# Improving regional EEW system with near-real-time source parameter estimation

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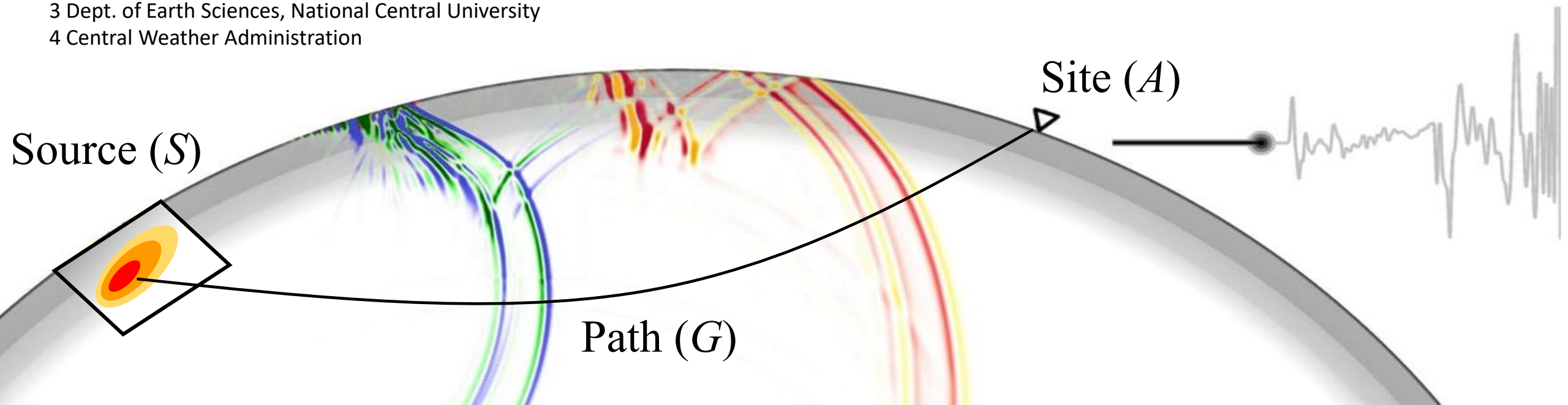
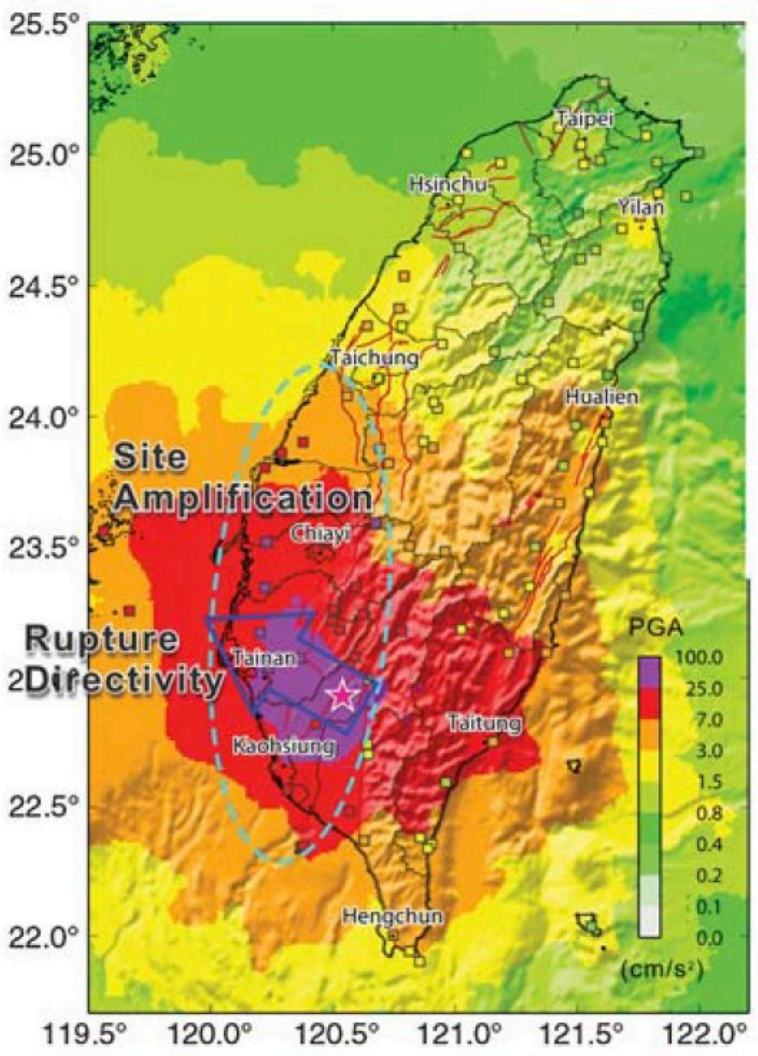
4 Central Weather Administration

