GPU-accelerated Automatic Microseismic Monitoring Algorithm (GAMMA) & its Application to the 2019 Ridgecrest Earthquake Sequence

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Overview

NCKU ES

- Why?
- How?
- What?

WHY?

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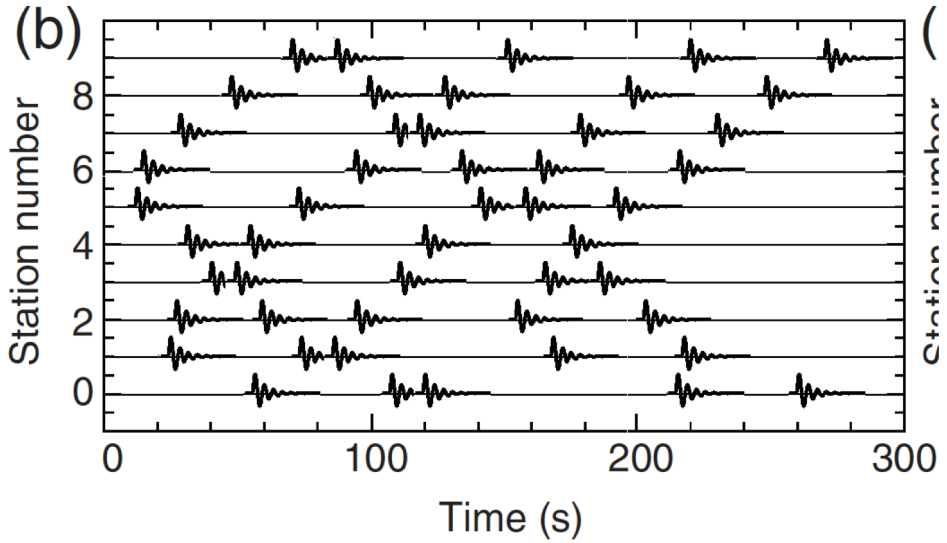
- 地震監測?
- 自動化
  - Earthquake detection
  - Earthquake location
- 小地震
  - Template matching (waveform-based method)
  - Foreshocks, aftershocks, tremors, ….
- 近即時地震監測
  - GPU



HOW?

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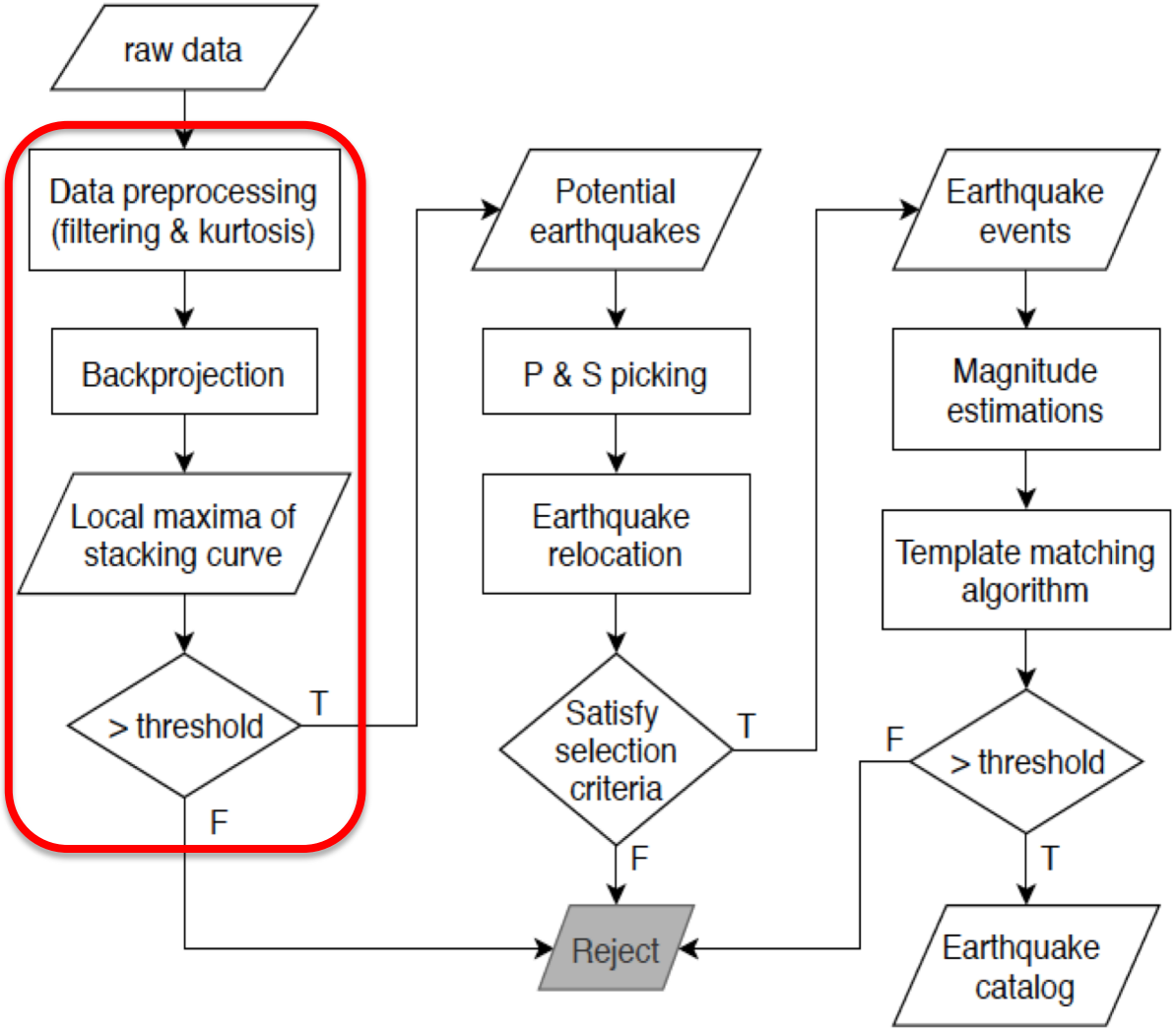
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Backprojection
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> threshold
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P & S picking
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Reject
Earthquake catalog

Backprojection

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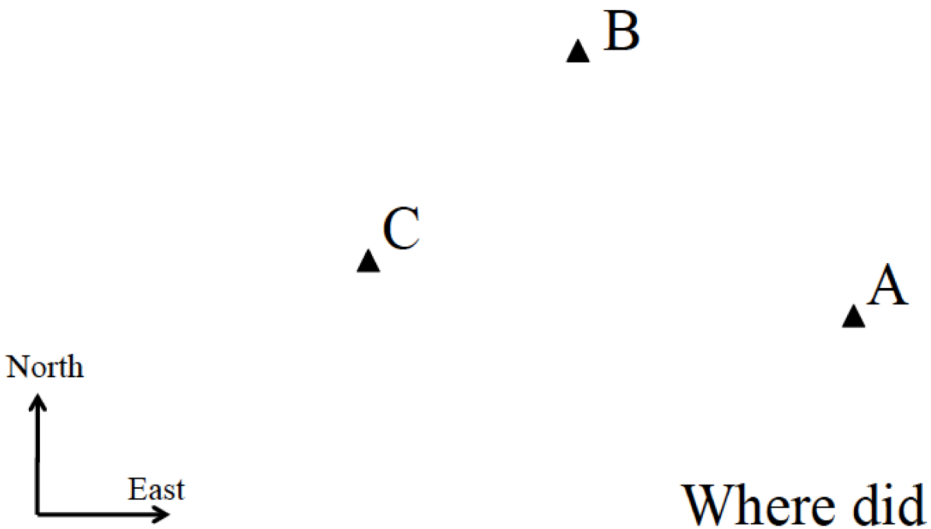
Earthquake!

Seismic waves recorded at three stations:



Where did it happen?

