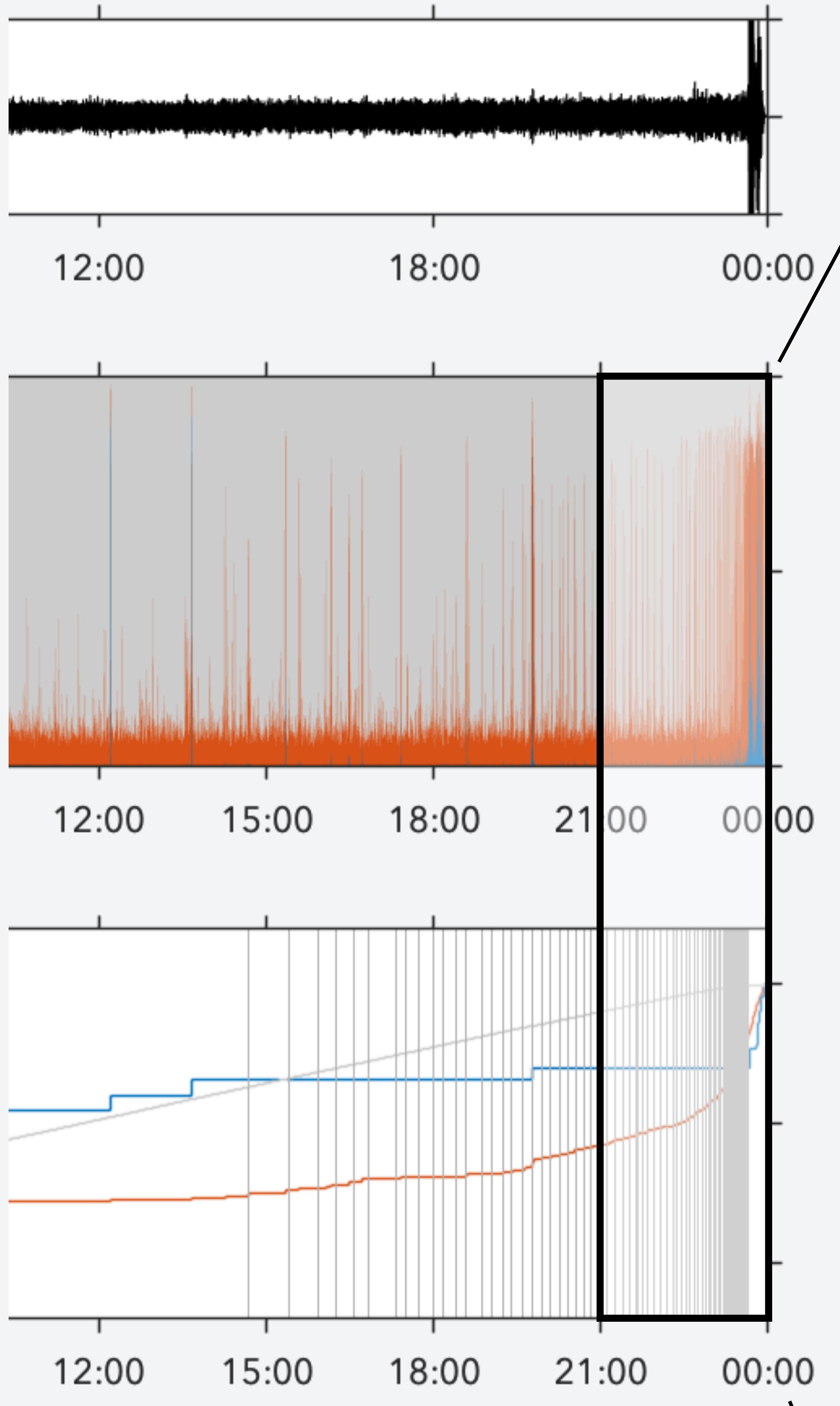