$$U = S * G * A$$



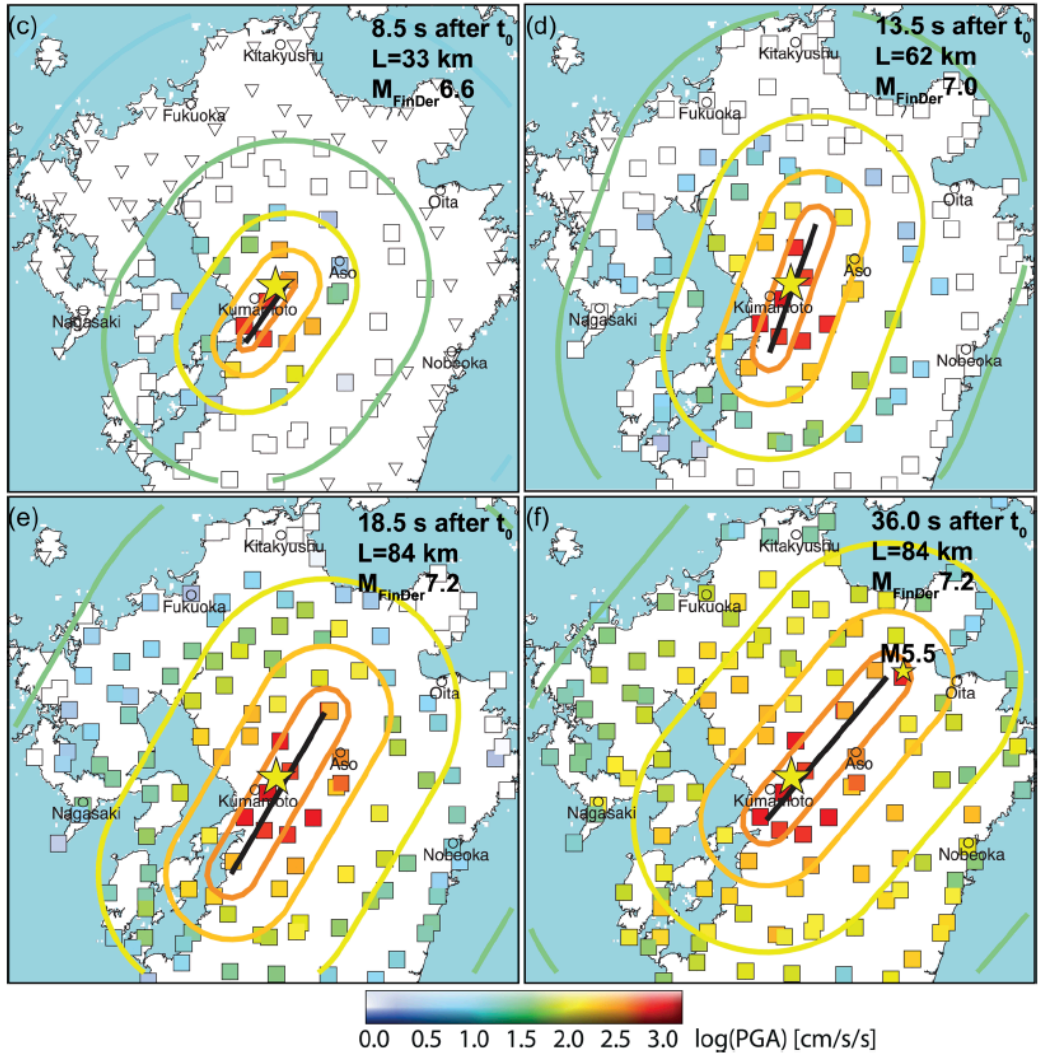
# Important source parameters not considered in EEW

