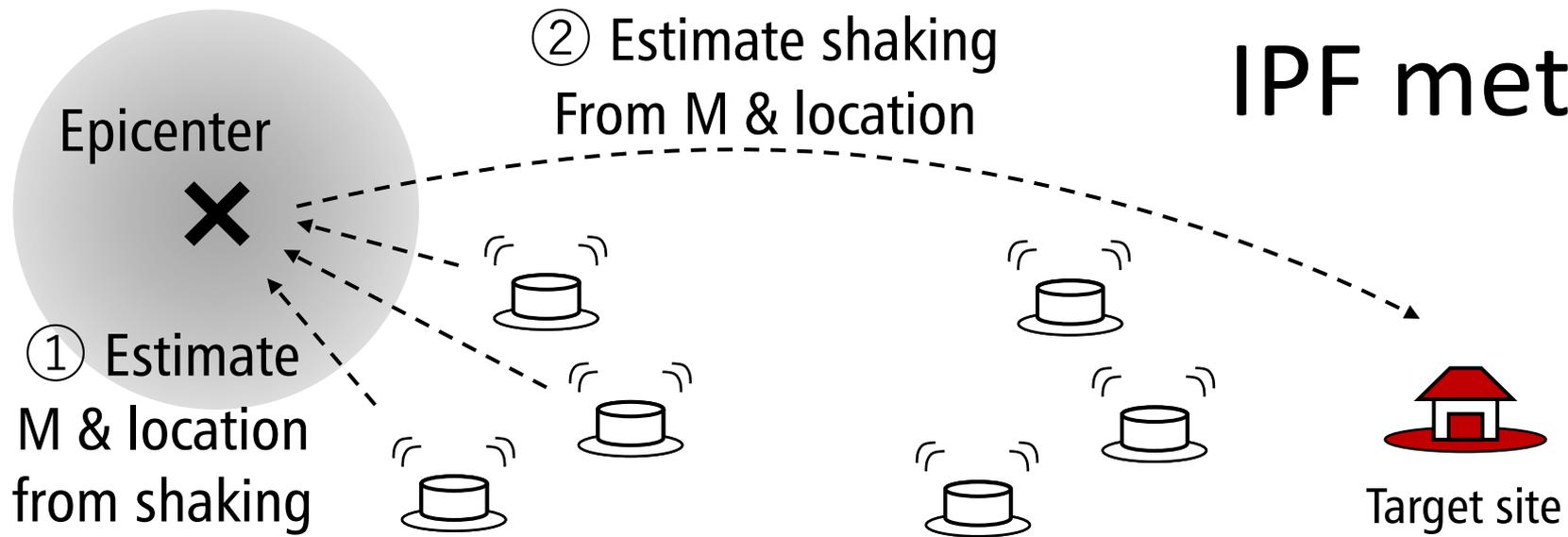


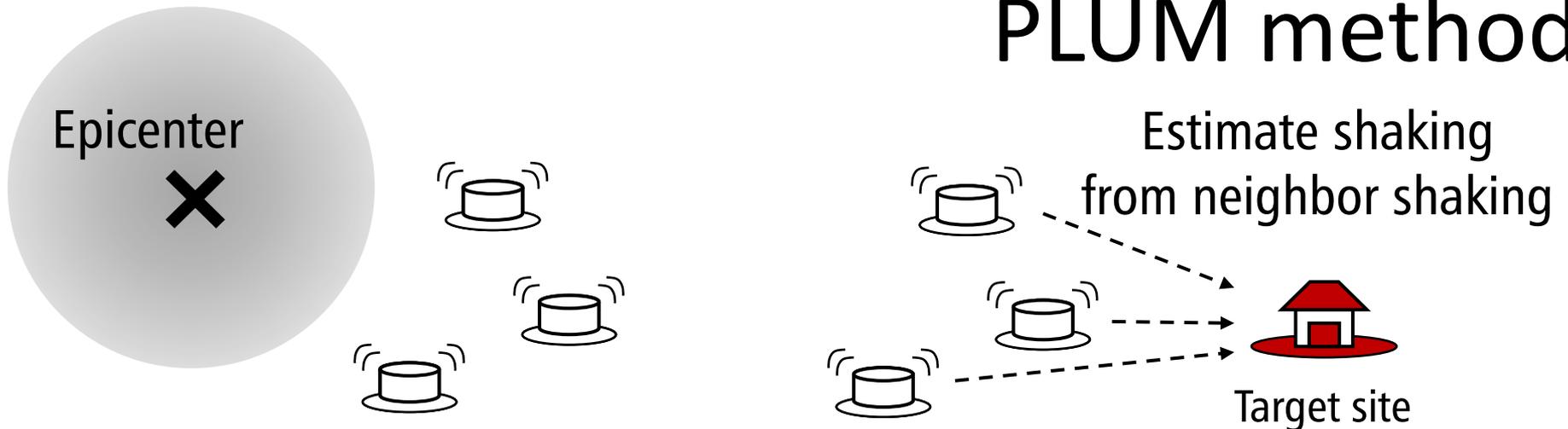
Japanese earthquake early warning system and application to the Taiwanese network

京都大学防災研究所 山田 真澄
台湾中央気象局 陳 達毅

IPF method



PLUM method



IPF method

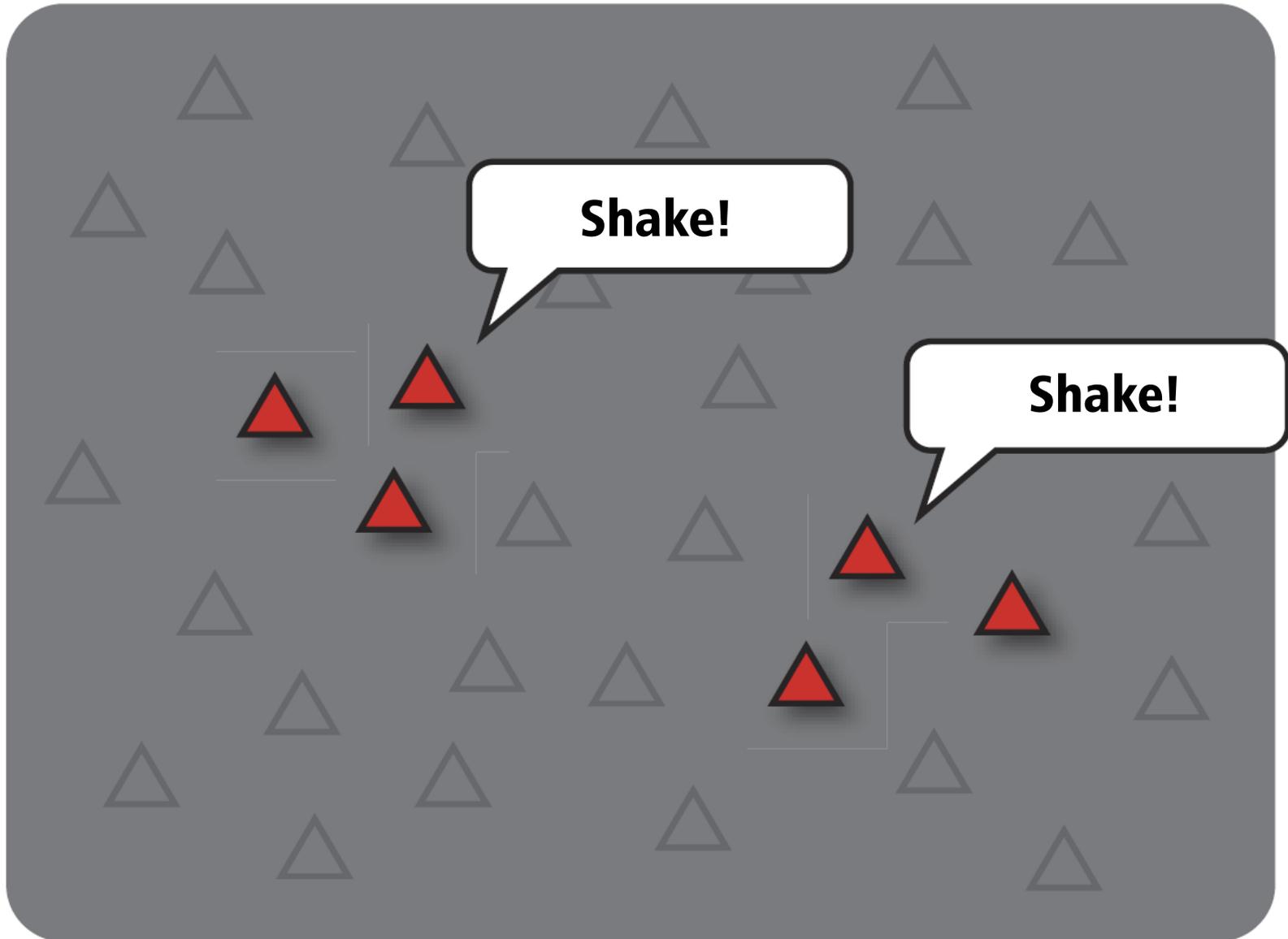
(Integrated Particle Filter)

- Source determination approach -

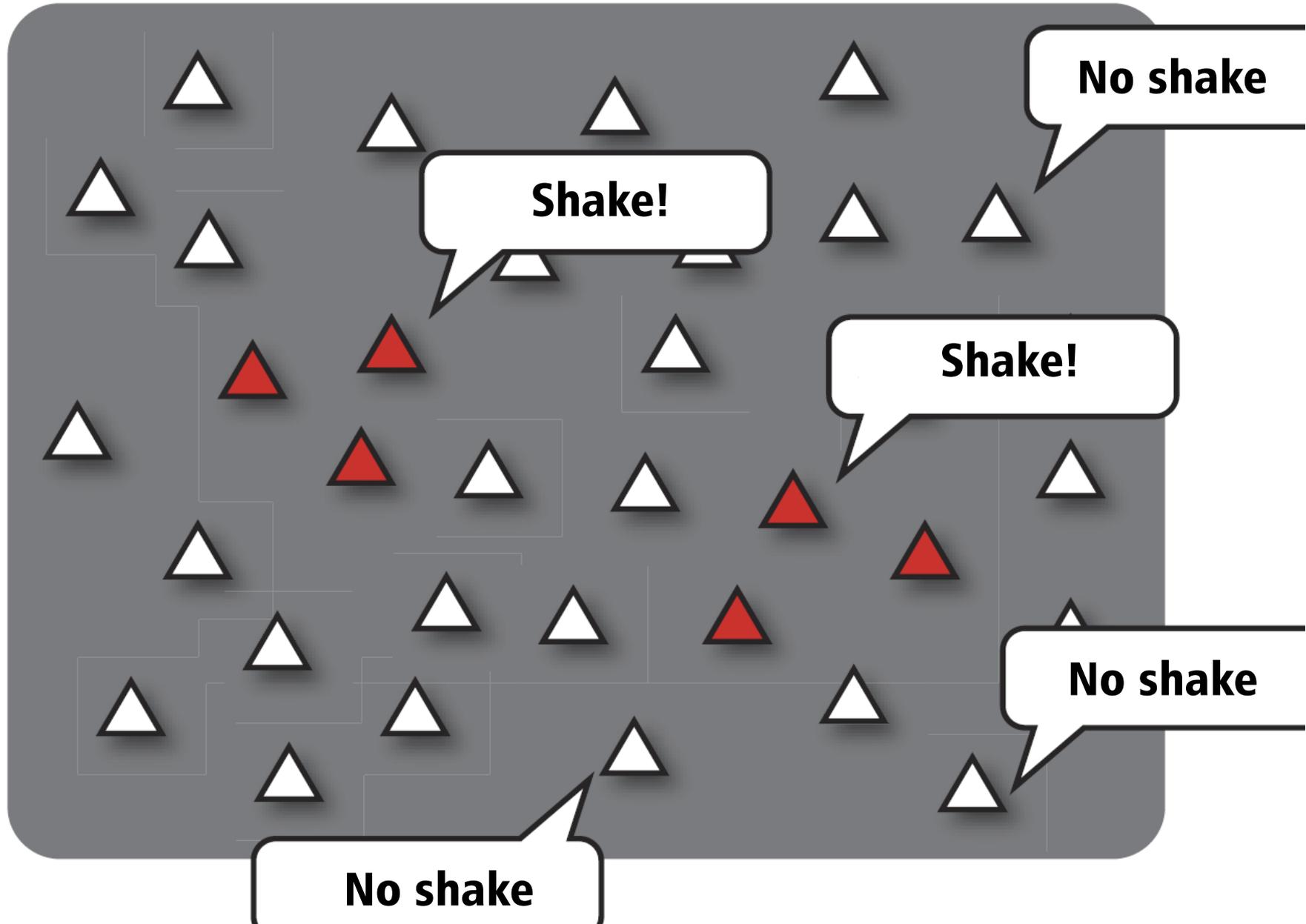
What is IPF?