From Peter M Shearer
http://igppweb.ucsd.edu/~shearer/SCECERI/

Backprojection

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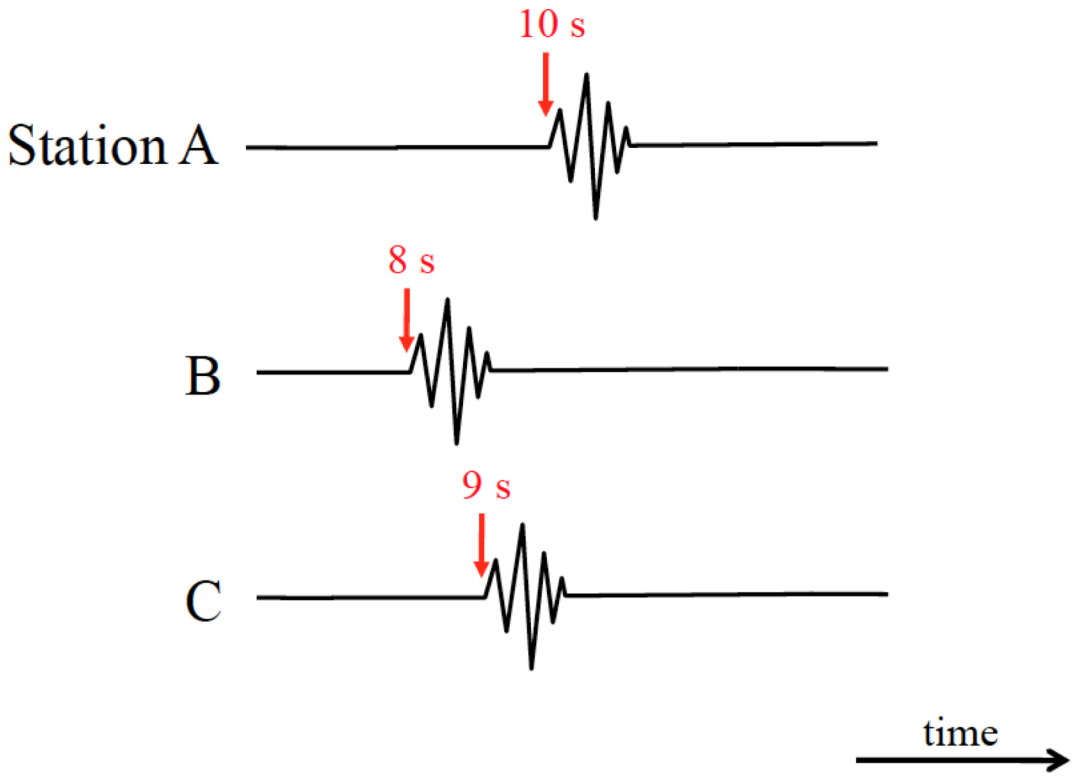
Measure seismic wave arrival times



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Backprojection

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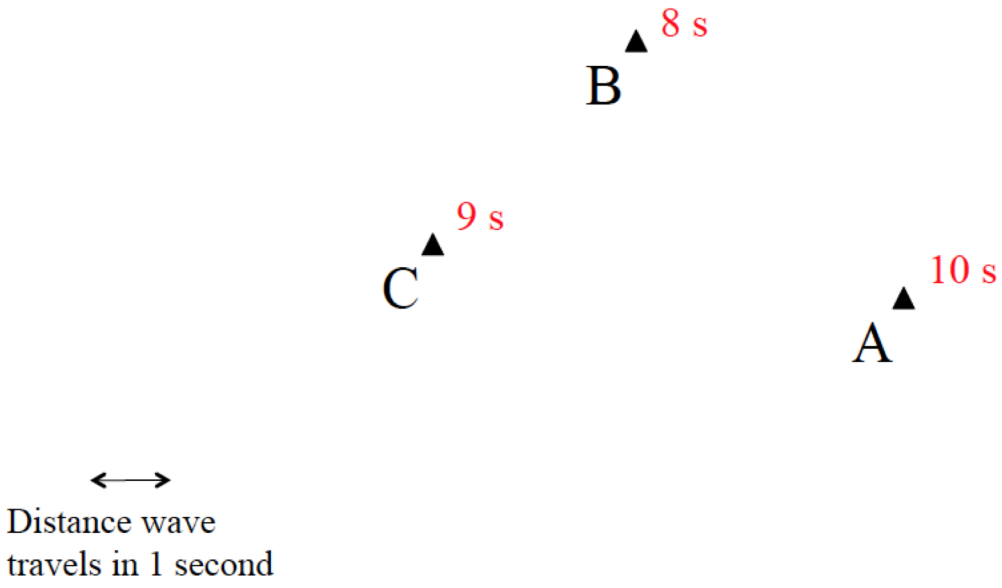
P-wave arrival times



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Backprojection

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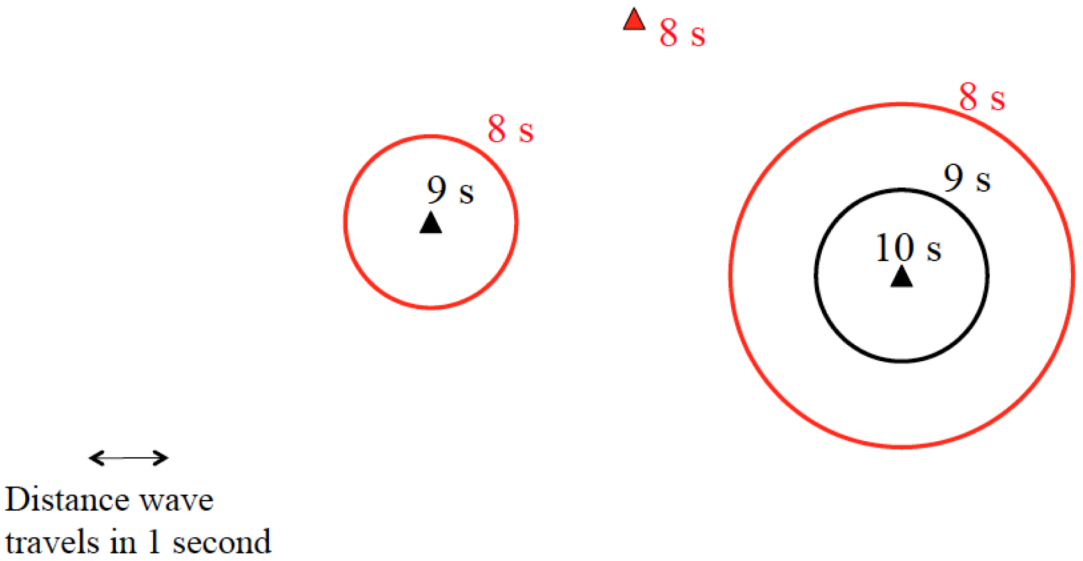
Possible event locations at 8 s (red circles)



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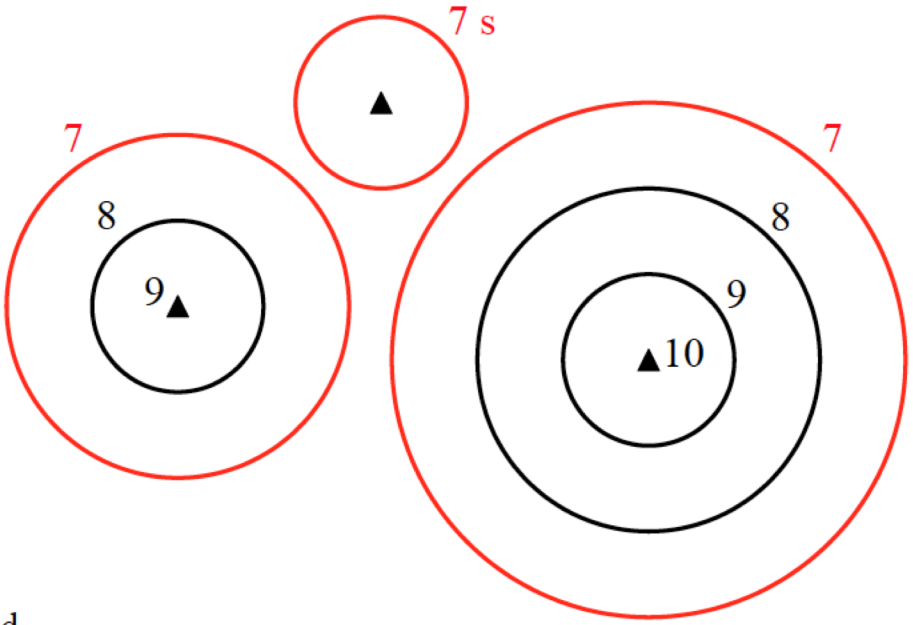
Backprojection

NCKU ES

Possible event locations at 7 s (red circles)