**Rupture directivity**



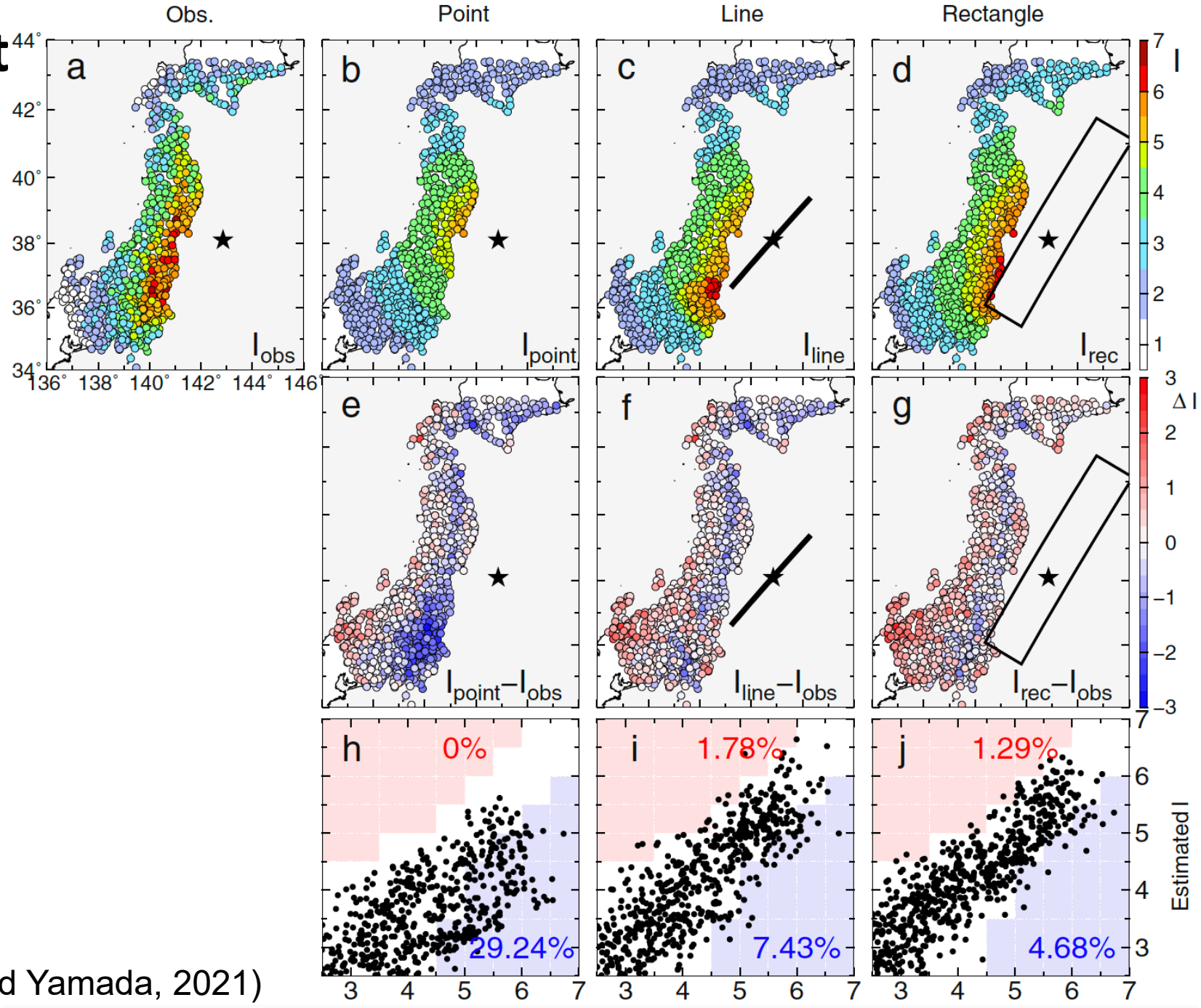

(Lee et al., 2016)

**Finite source**




(Bose et al., 2018)