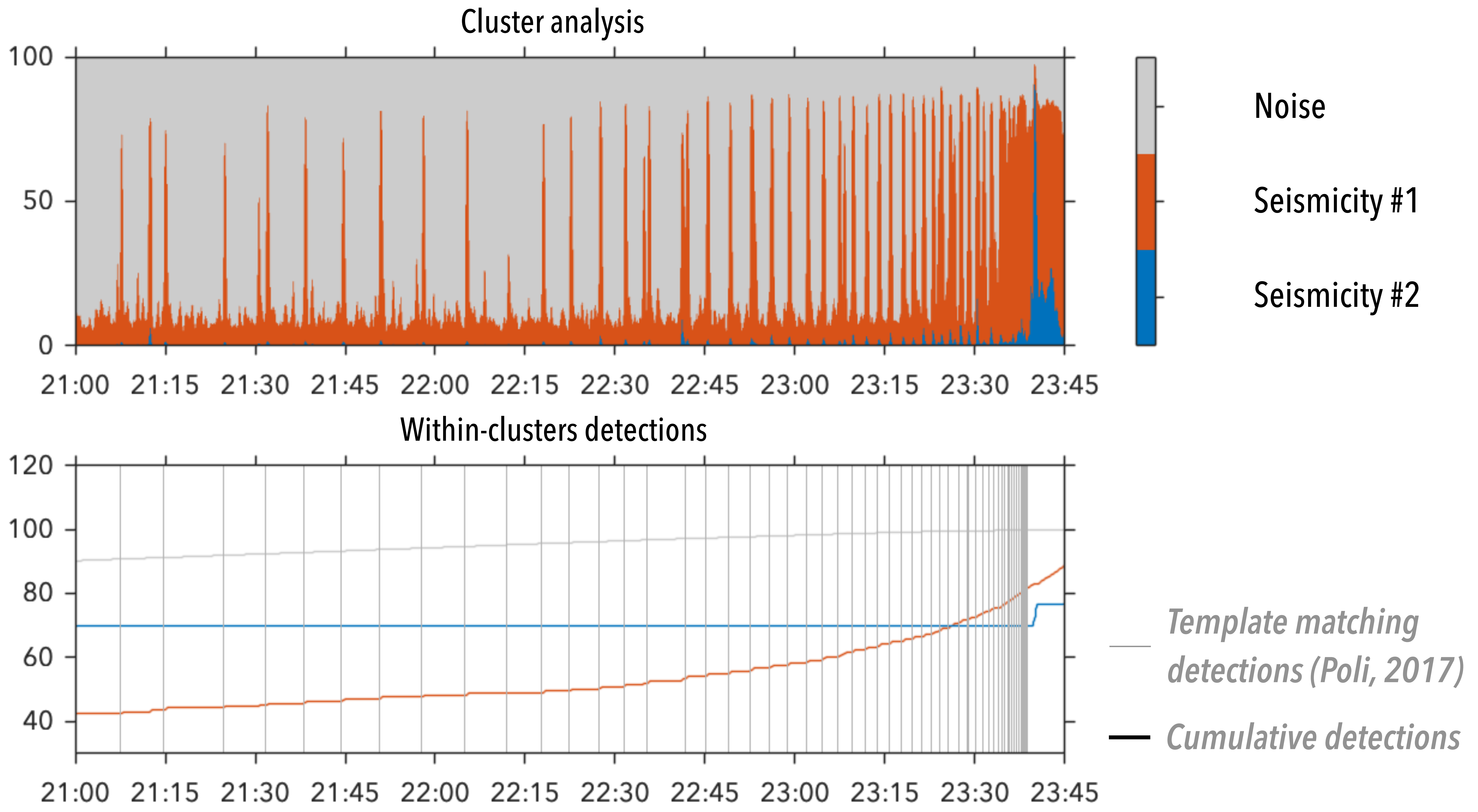
CLUSTER ANALYSIS OVER THE FULL DAY