Distance wave
travels in 1 second

From Peter M Shearer
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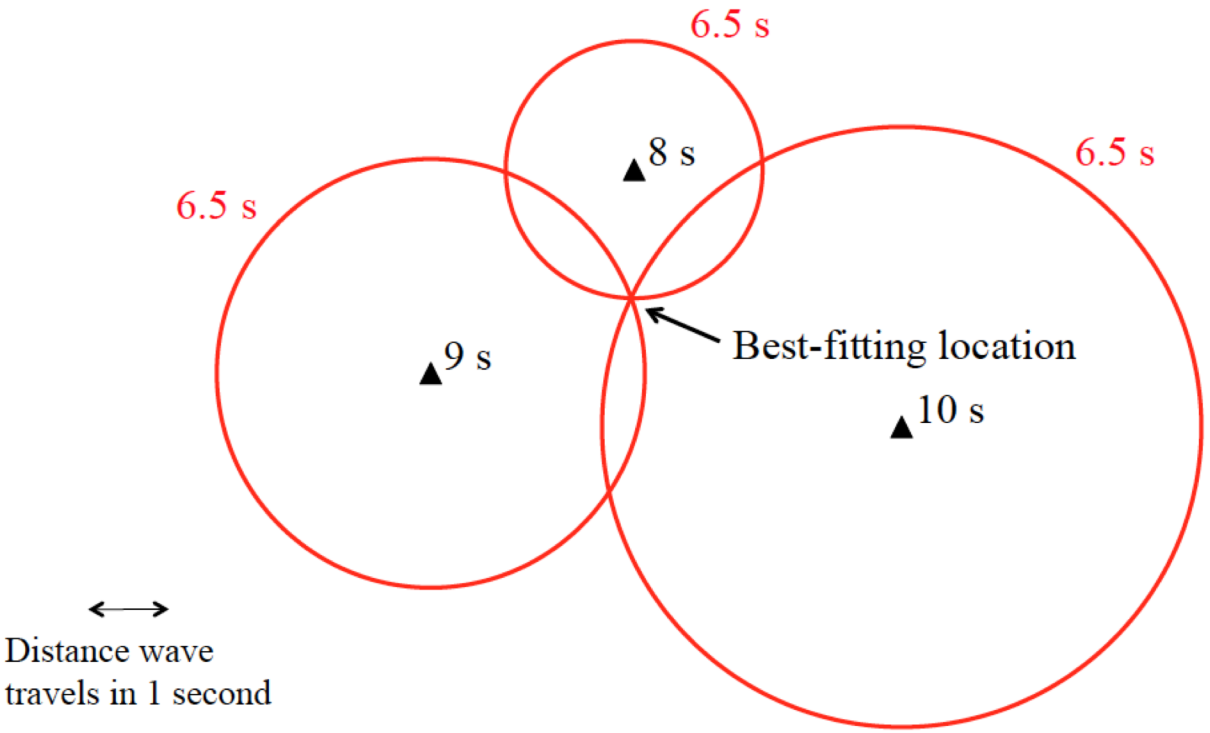
Backprojection

NCKU ES

Possible event locations at 6.5 s (red circles)



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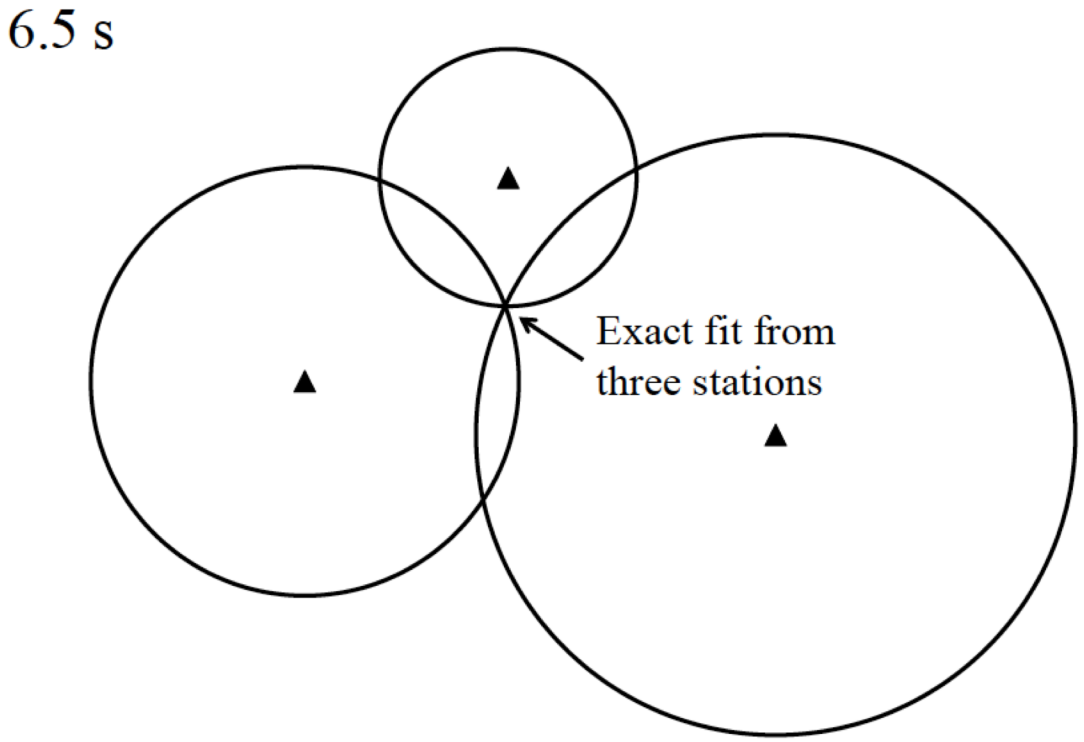
NCKU ES



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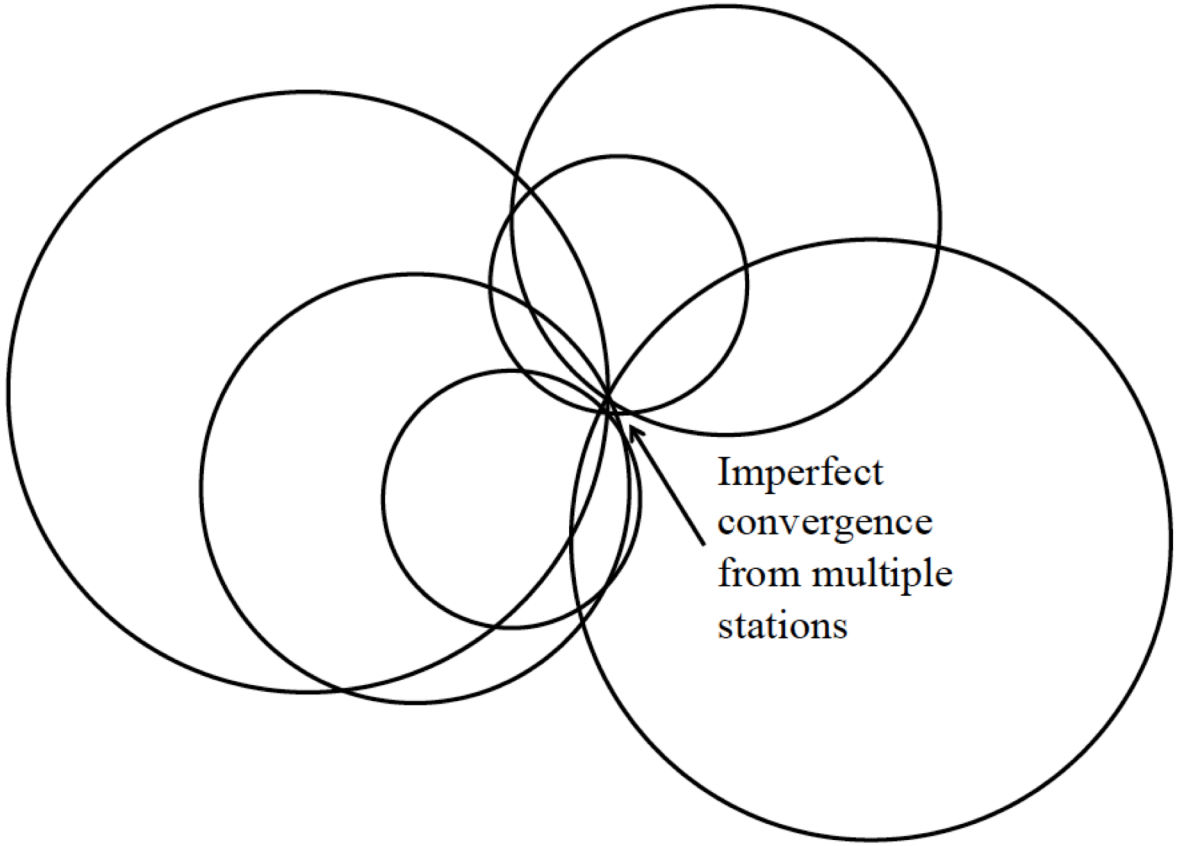