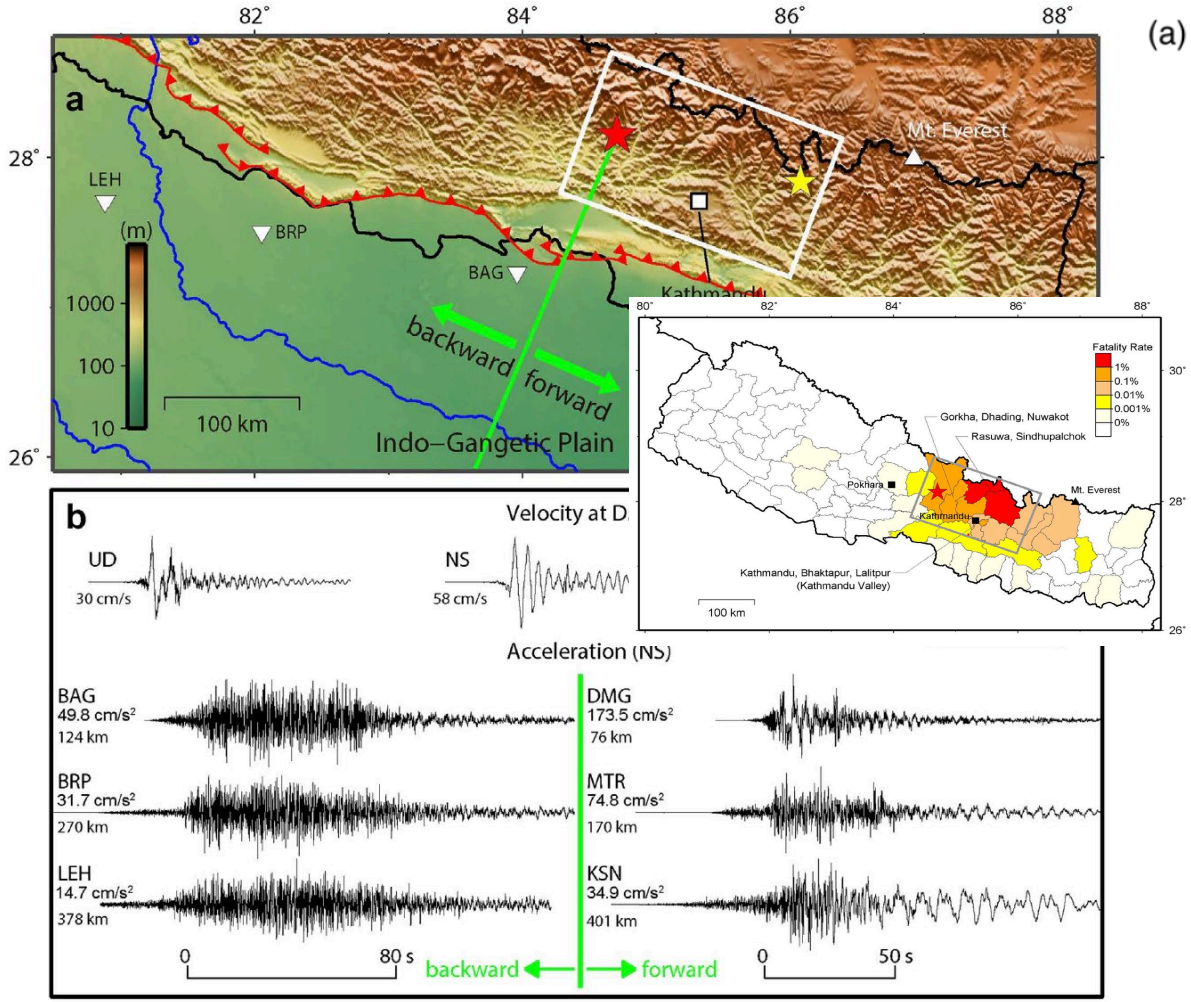
# Finite source effect




(Xiao and Yamada, 2021)