- 1) Use of non-triggered data
- 2) Smart phase association
- 3) Particle filter optimization

Conventional approach



IPF method



Smart Phase Association

Can a phase information be explained by the event?

$$p = \left[-\frac{(M_i - \hat{M}_i)^2}{\sigma_M^2} \right] + \left[-\frac{(T_{p,i} - \hat{T}_{p,i})^2}{\sigma_T^2} \right]$$

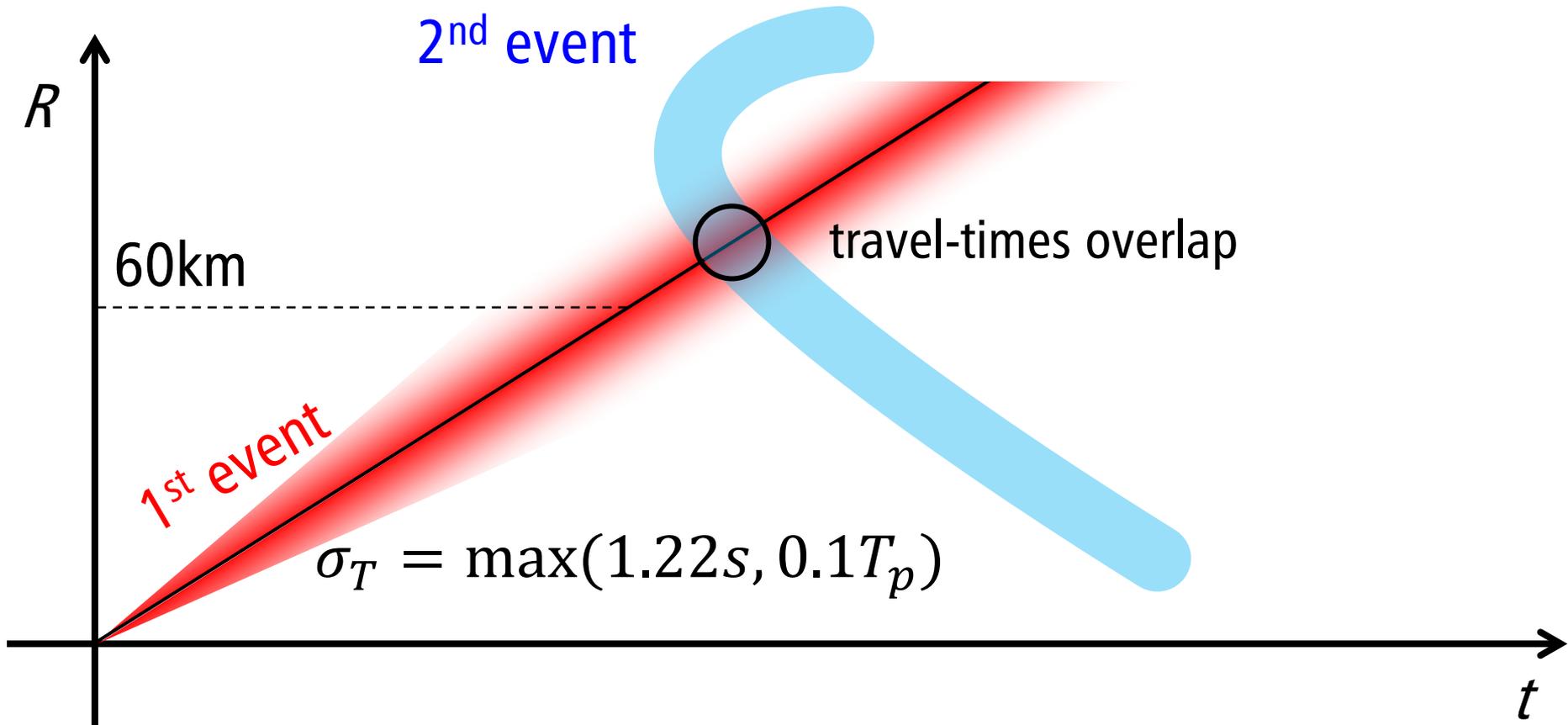
Vel Amp in 5s Tp

If $p \leq (5)^2$: same event

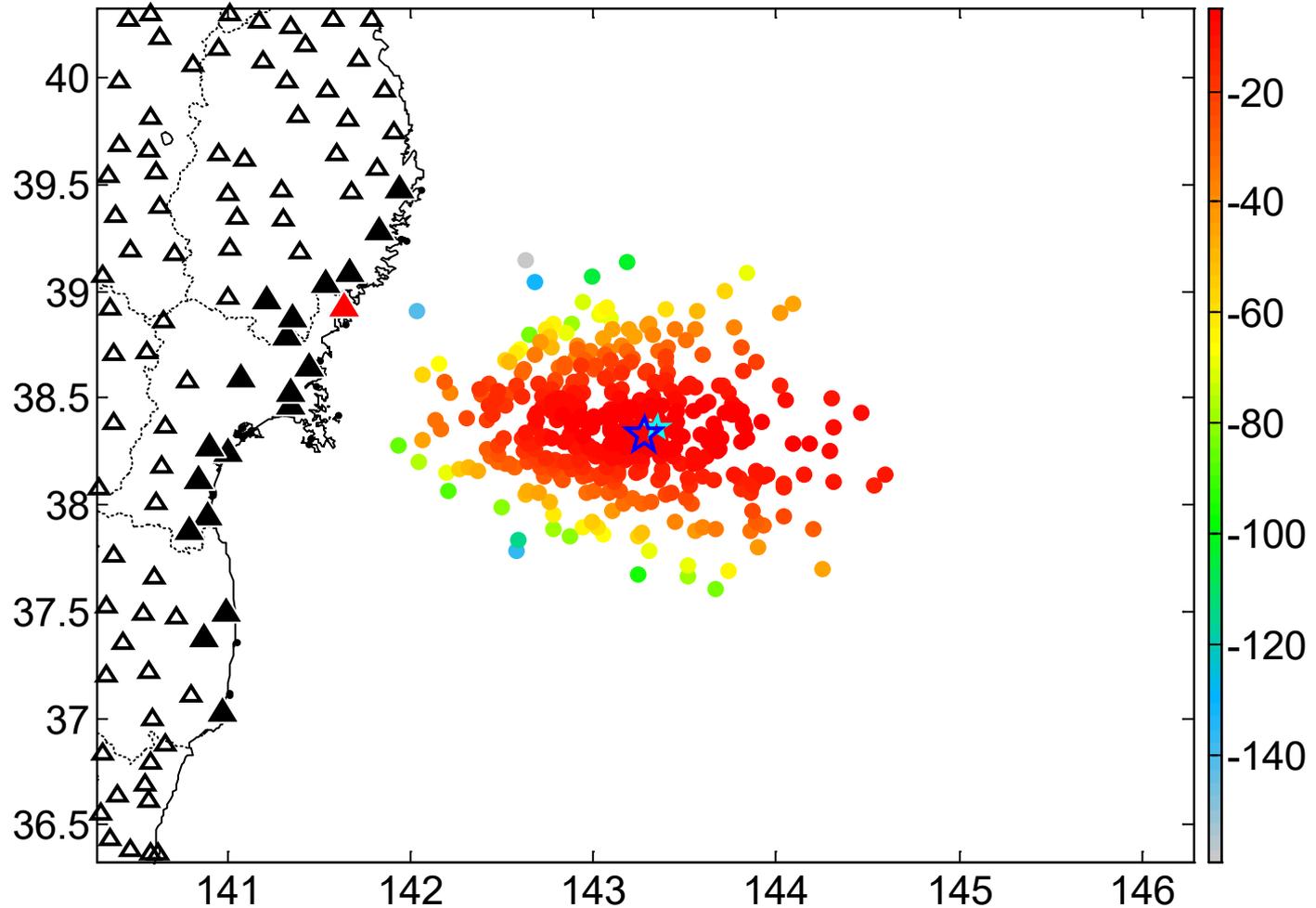
If $p > (5)^2$: new event

Smart Phase Association

$$p = \left[-\frac{(M_i - \hat{M}_i)^2}{\sigma_M^2} \right] + \left[-\frac{(T_{p,i} - \hat{T}_{p,i})^2}{\sigma_T^2} \right] > (5)^2$$



Location search (Particle filter)



→ Faster & more accurate than gridsearch

Likelihood fn for Source Estimation

$$p(D | \theta) = p(A | \theta) p(T_p | \theta)$$

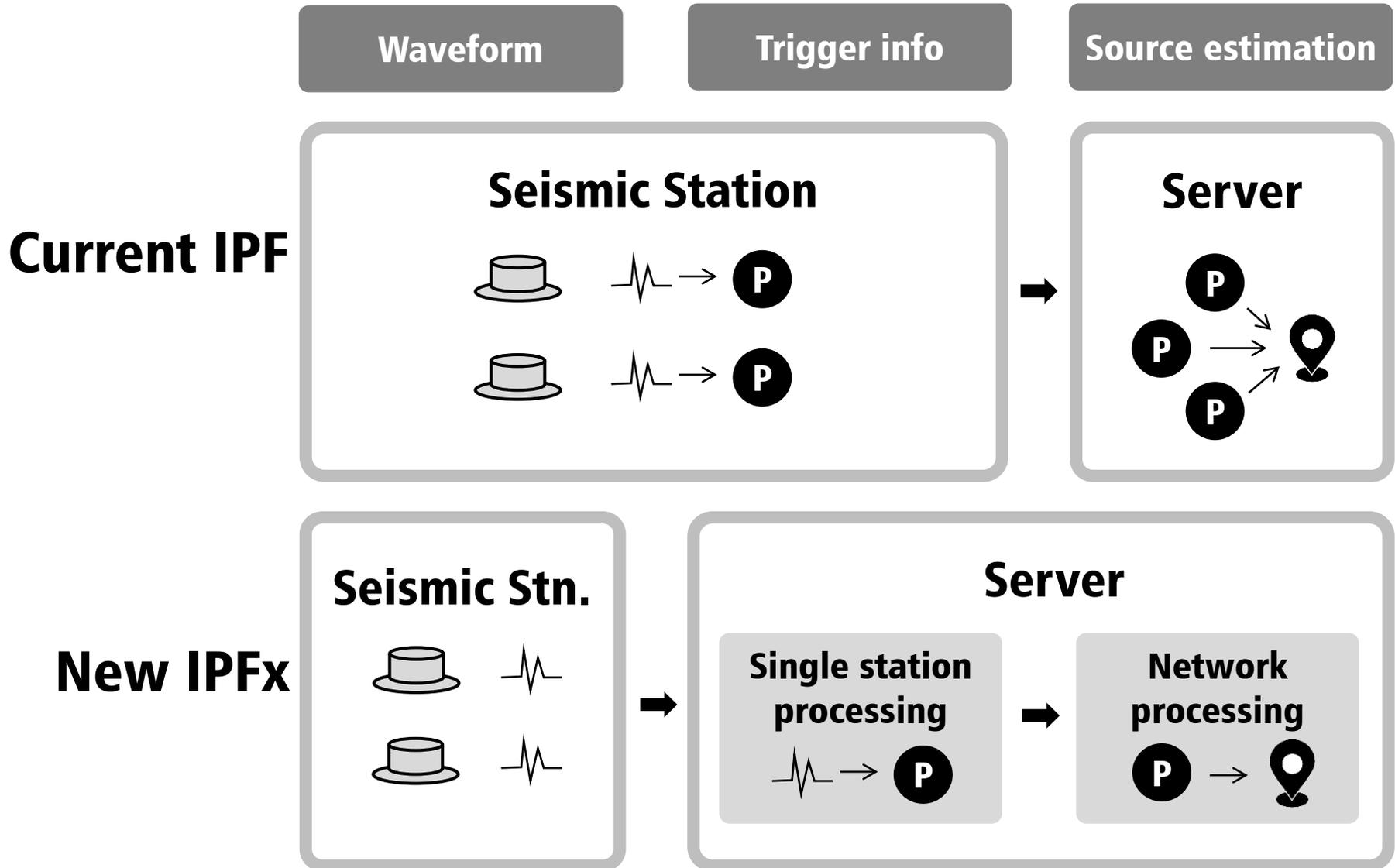
$$\ln p(D | \theta) \propto \sum_j \left[-\frac{(A_j - \hat{A}_j)^2}{2\sigma_A^2} \right] + \sum_j \left[-\frac{(T_{p,j} - \hat{T}_{p,j})^2}{2\sigma_{T_p}^2} \right]$$