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Data Processing

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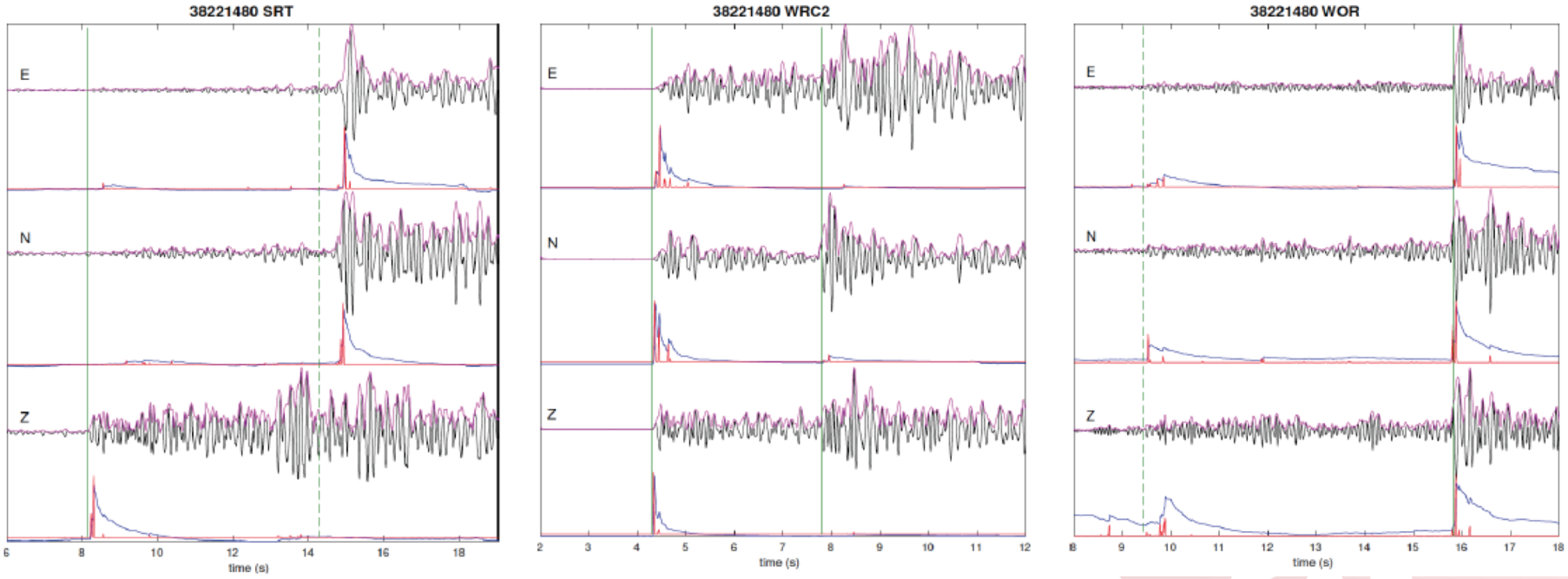

Black: data waveform

Purple: waveform envelope

Green: P & S arrivals

Blue : kurtosis

Red : positive time derivatives of kurtosis functions

Backprojection results

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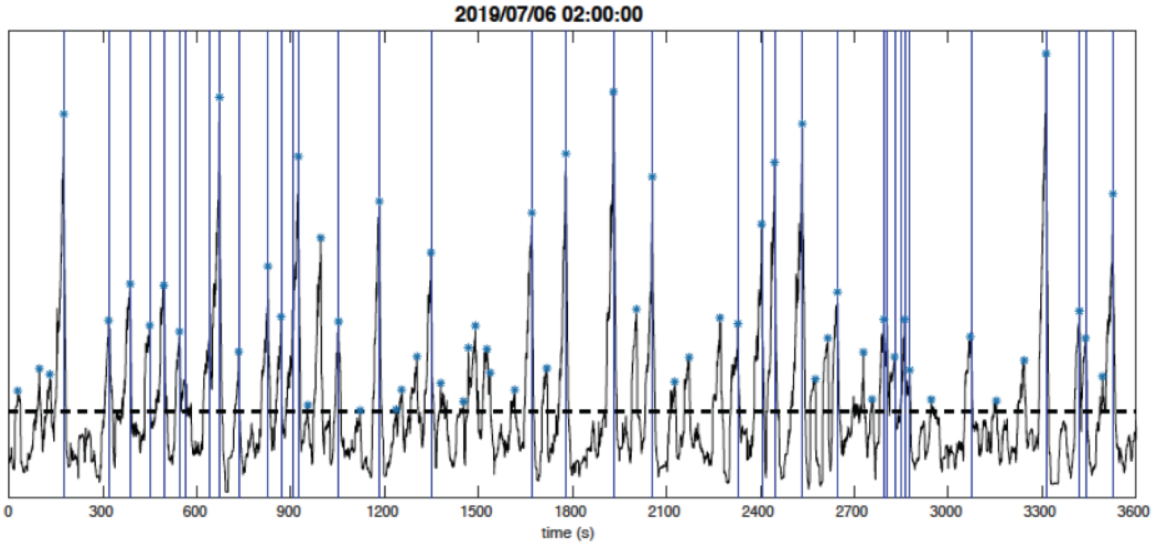
black solid lines : stacked kurtosis functions

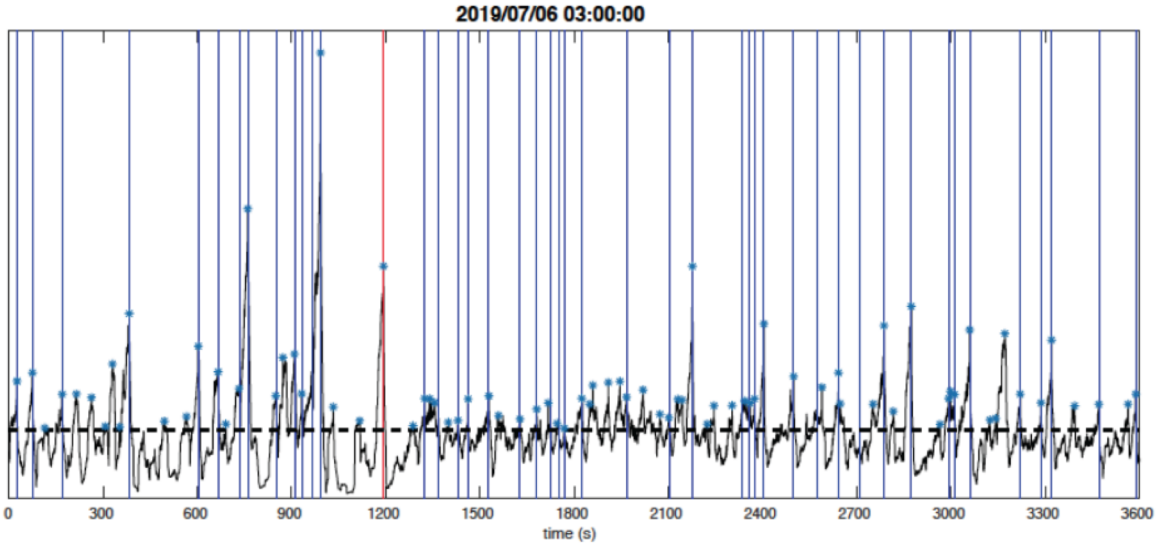
blue stars: OT of potential events

Blue vertical lines: OT of the events in SCEC catalog

Red vertical line: OT of the mainshock

black dash line: the selection threshold





HOW?