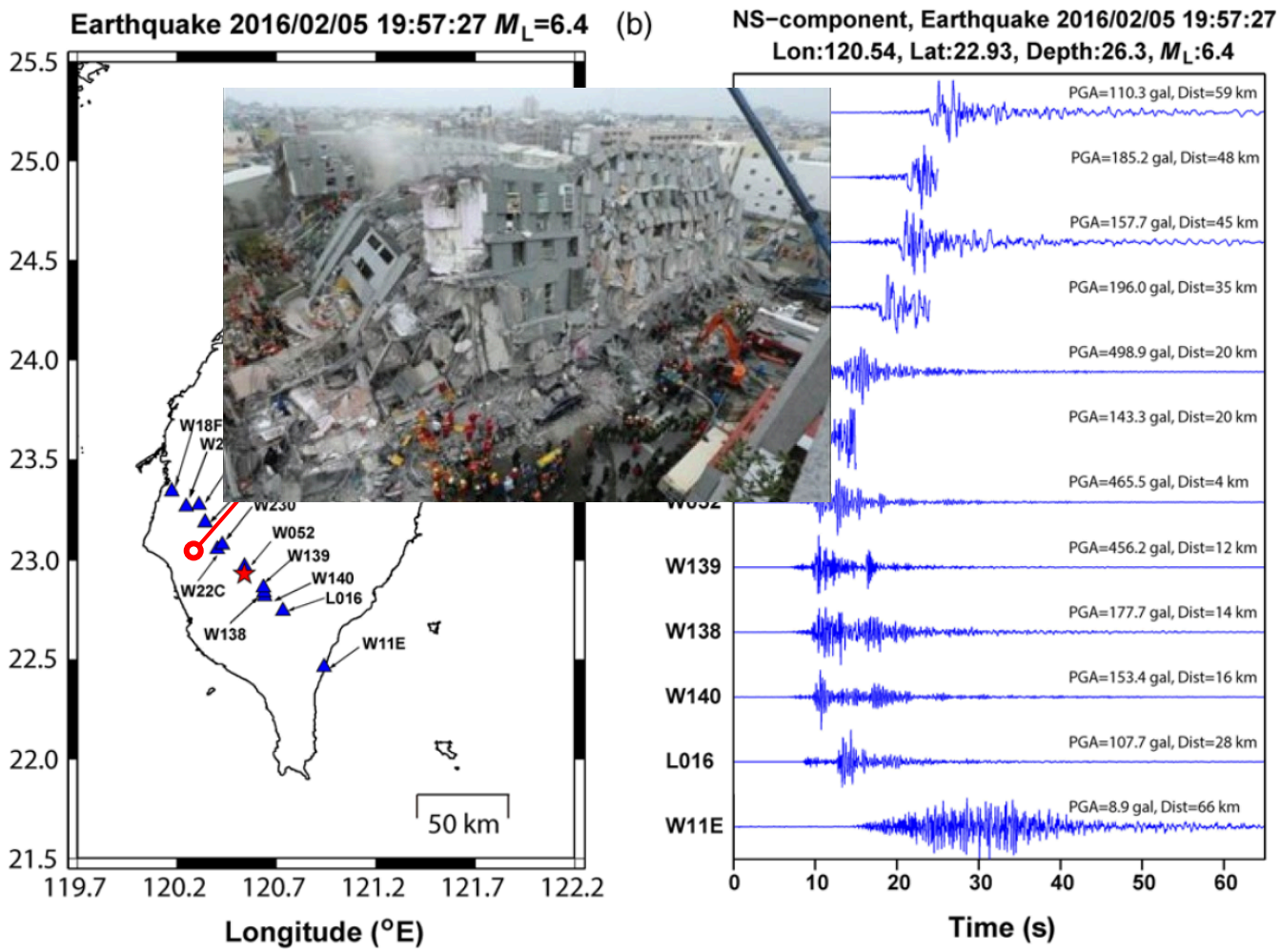
# Rupture directivity amplifies the ground shaking