Amplitude
residual

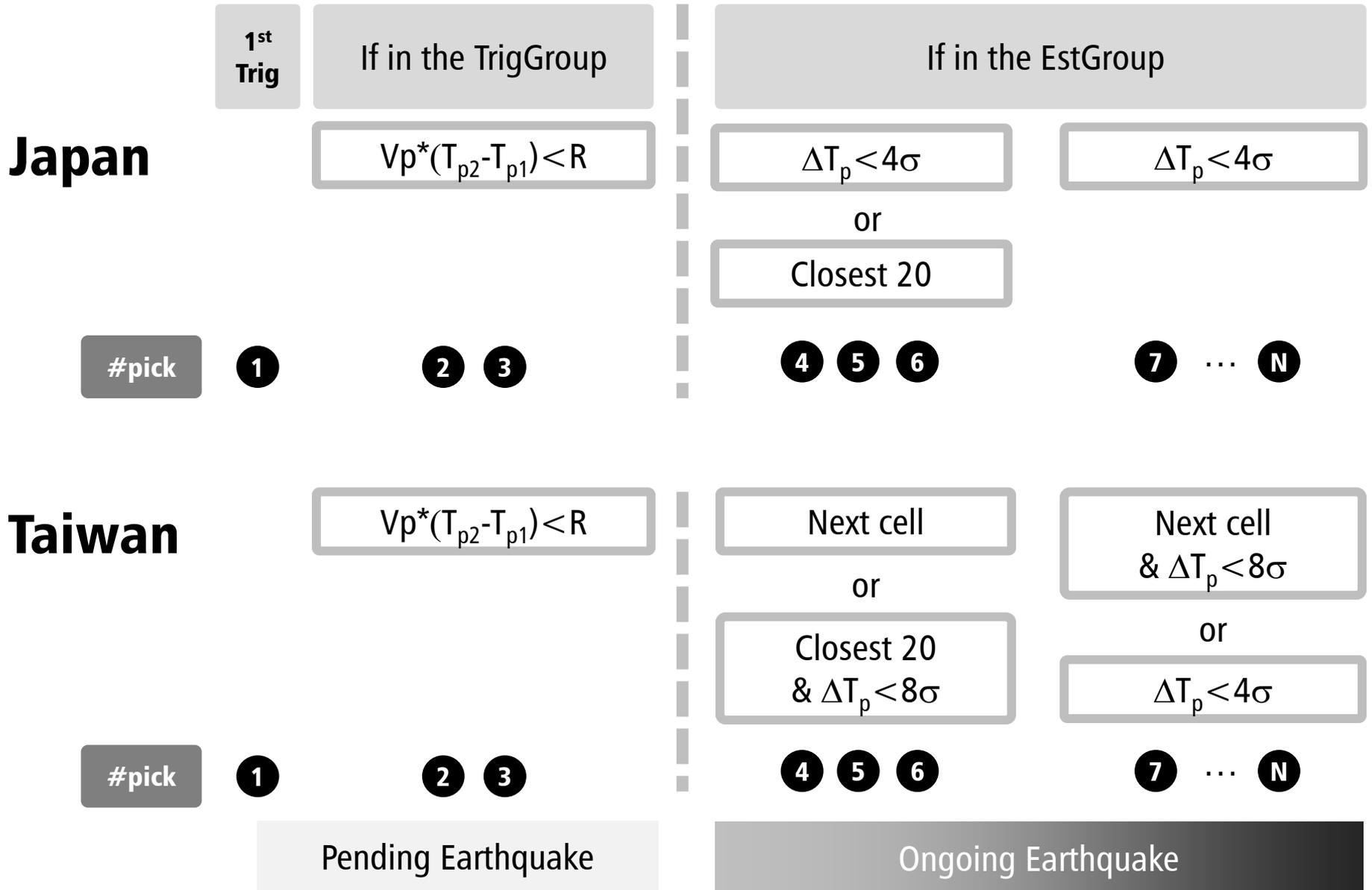
Picking time
residual

Modification for Taiwan Network

Extended IPF (IPFx) method

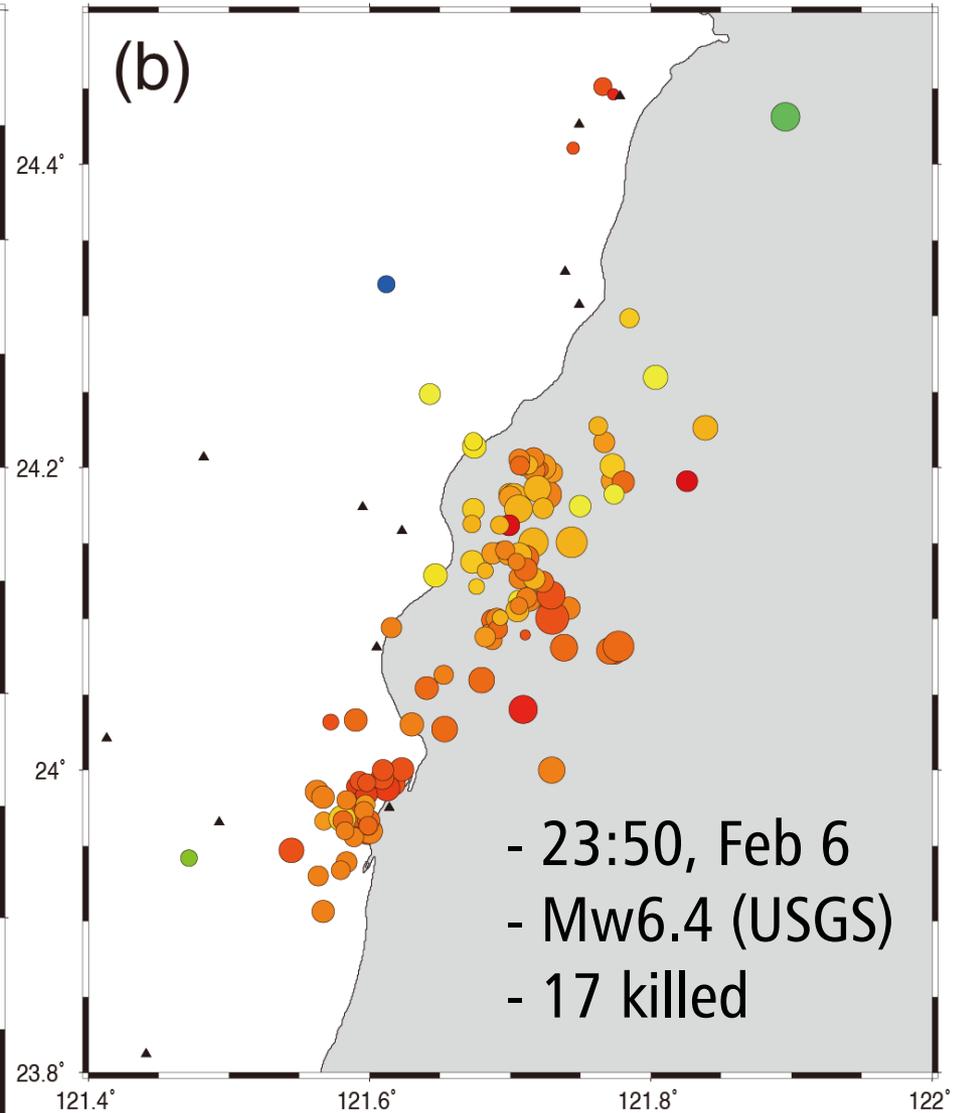
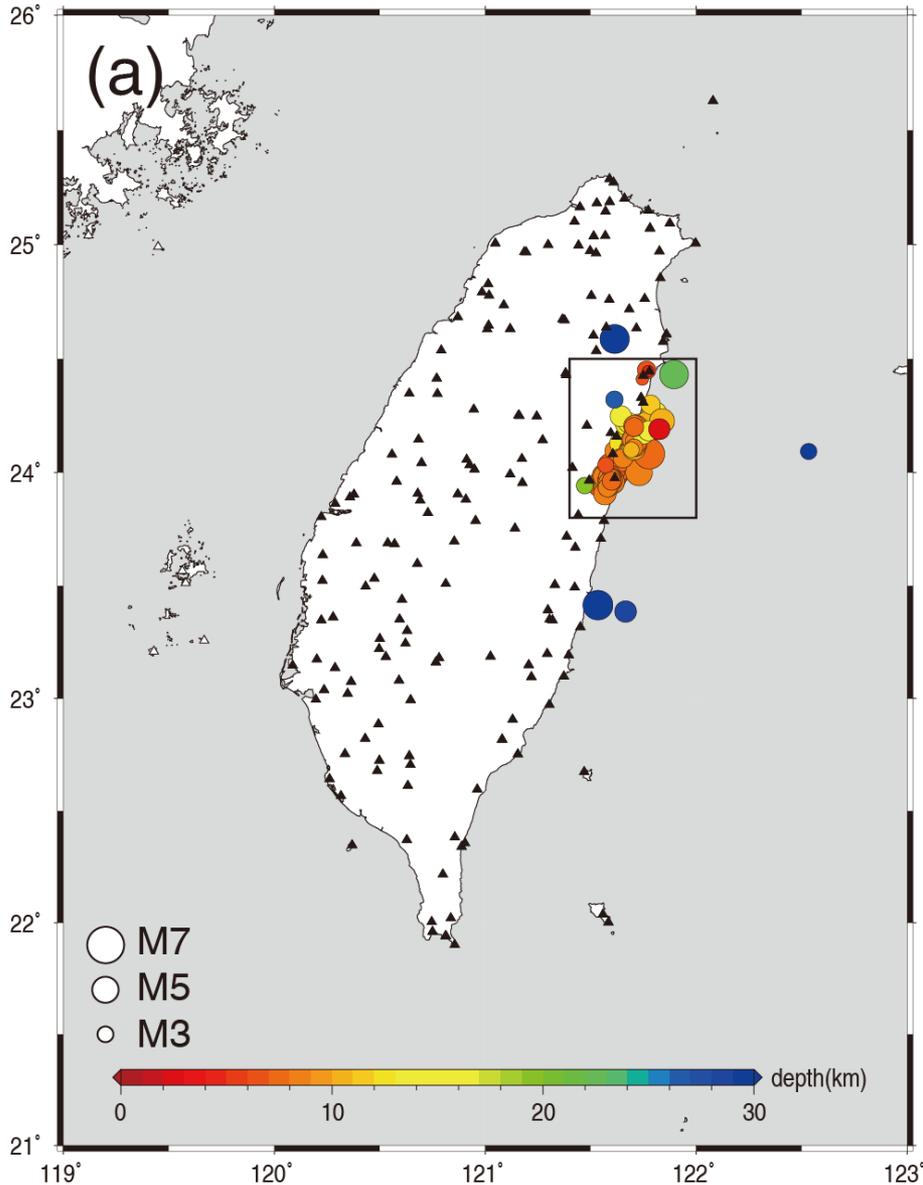


Modification of Phase Association

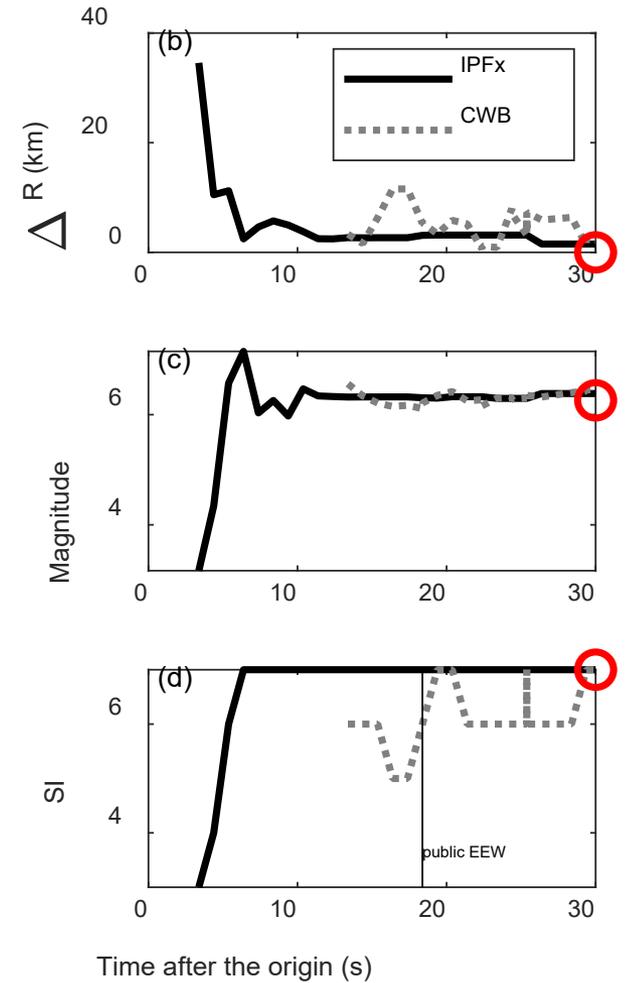
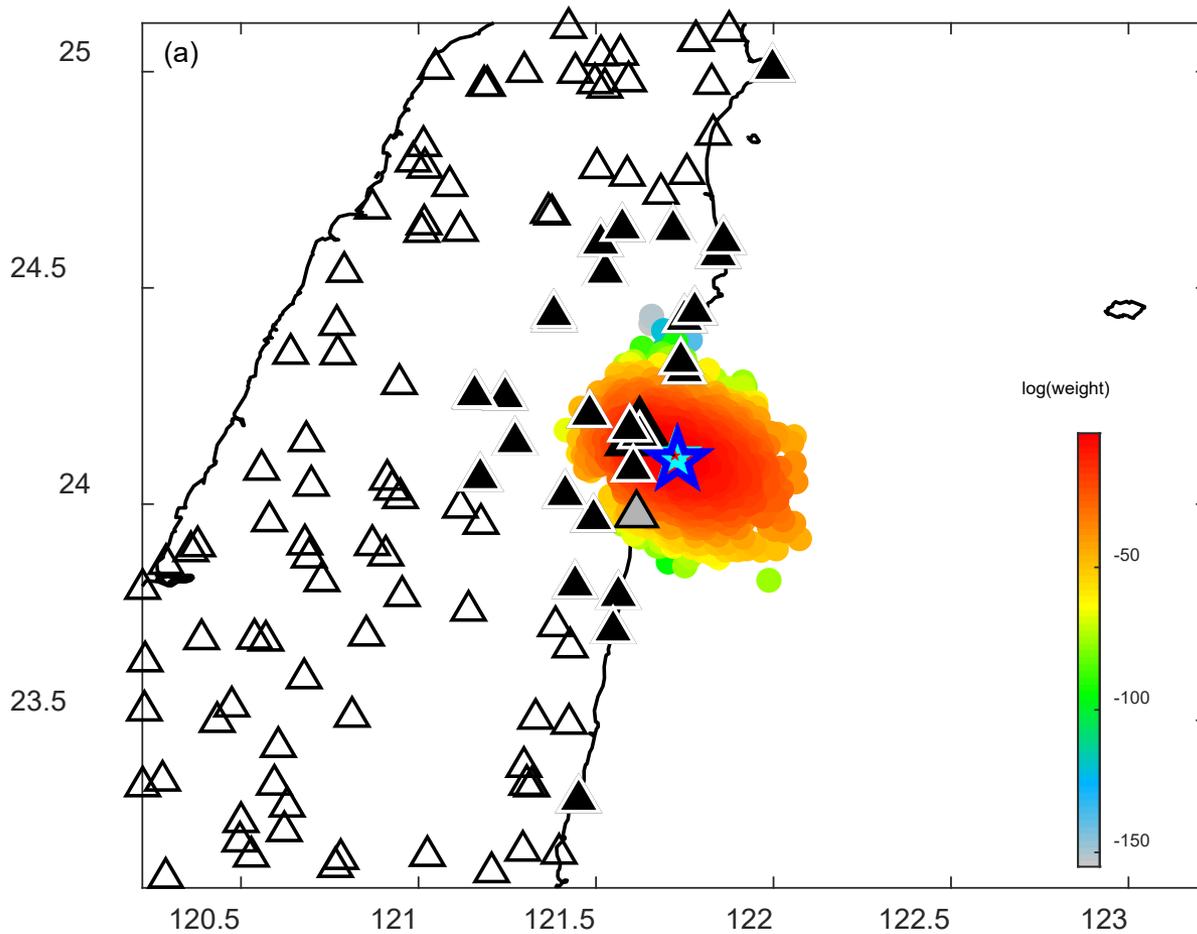