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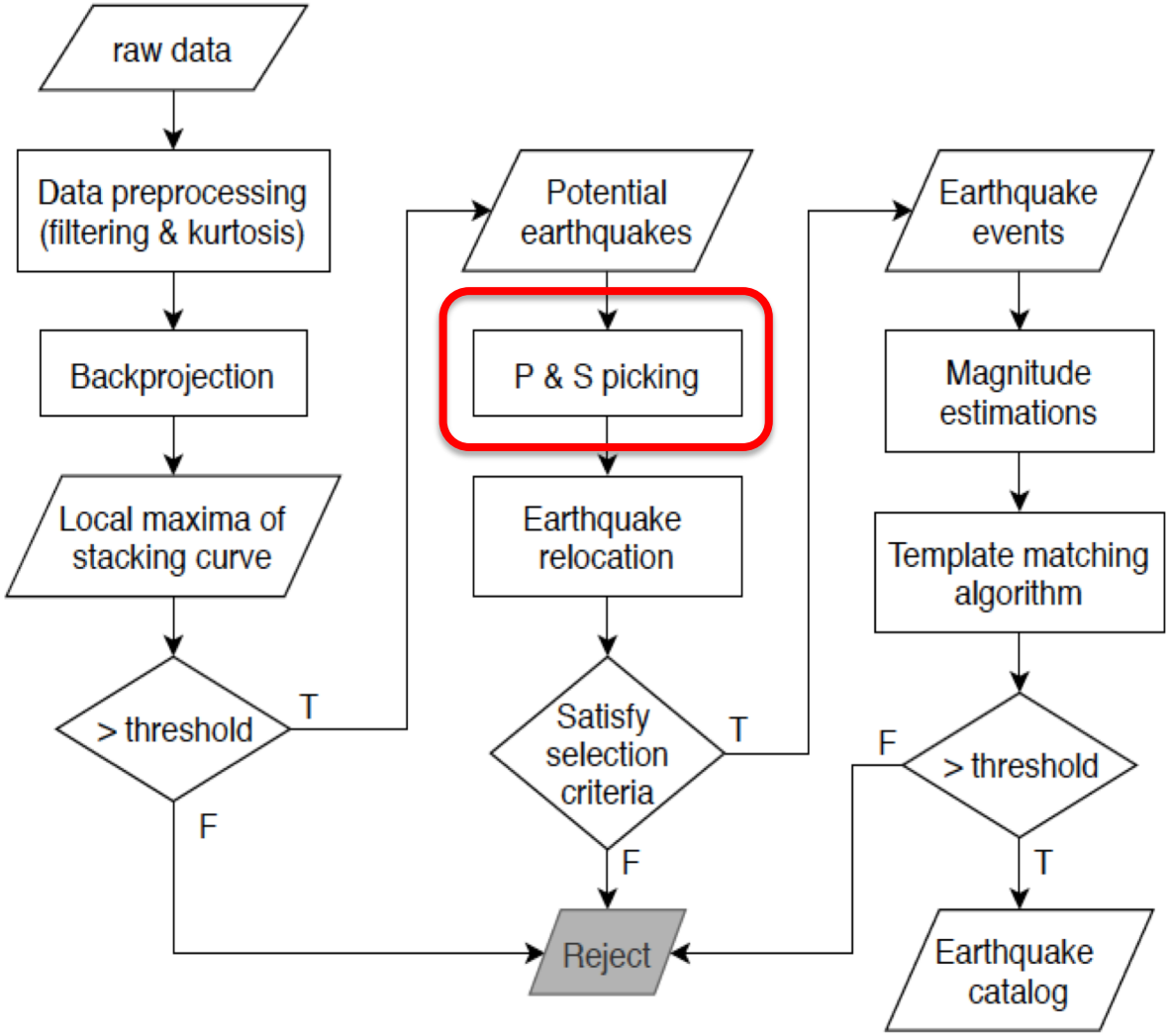
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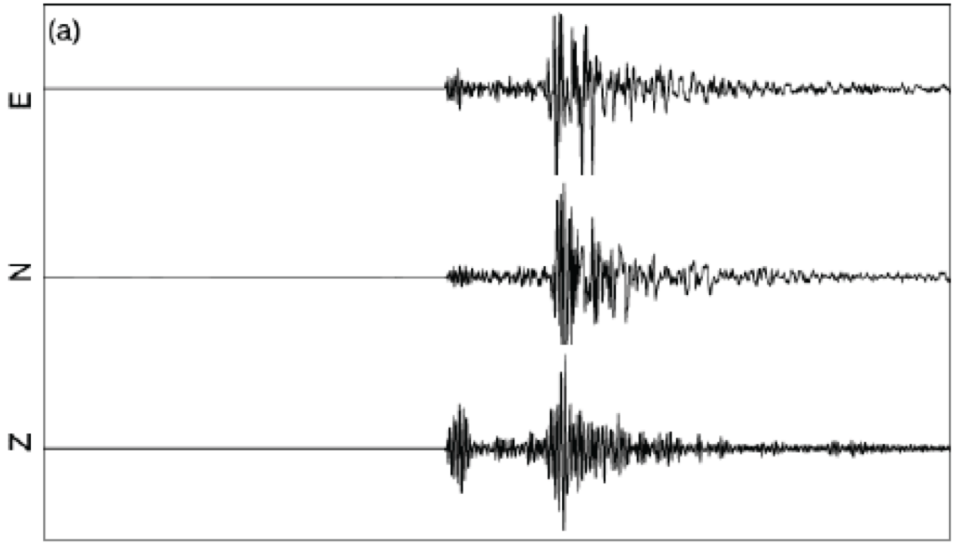
P & S picking

NCKU ES

- Why deep learning ?
- Seismic phases
  - P & S waves
- Attention mechanisms



Attention U-net

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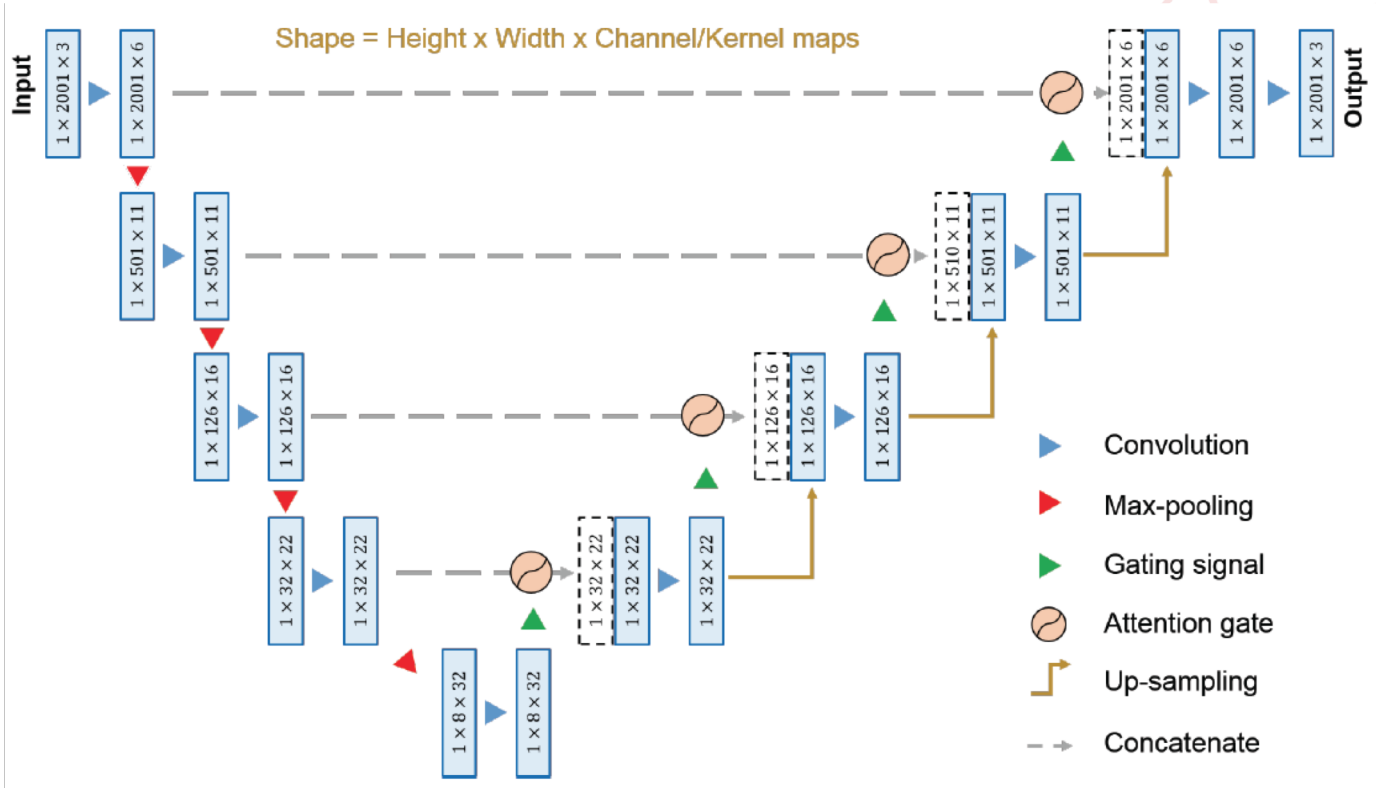
- Attention U-net
  - U-Net導入注意力機制(attention mechanism)
  - 訓練過程中專注P及S波，降低誤判