2015 $M_W$7.8 Gorkha, Nepal earthquake



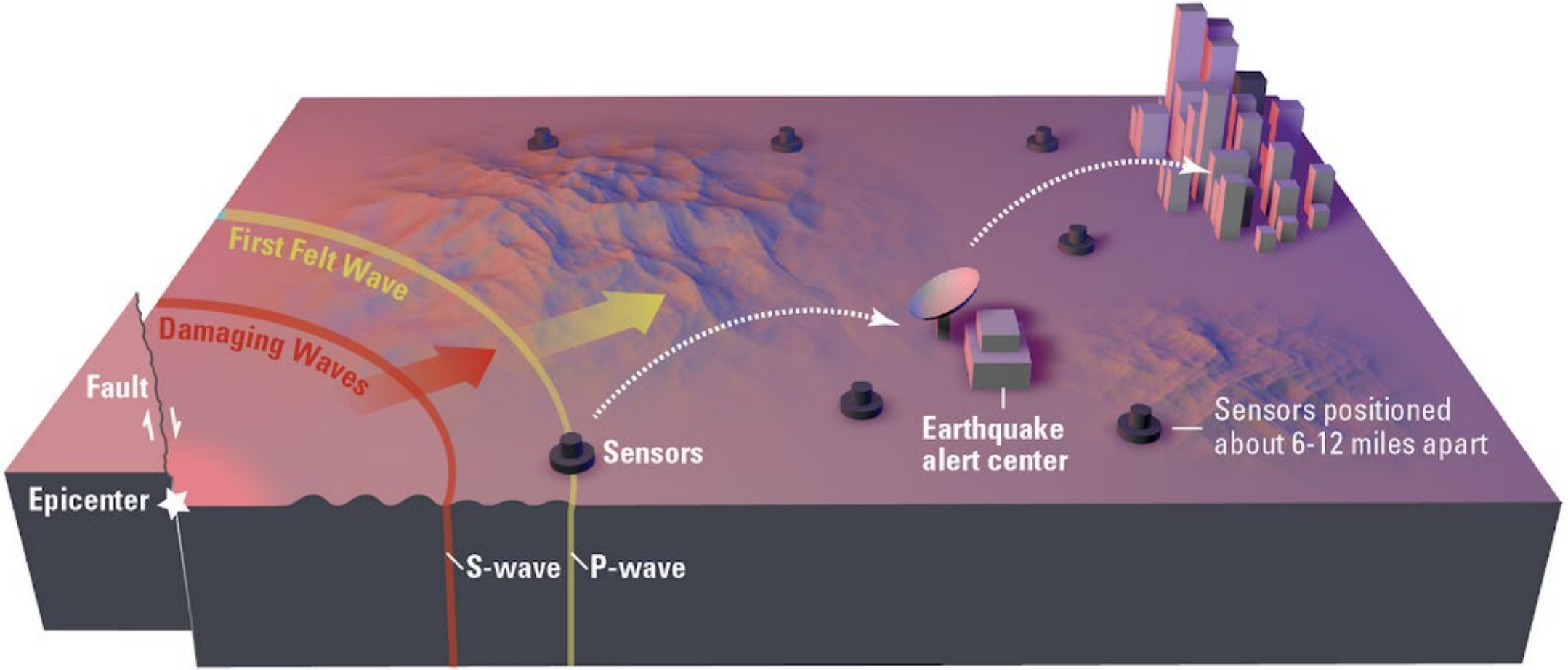

(Koketsu et al., 2016)