Results of 2018 Hualien EQ

2018 Hualien Sequence



Mainshock Performance



1-month Performance

Obs

127 EQs with $SI \geq 4$

IPFx

22 missed

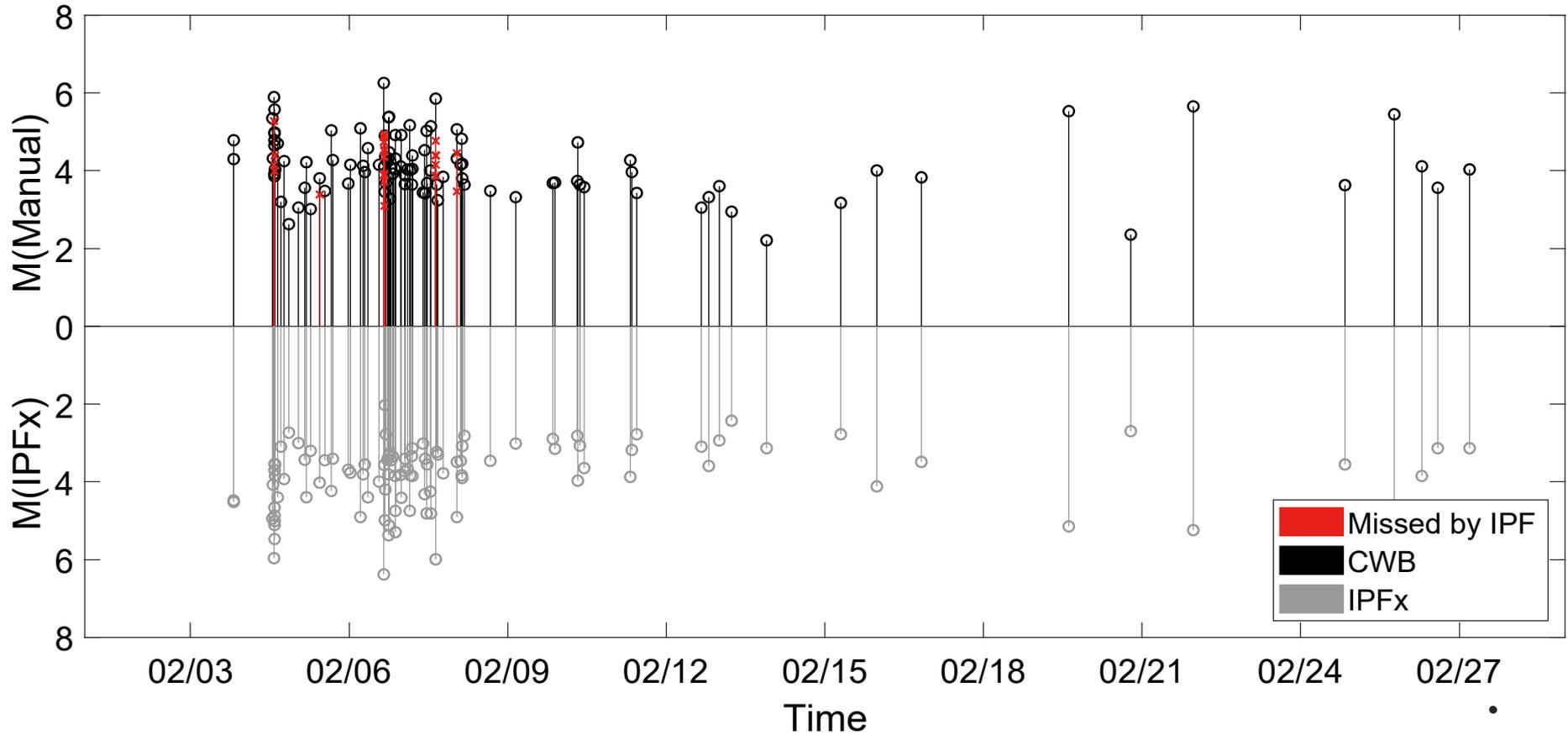
105 detected

2

103 correct

with large location error
 $\Delta R > 30\text{km}$

1-month M-T diagram

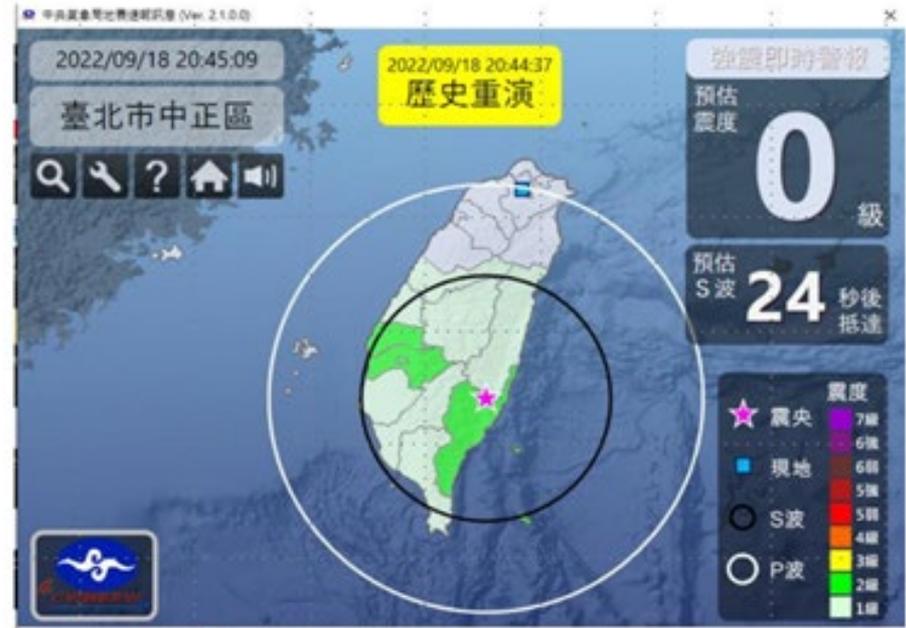


False Alarm (2022/9/18 Taitung)