Attention U-net

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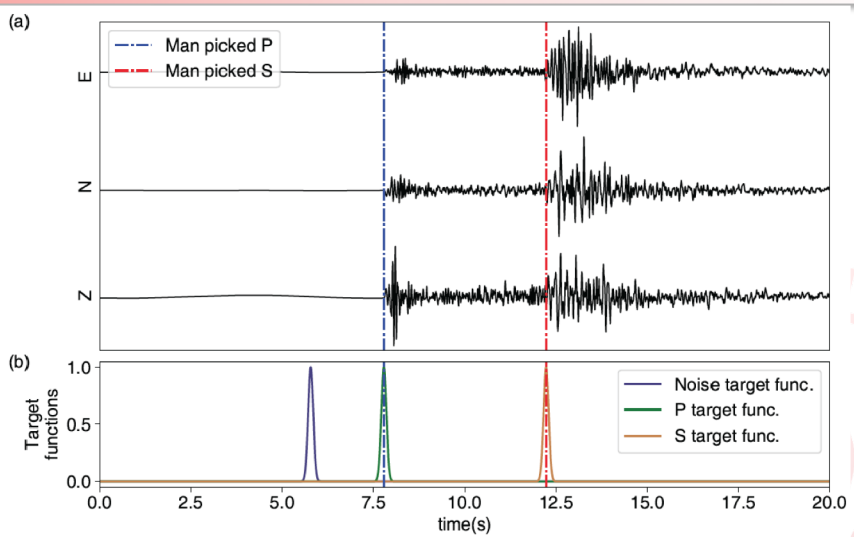
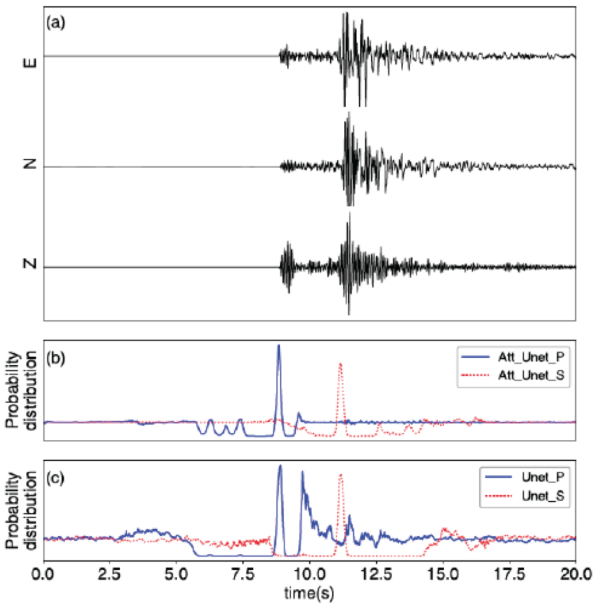
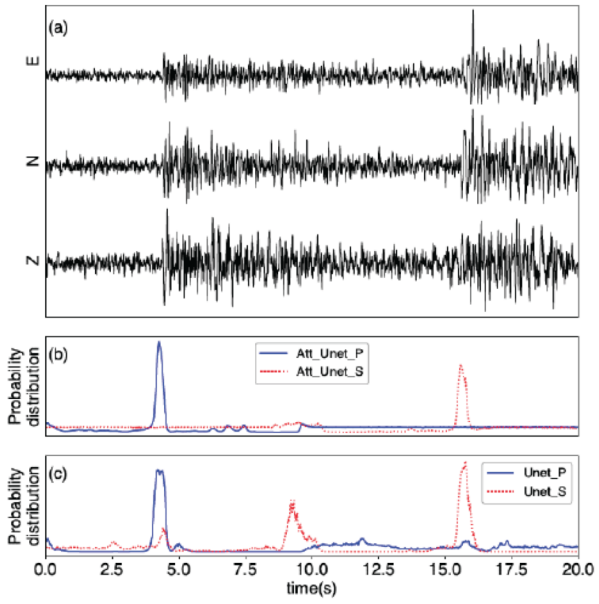
- Examples of training data and the “target functions”
- Probability predictions made using our attention U-Net and the standard U-Net







HOW?

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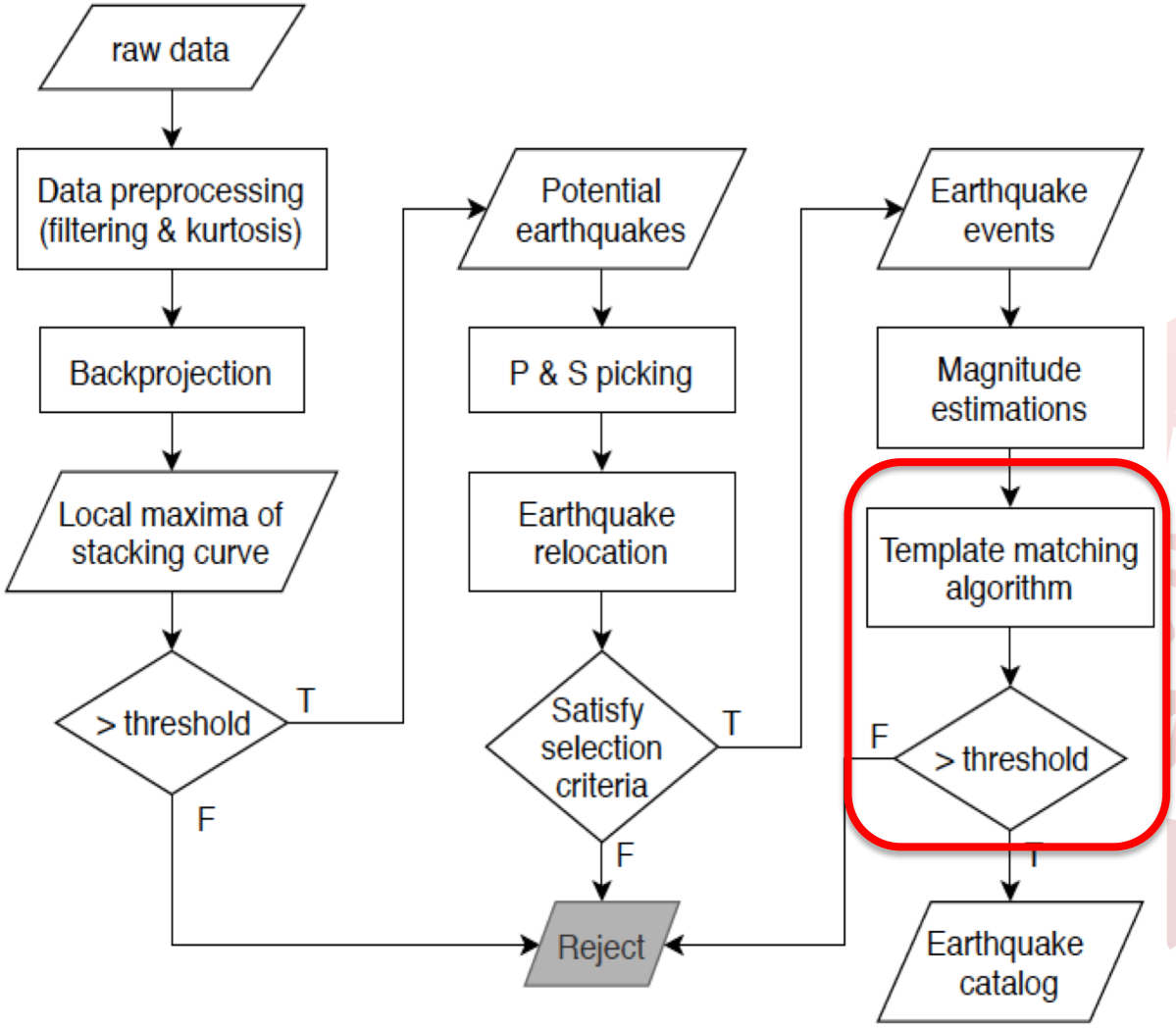
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Reject