2016 $M_L$6.4 Meinong, Taiwan earthquake



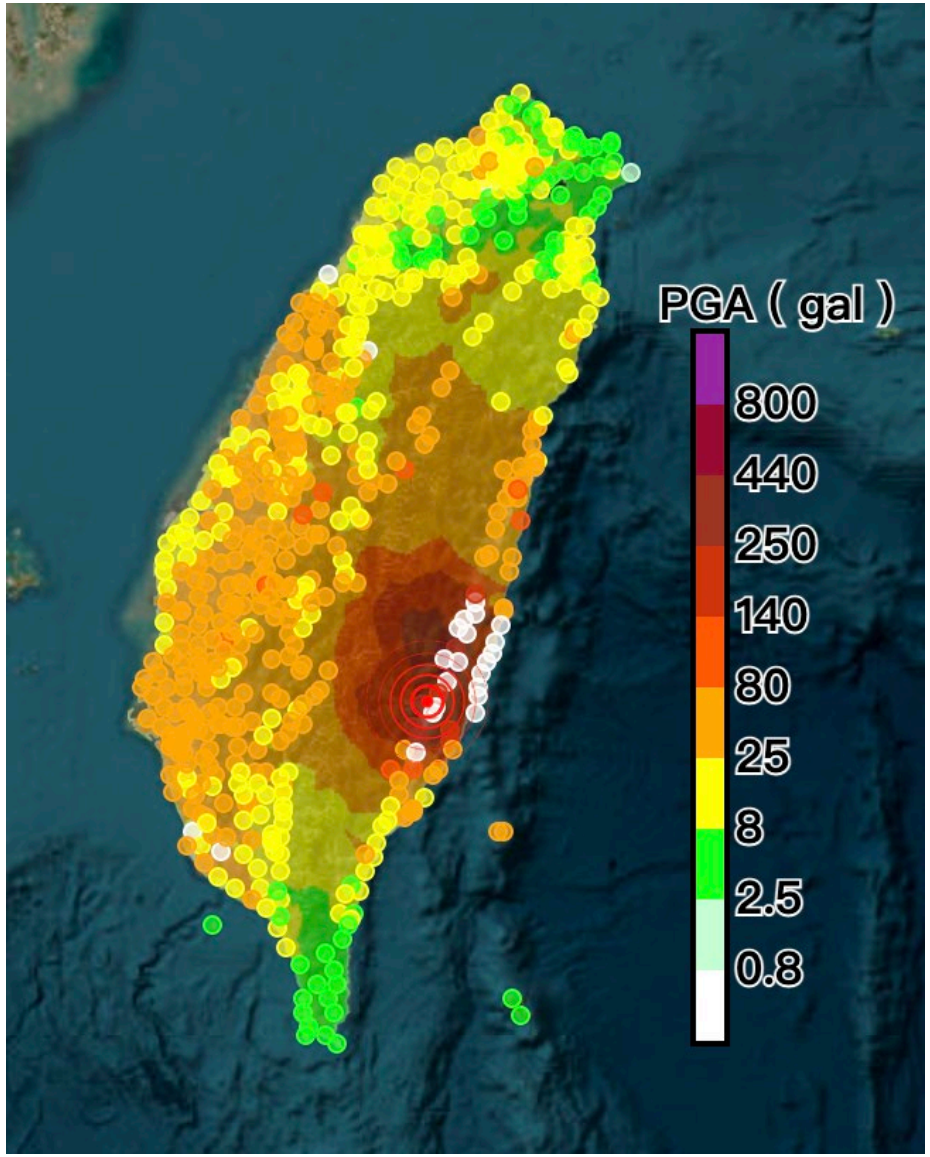

(Wu et al., 2016)

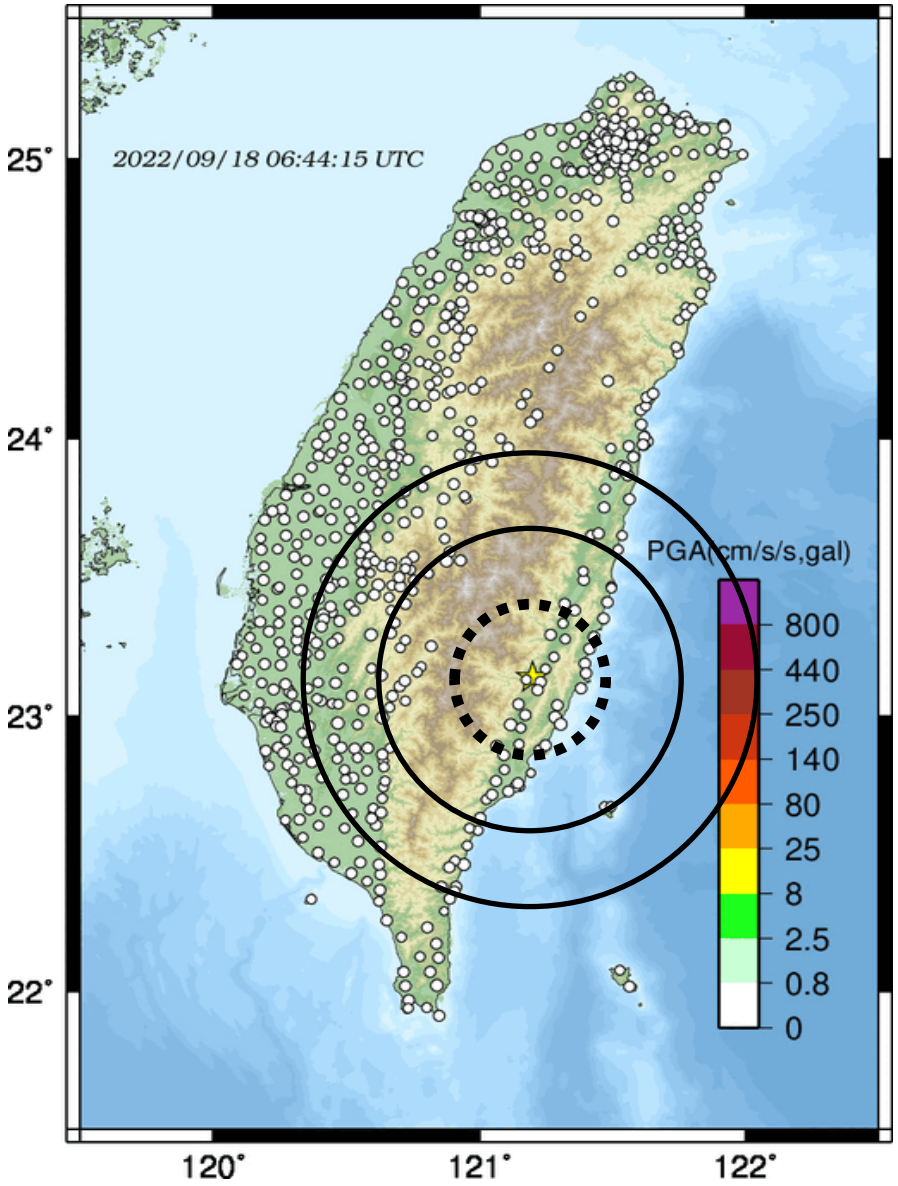
# Near-real-time estimation of source rupture parameters