Realtime estimation



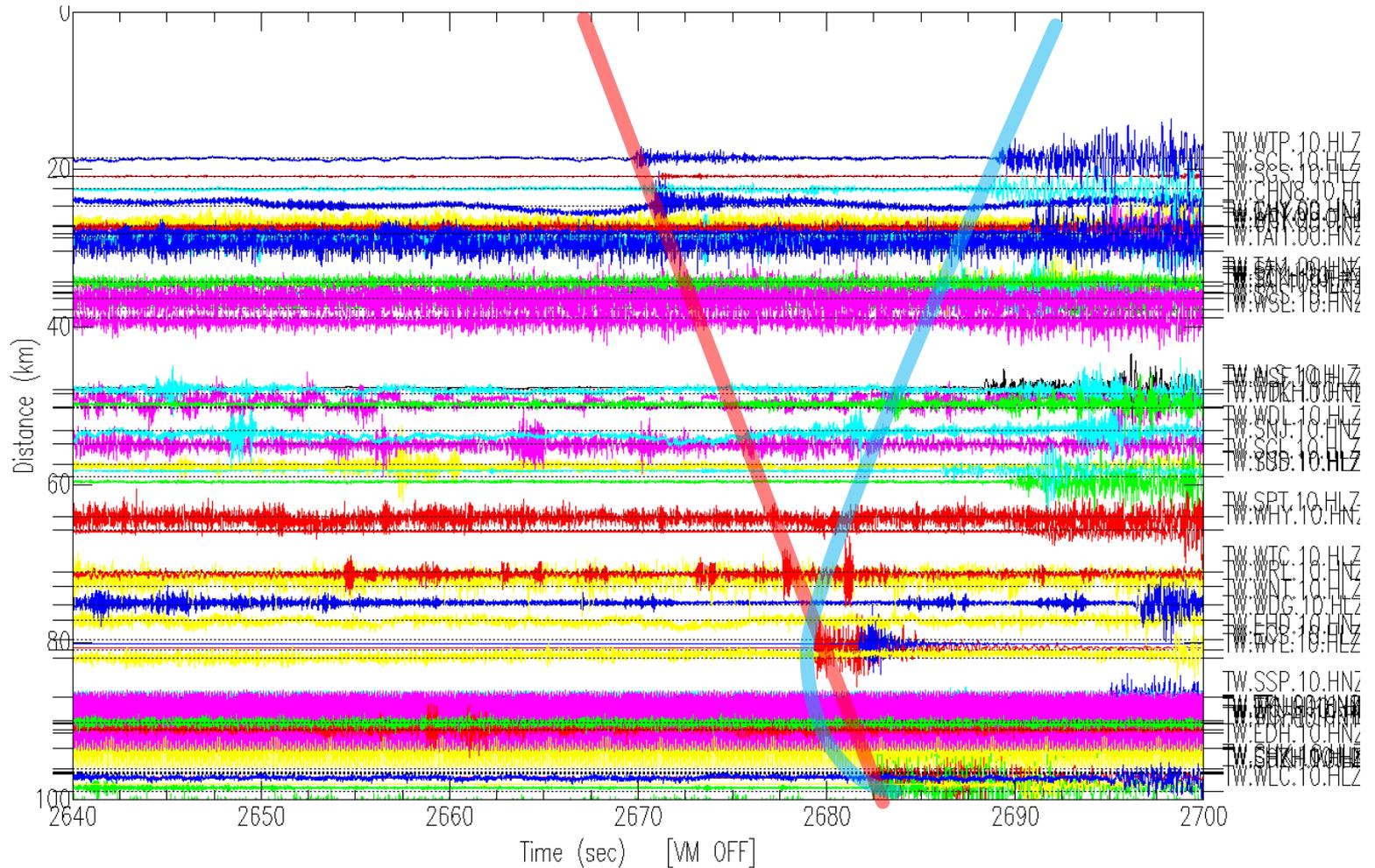
Correct estimation



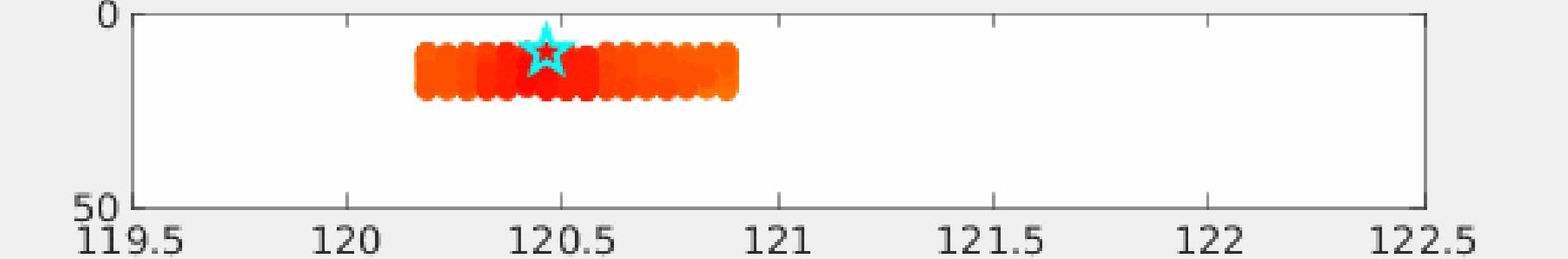
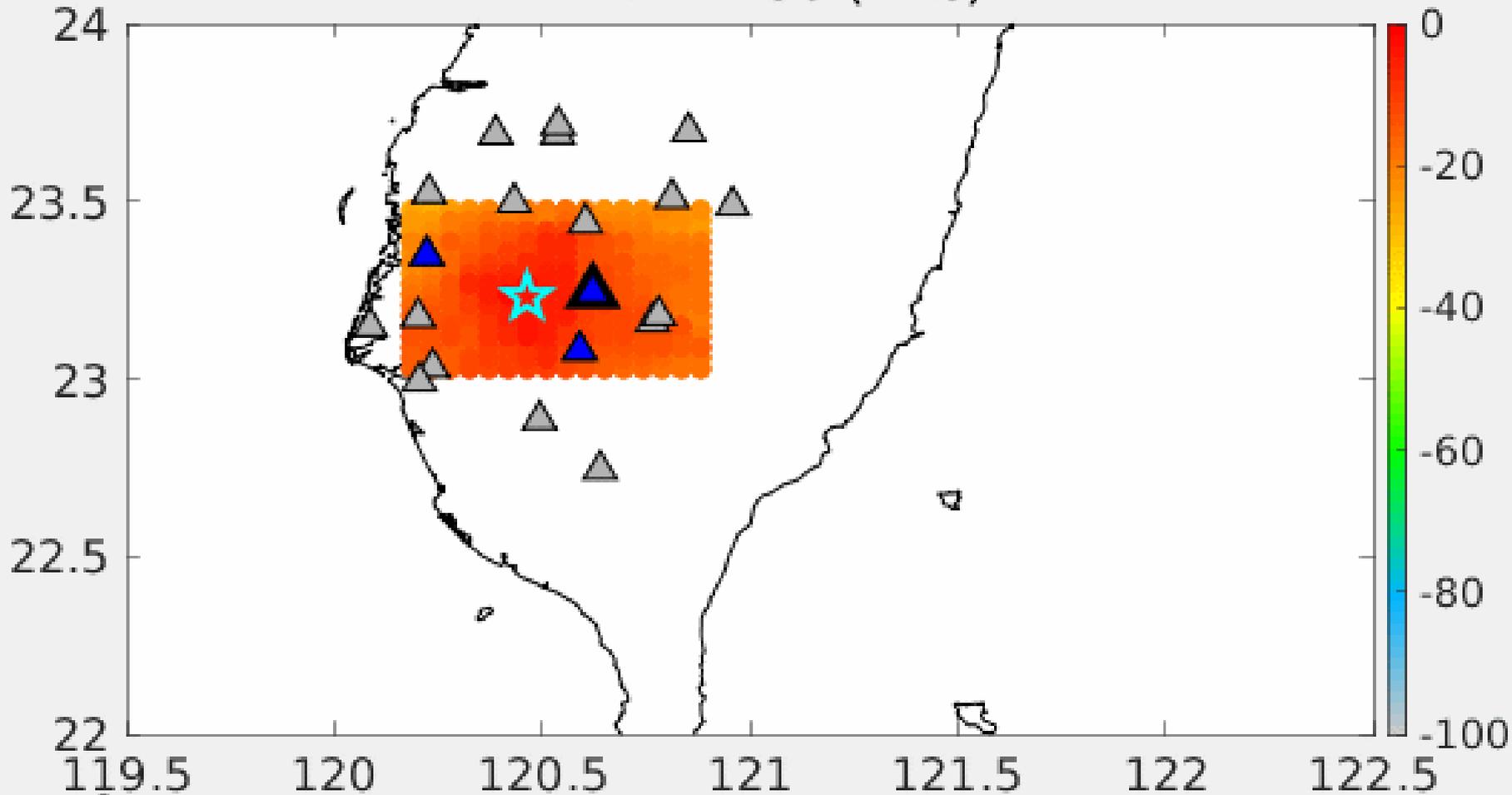
Waveforms

1st event

2nd event

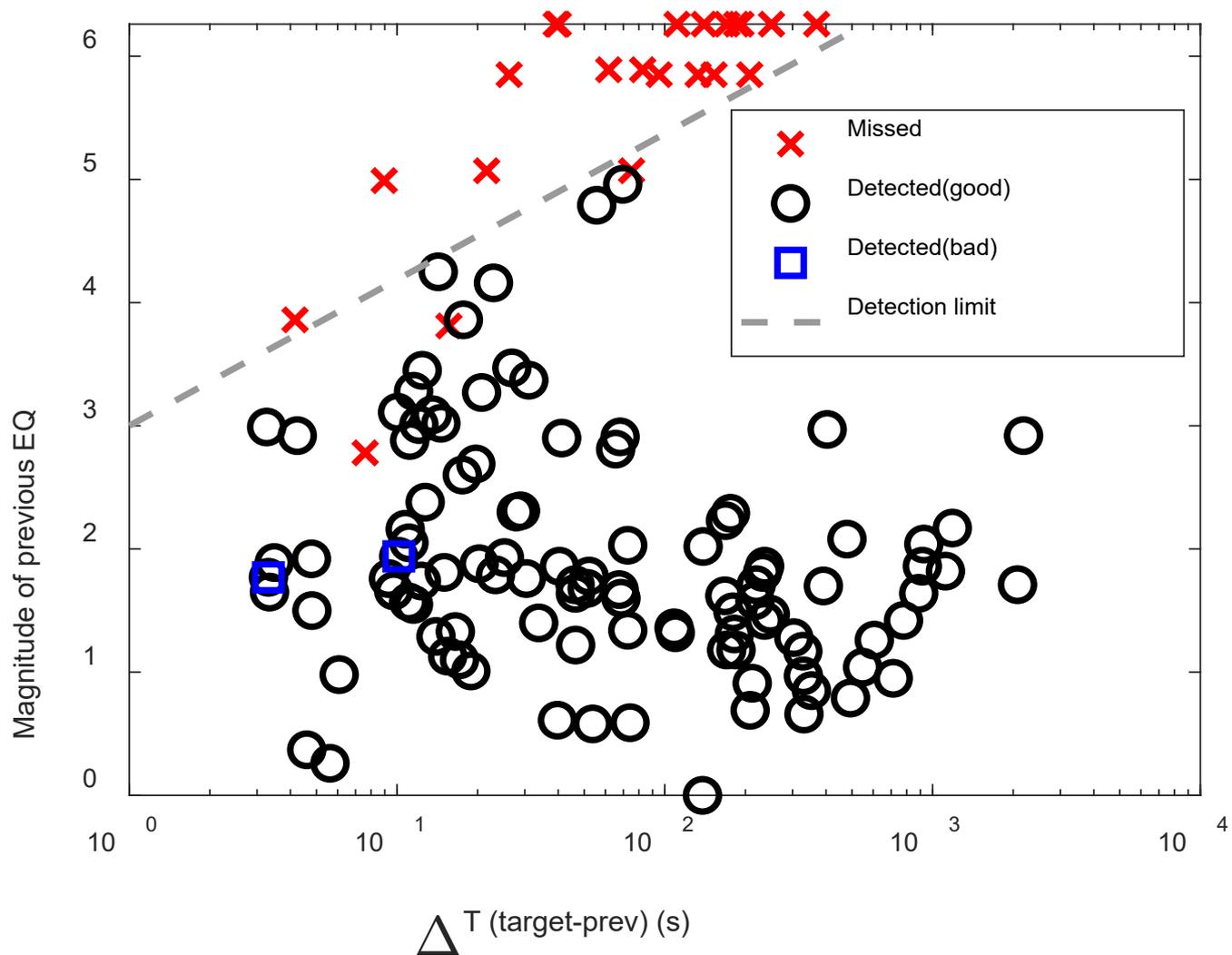


T = 12:44:30 (+1s)



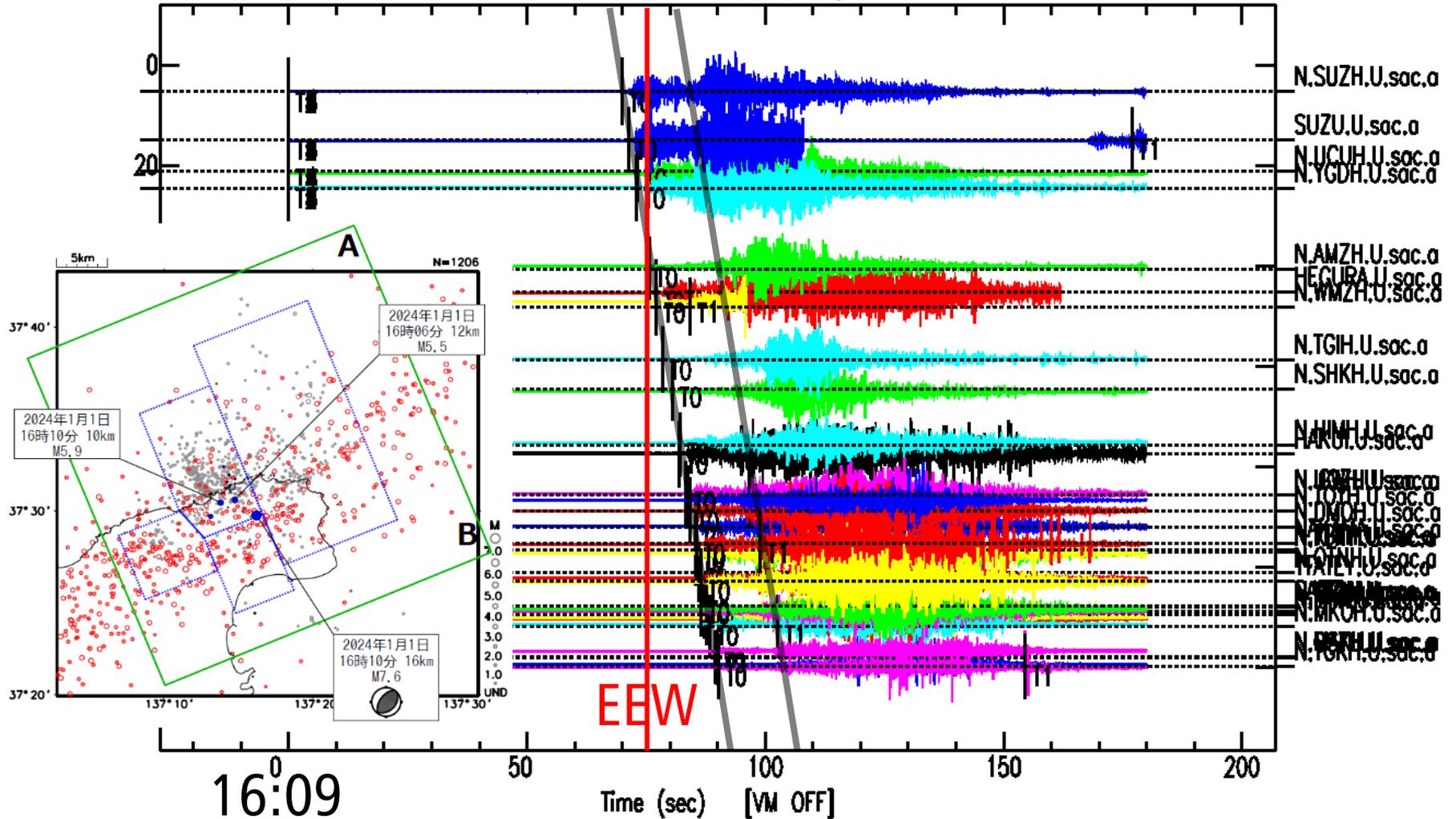
IPFx Simulation (2022/9/18 Taitung)