Template matching

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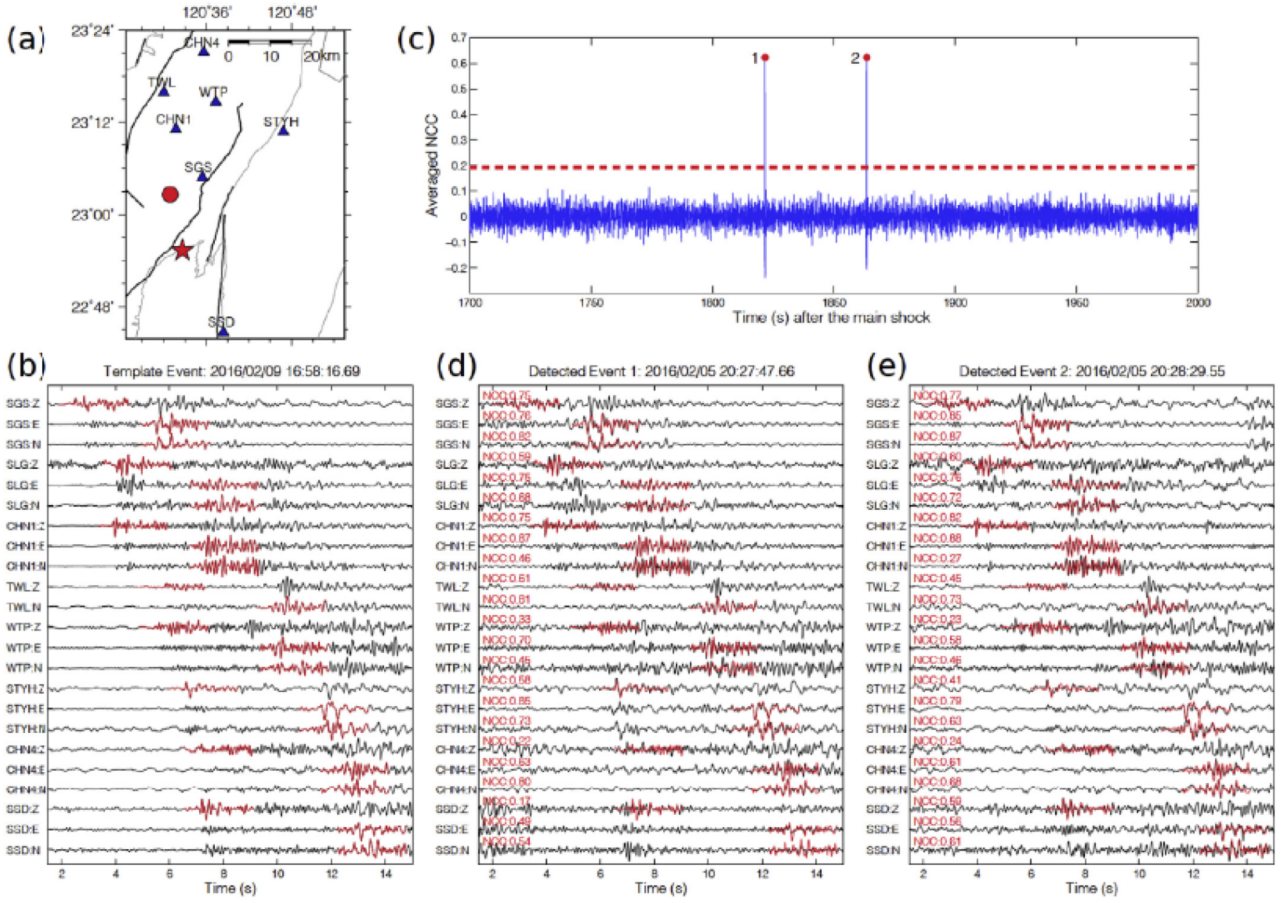
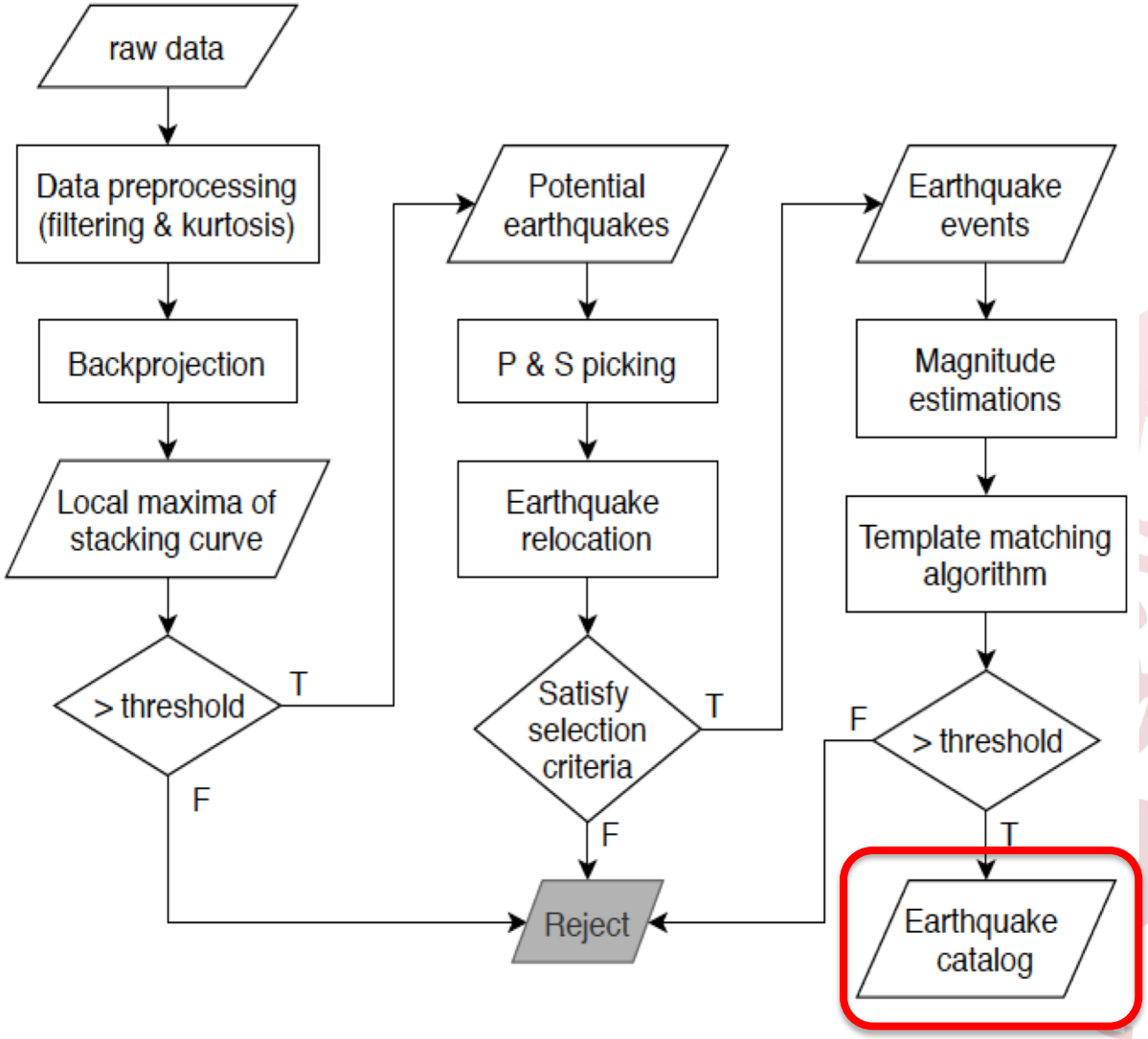
- 利用已知地震的波形，在連續紀錄搜尋微震
- 不需人工判別P波、S波到時
- 可搜尋更小規模地震
- 常用於微震活動分析



HOW?

NCKU ES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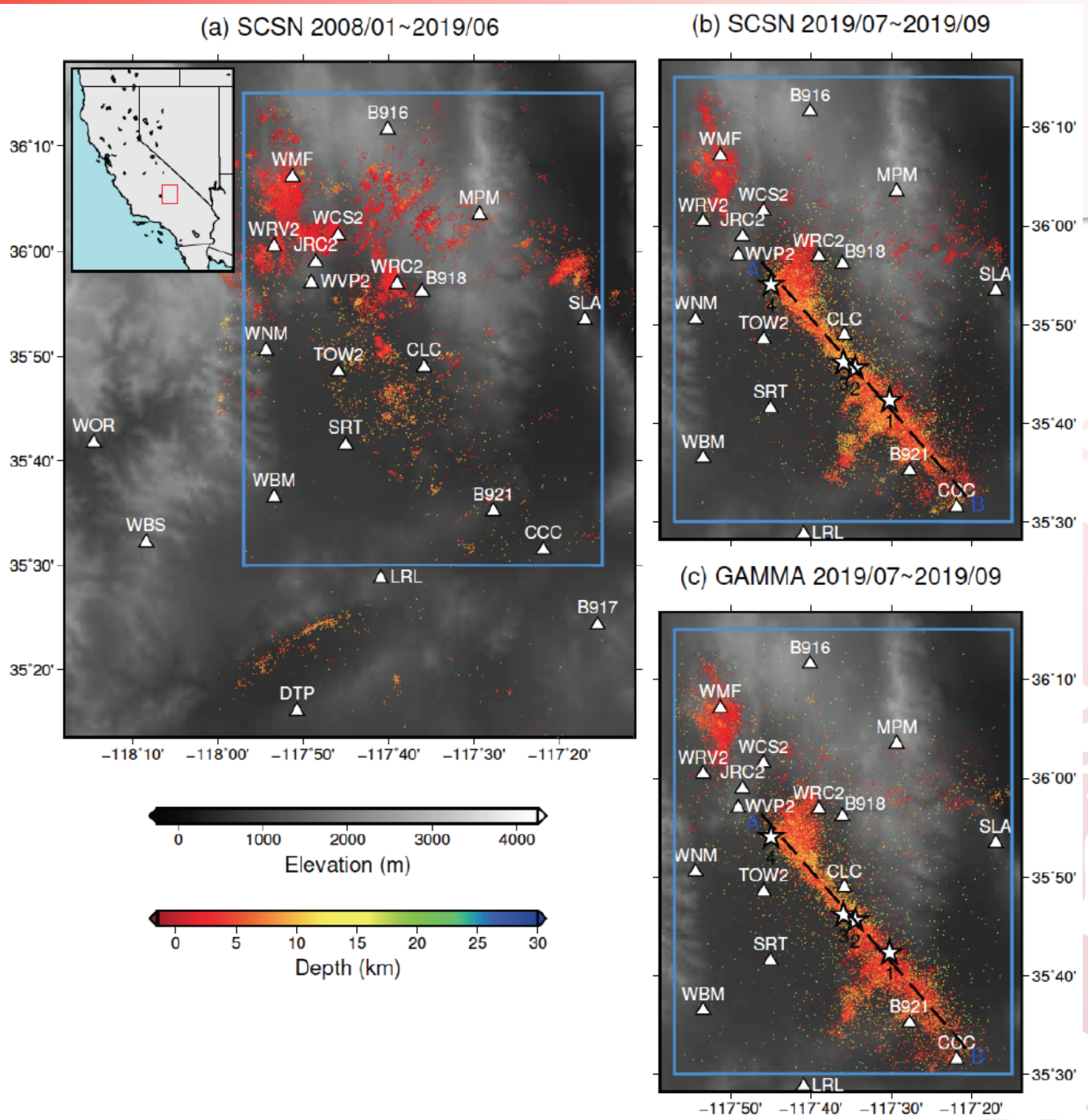
(a) SCSN 2008/01~2019/06
(b) SCSN 2019/07~2019/09
(c) GAMMA 2019/07~2019/09
B916
WMF
MPM
WCS2
WRV2
JRC2
WRC2
B918
WVP2
SLA
WNM
TOW2
CLC
SRT
WOR
WBM
B921
CCC
WBS
LRL
B917
DTP
36°10'
36°00'
35°50'
35°40'
35°30'
35°20'
−118°10'
−118°00'
−117°50'
−117°40'
−117°30'
−117°20'
0
1000
2000
3000
4000
Elevation (m)
0
5
10
15
20
25
30
Depth (km)

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What?