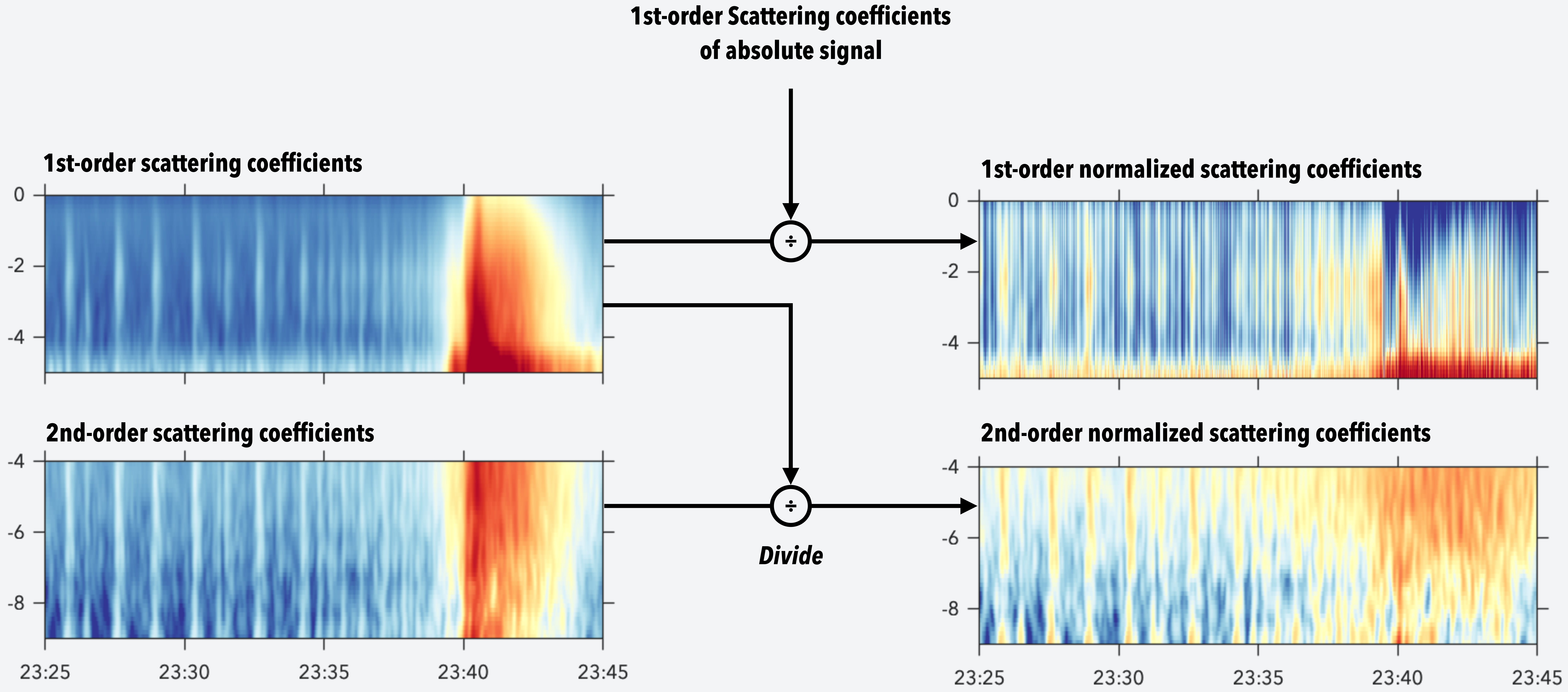




TEMPLATE MATCHING DETECTION 88%
INCLUDED INTO THE RED CLUSTER

X

"PARENT" NORMALIZATION OF THE SCATTERING COEFFICIENTS



HIGH-AMPLITUDE SIGNAL DOMINATES → **SIGNALS DESCRIBED WITHOUT AMPLITUDE**

X

Siffre et al. (2014)