Detection Limit



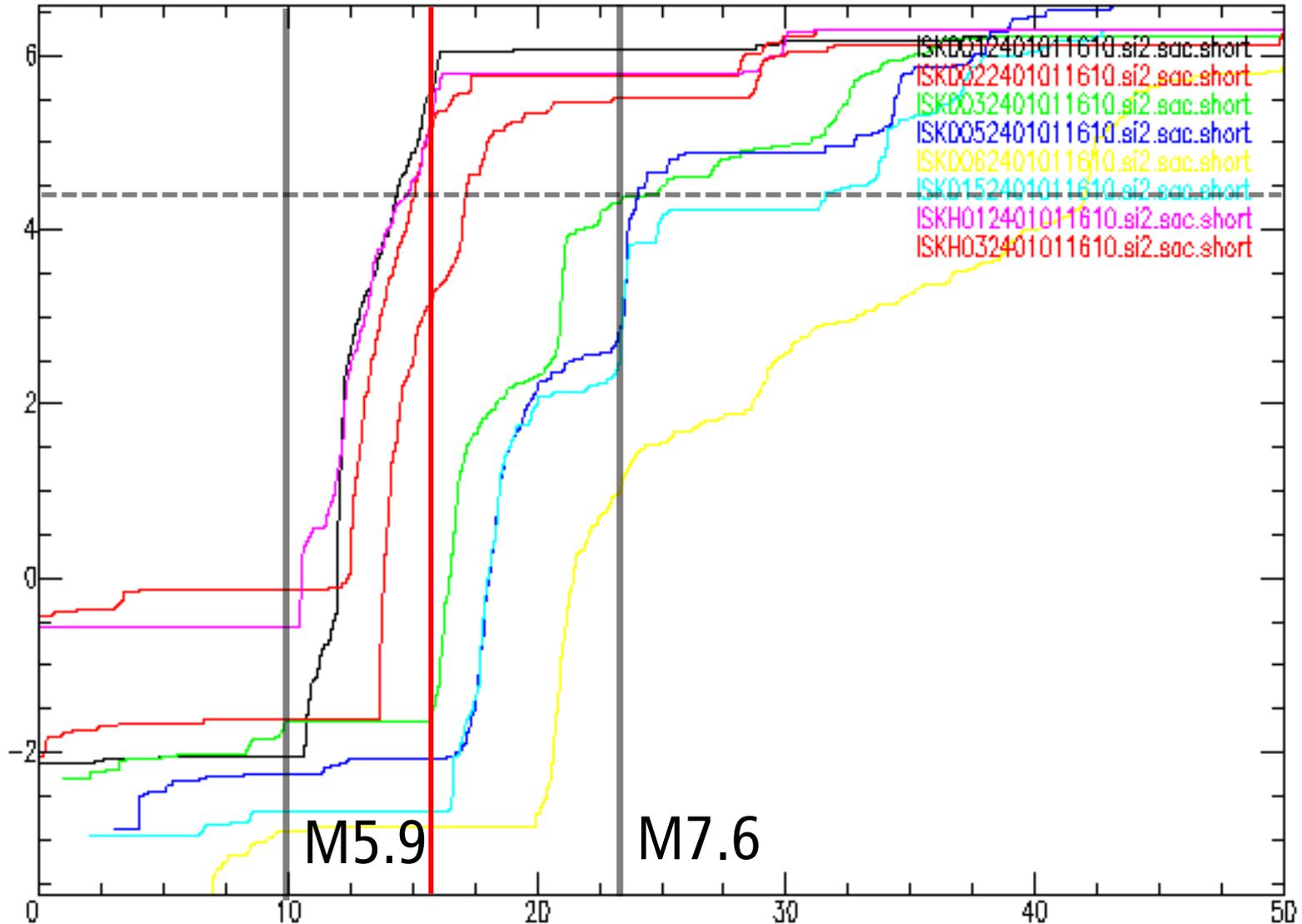
2024 Noto Earthquake

16:10:10 16:10:23
M5.9 M7.6

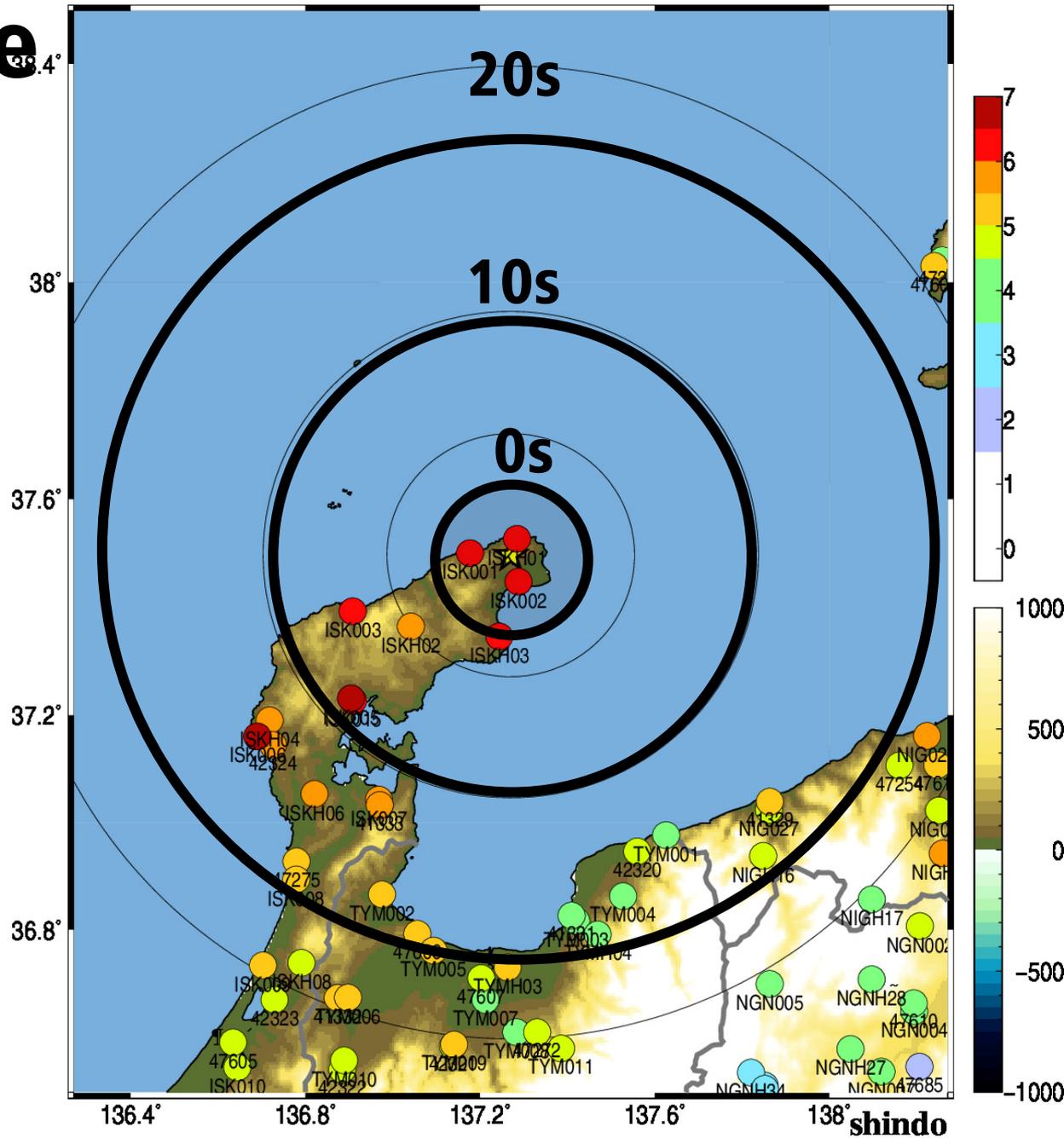


2024 Noto Earthquake

EEW



Warning time vs intensity



Summary

- 1) IPFx method was applied to 2018 Hualien sequence (1-mon).
- 2) Improvement of the filter for the phase association.
- 3) Mainshock could be detected 10s earlier than CWB EEW.
- 4) Improvement for the simultaneous earthquakes and limitation.

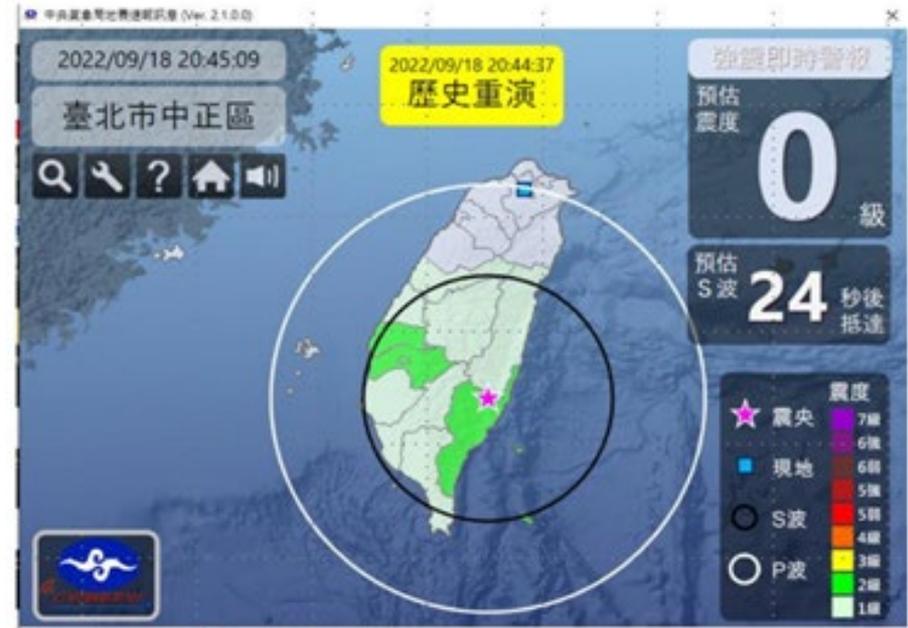
Yamada, M. and D.-Y. Chen (2022). Automatic Hypocenter Determination with the IPFx method for the 2018 Hualien earthquake sequence. *Terrestrial, Atmospheric and Oceanic Sciences*, 33:18.
(Open access)

False Alarm (2022/9/18 Taitung)