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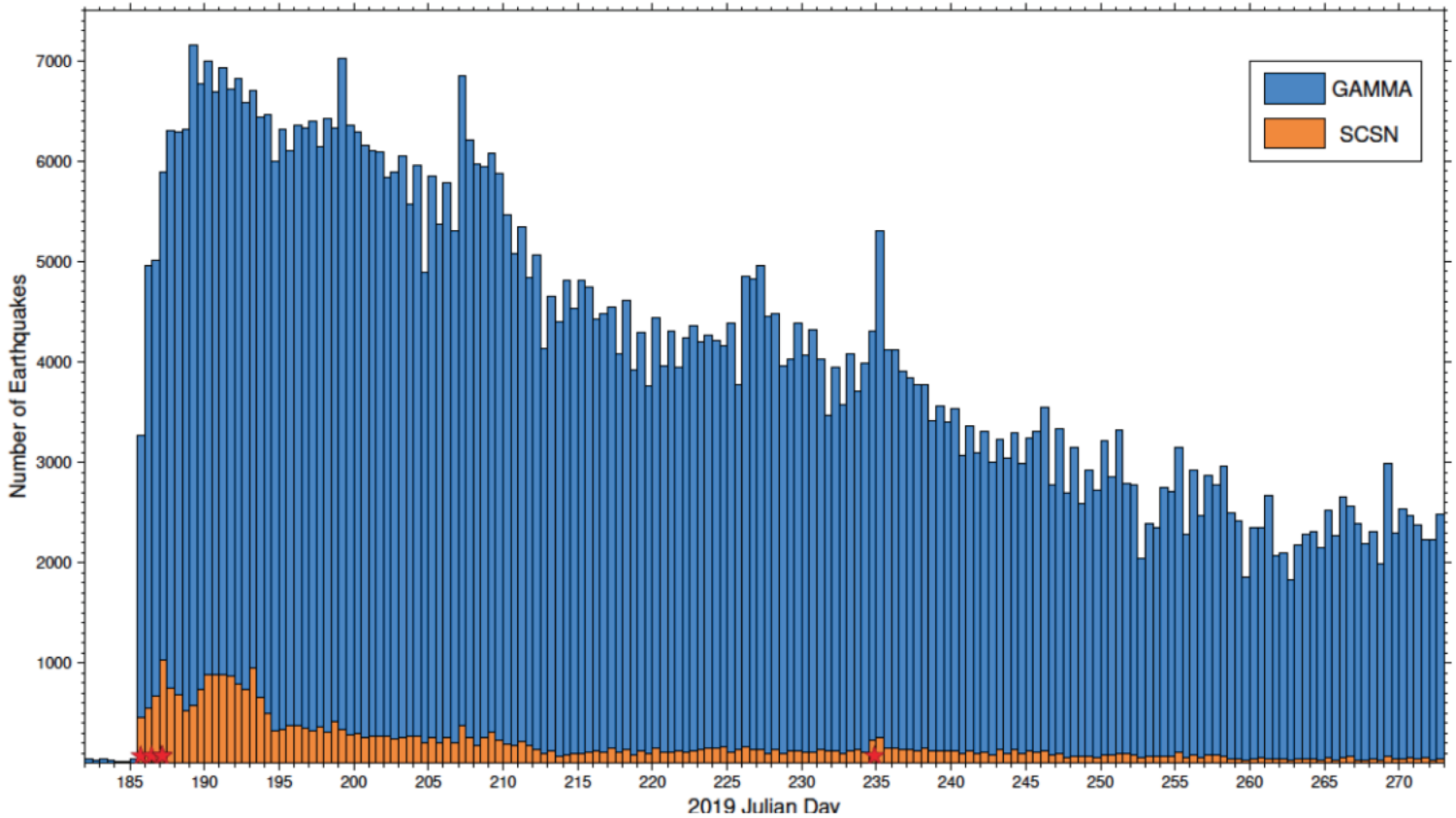
- The number of earthquakes detected by GAMMA is more than 20 times of that in SCSN catalog



What?

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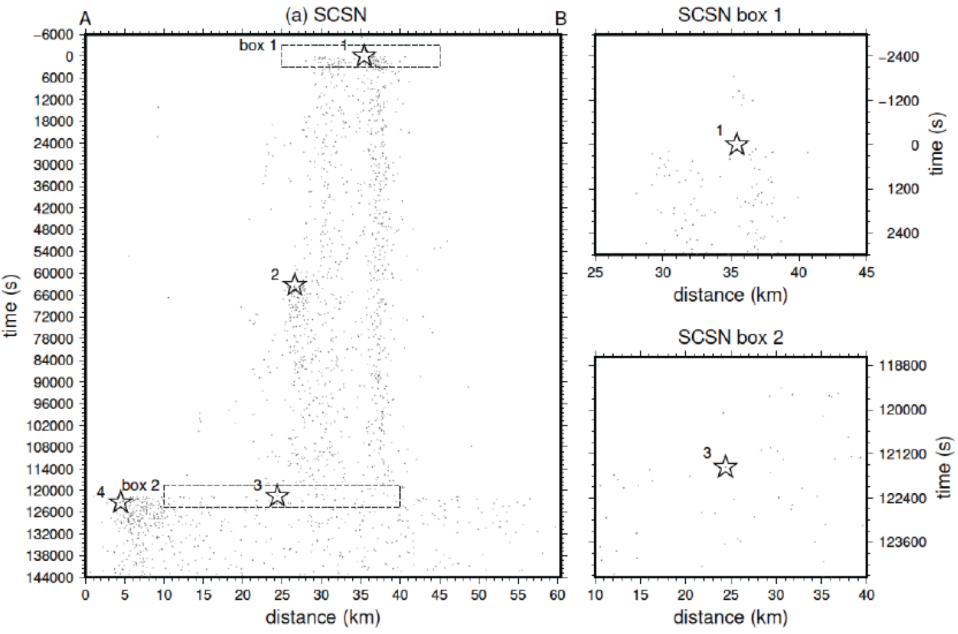
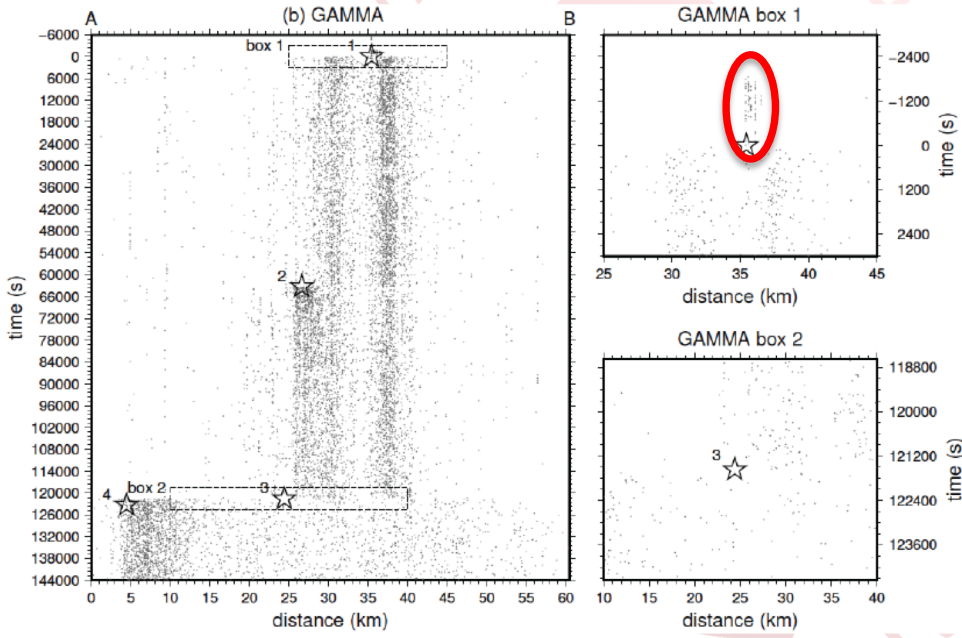
- More complete catalog
- More foreshocks before the Mw6.4 event





Summary

NCKU ES

- Automatic earthquake monitoring
- GPU for near real-time
  - Backprojection: hourly data takes 2.5 minutes
  - TMA: daily data takes 2~3 hours (>32,000 events)
- Provide a more complete catalog
  - Foreshocks & aftershocks analysis
- Physical mechanisms of faulting
  - processes of faulting, nucleation of earthquakes, earthquake triggering mechanisms, postseismic deformation, ….


Thank you!!