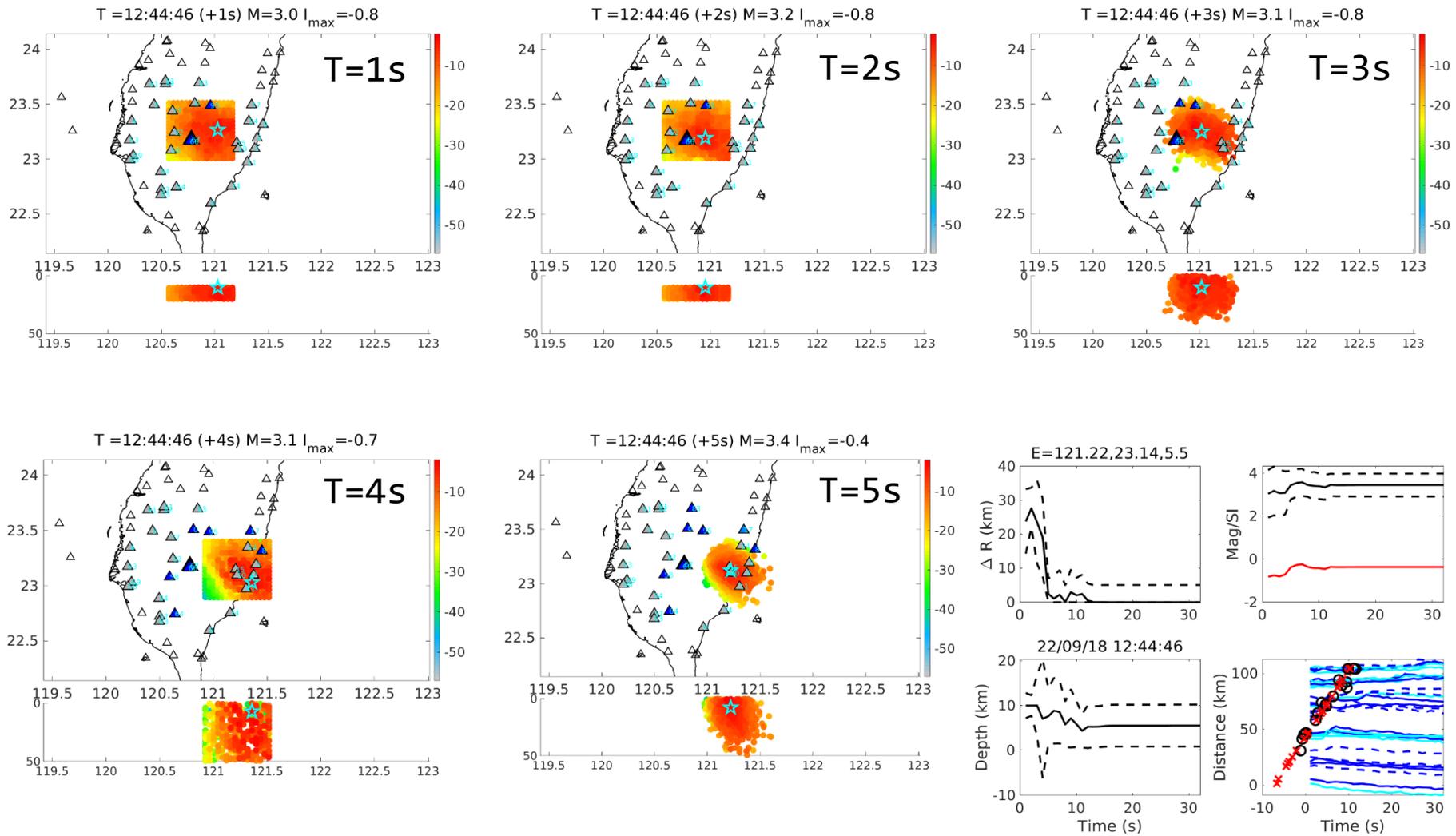
Realtime estimation



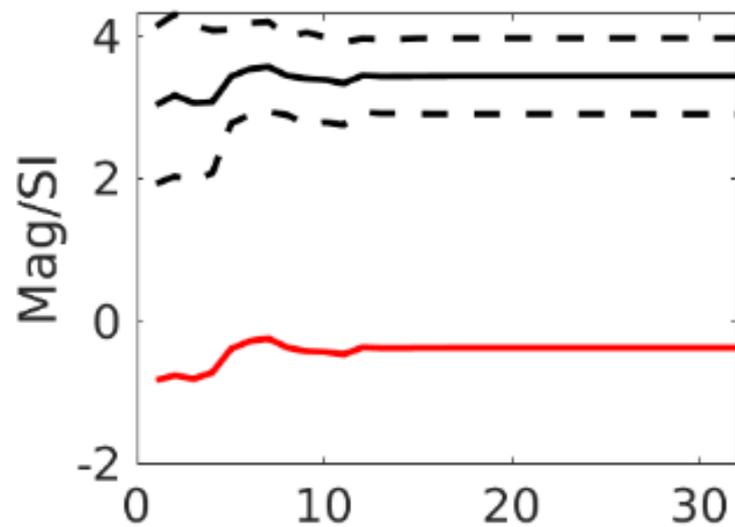
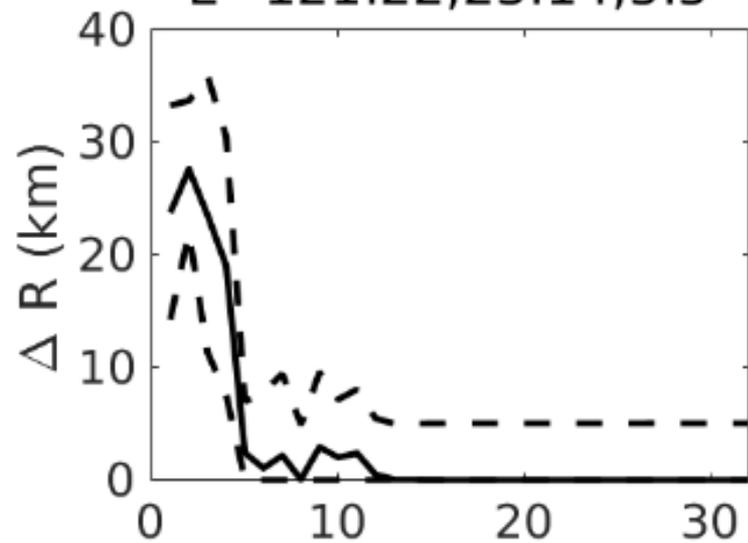
Correct estimation



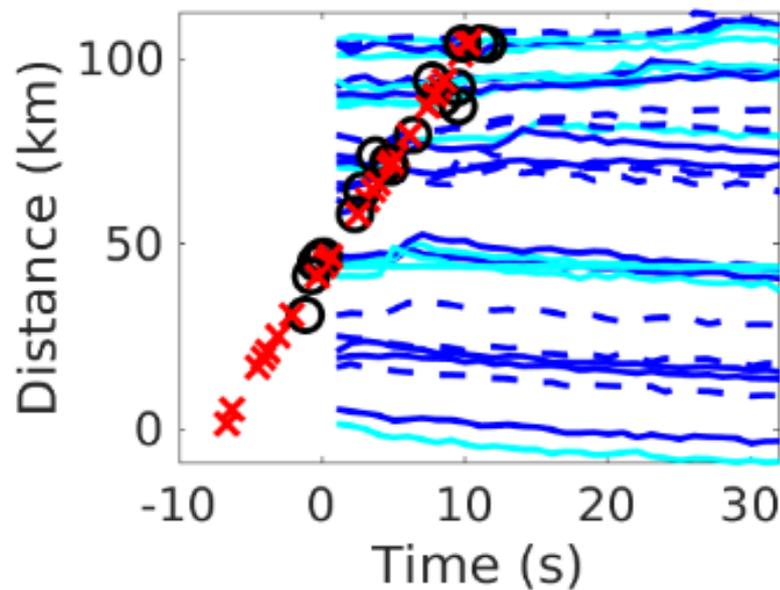
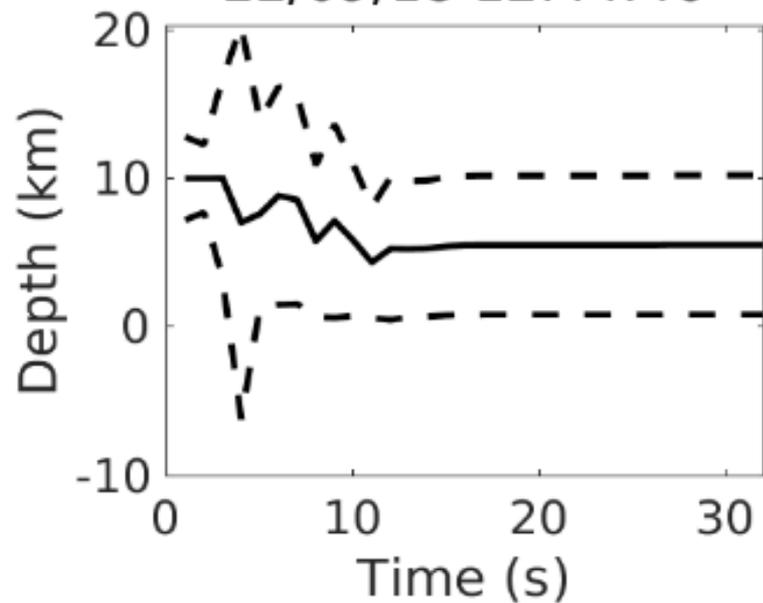
Result of 2022/09/18,12:44:38.270 23.1425 121.2172 5.52 3.44



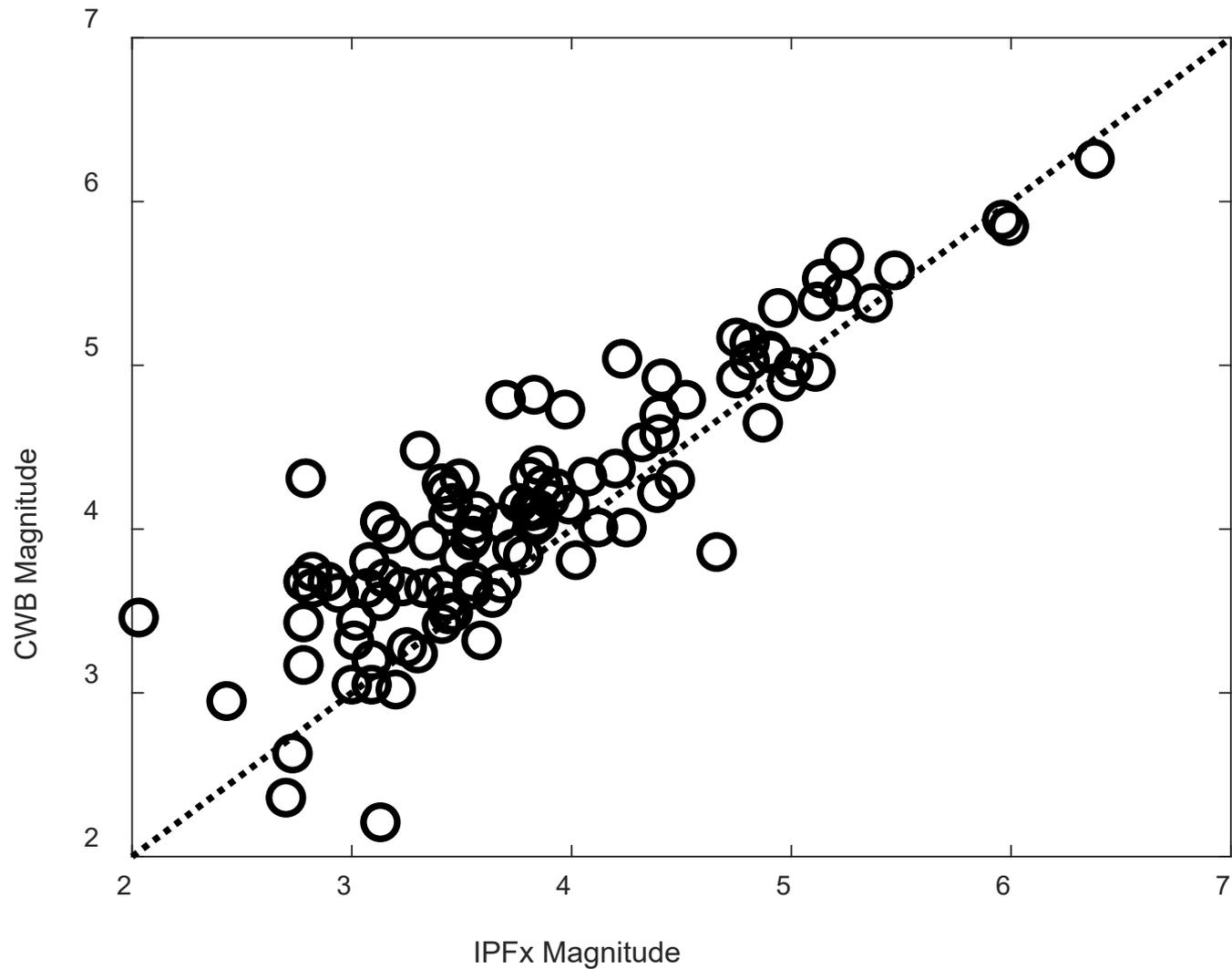
E=121.22,23.14,5.5

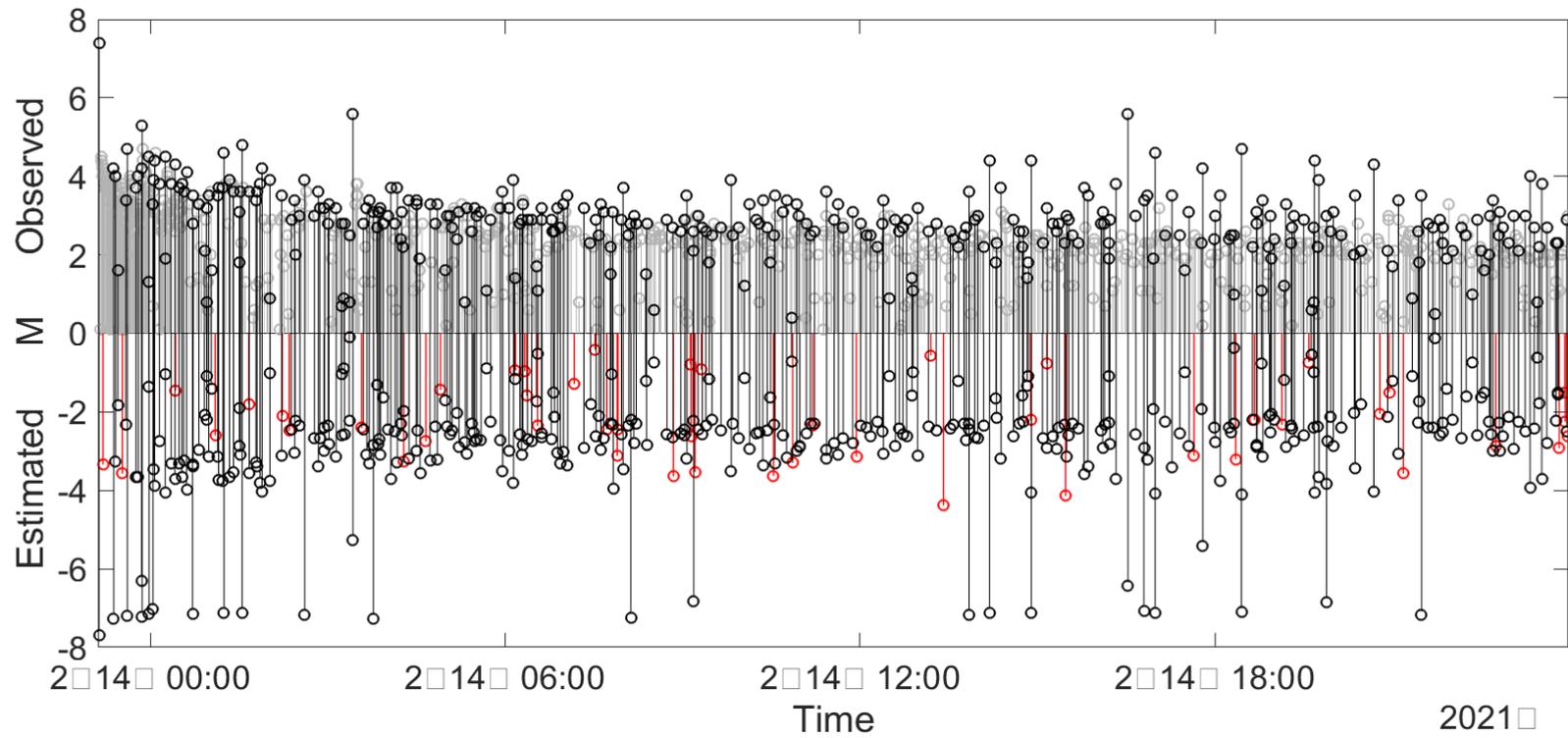


22/09/18 12:44:46



IPFx(JMA) Mag vs CWB Mag





Improvement from the current IPF

1) Single station processing

1a) lower the trigger level

1b) Update information every second

2) Network processing

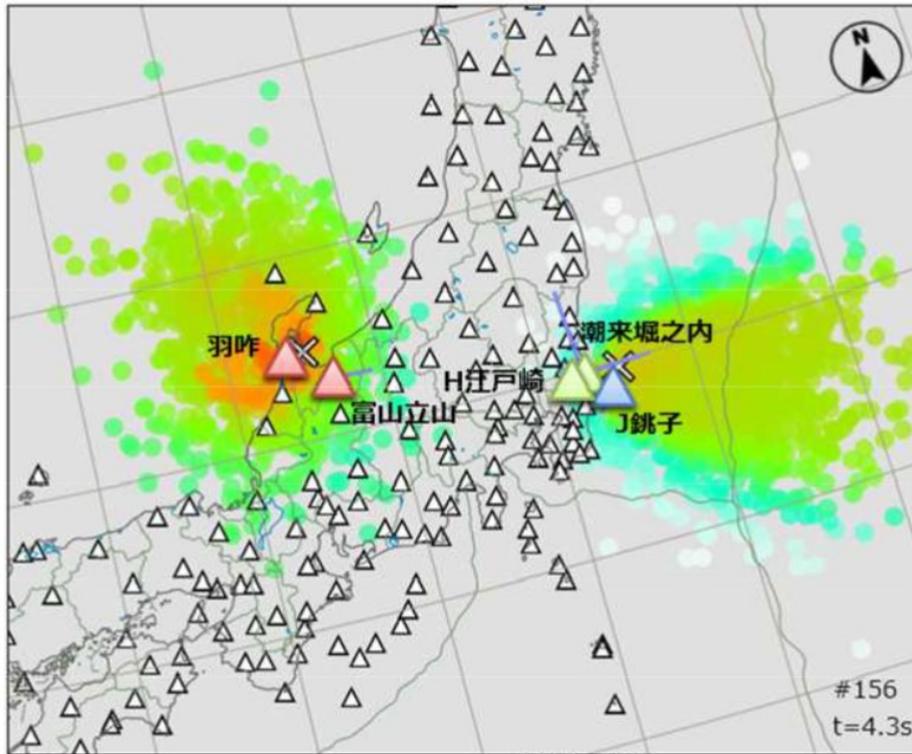
2a) trigger group

2b) estimation group

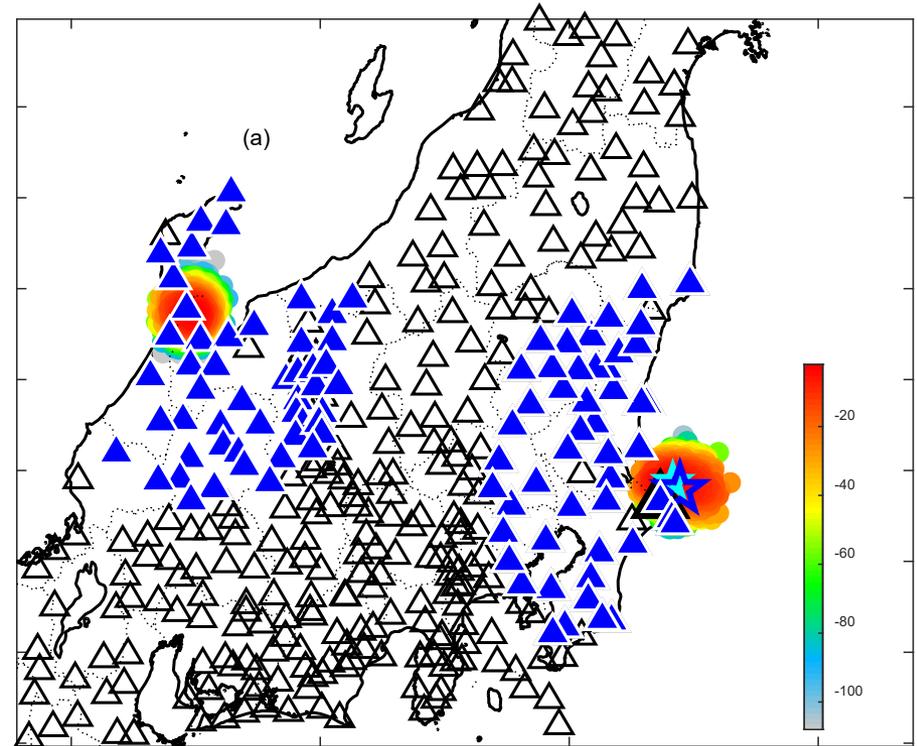
2c) no filter for M estimation

1a) Lower the trigger level

False alarm on January 5, 2018

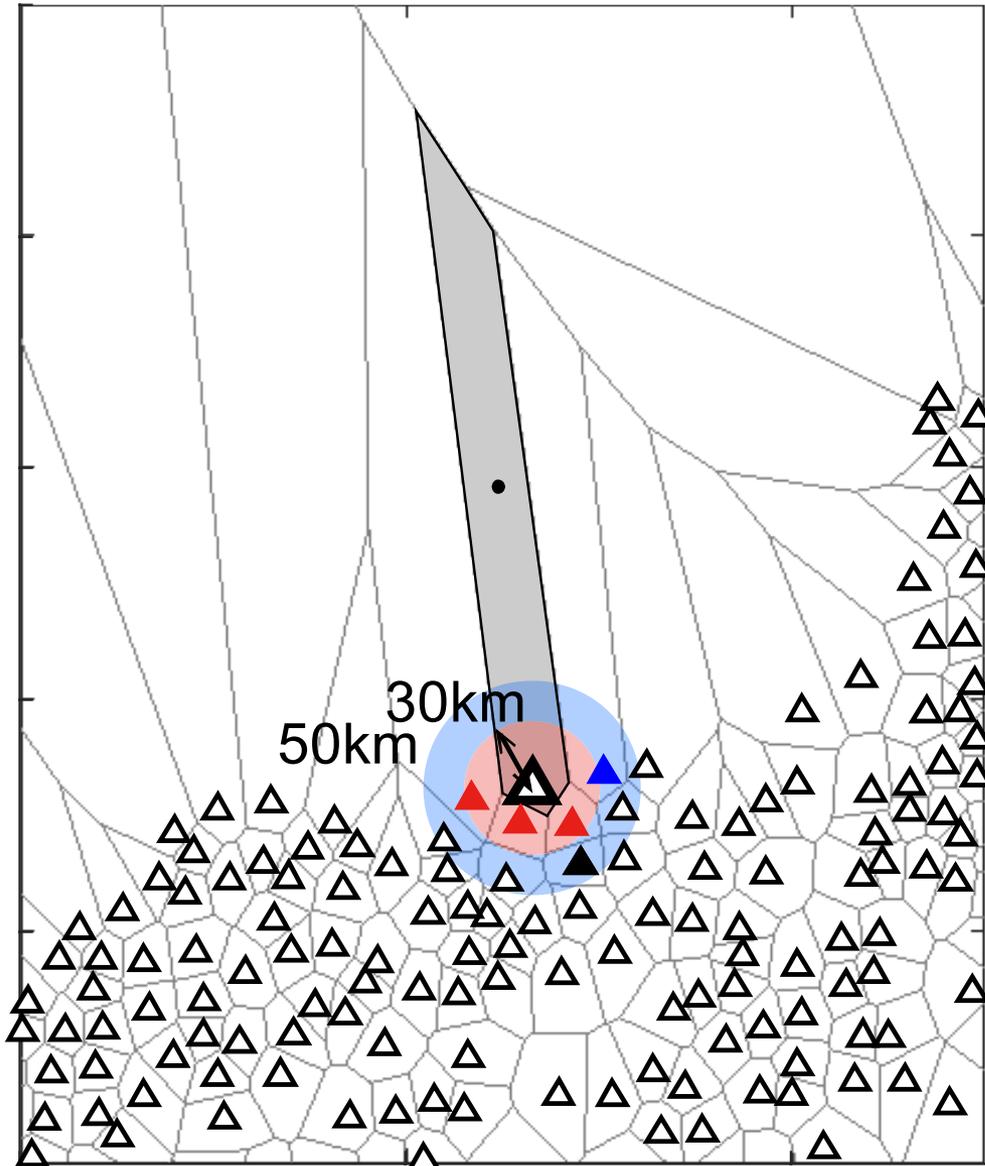


JMA: 5 stations triggered



IPFx: Closest 50 stns triggered

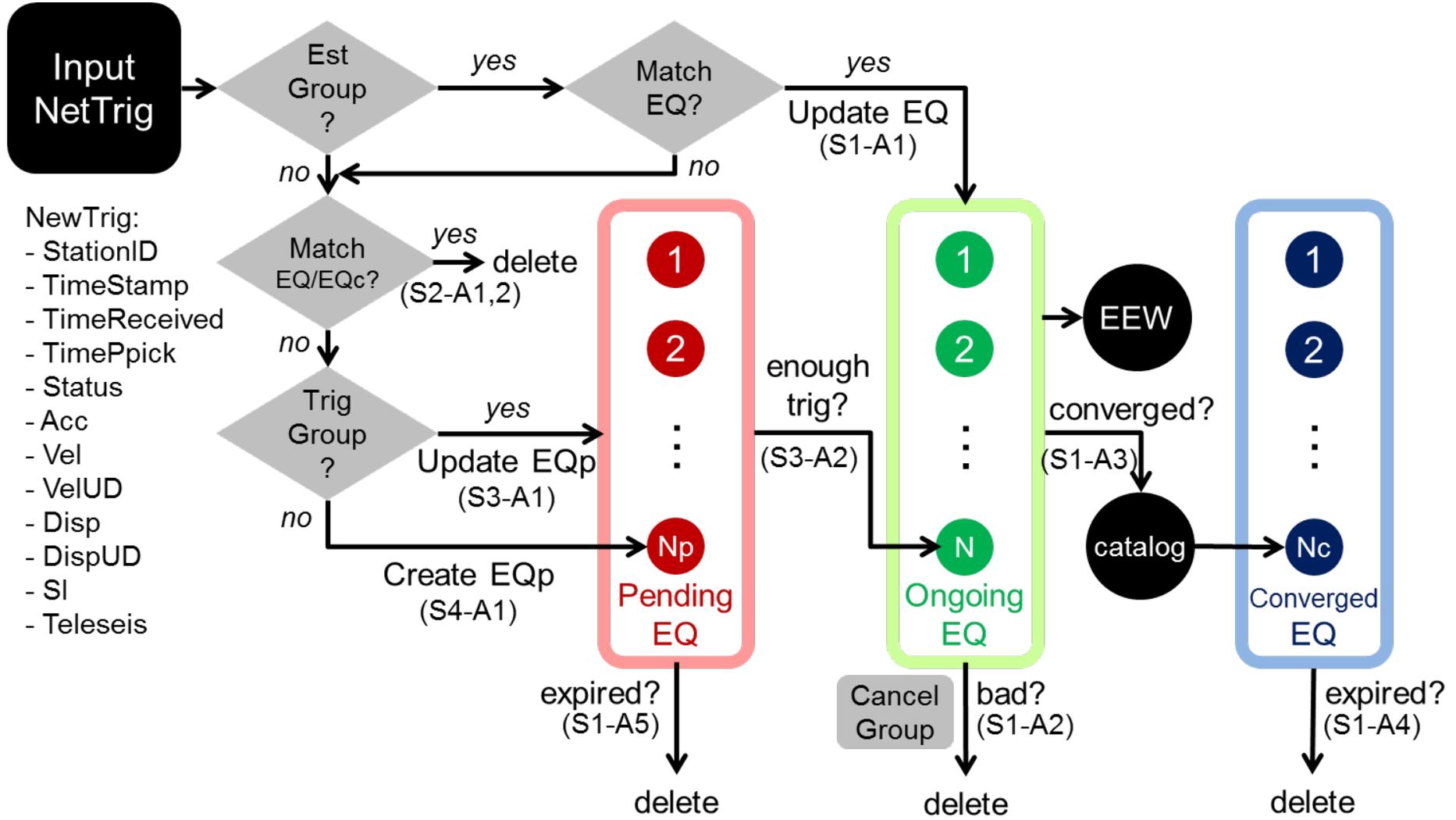
2a) Trigger Group



- All station within 30 km
- All neighboring station within 50 km
- If #station < 5, add up to 5 from the closest

Fast detection &
Avoid noise contamination

Source estimation process



- NewTrig:
- StationID
 - TimeStamp
 - TimeReceived
 - TimePpick
 - Status
 - Acc
 - Vel
 - VelUD
 - Disp
 - DispUD
 - Sl
 - Teleseis