**Using near-field ground motions to predict far-field ground motions!**

# Driectional ground motion characteristic from shake map

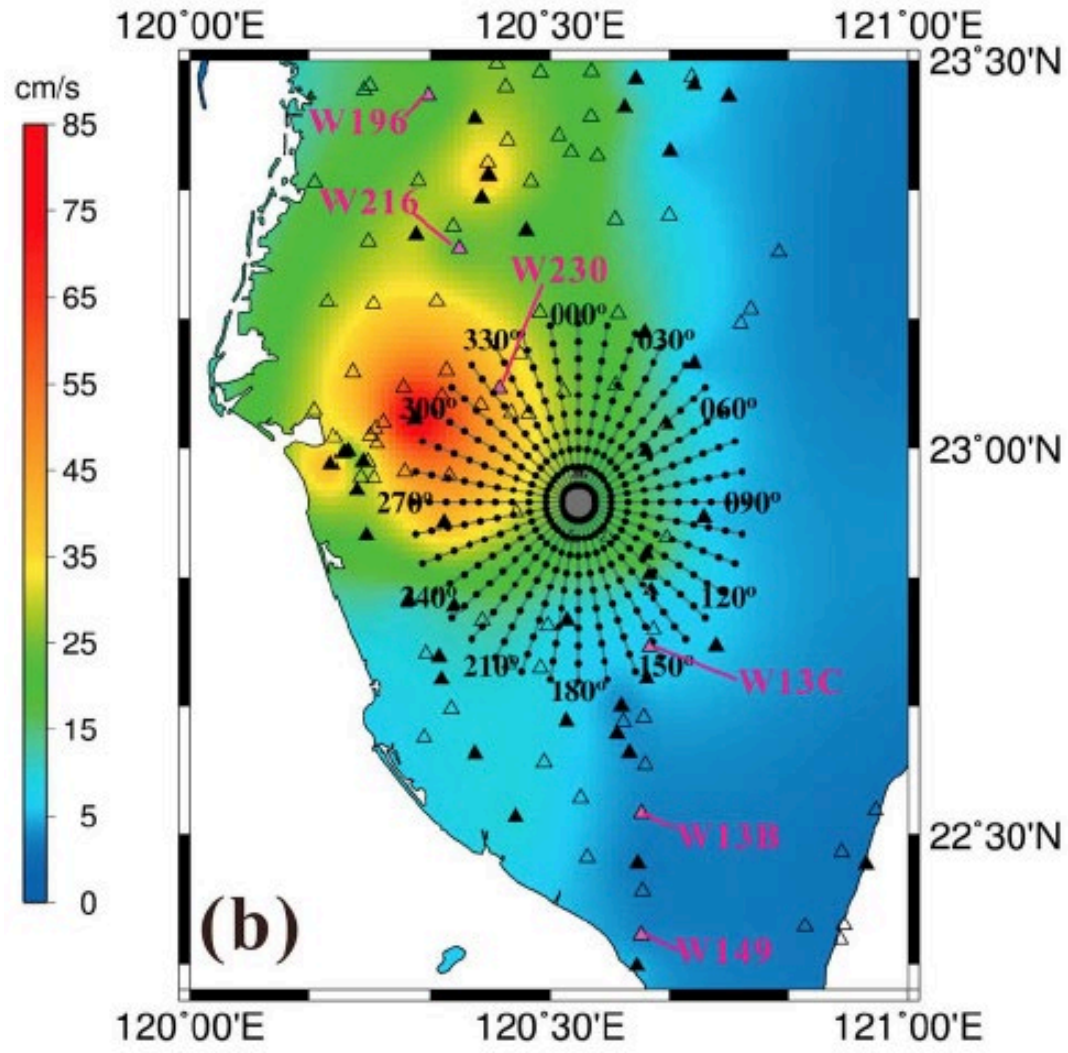


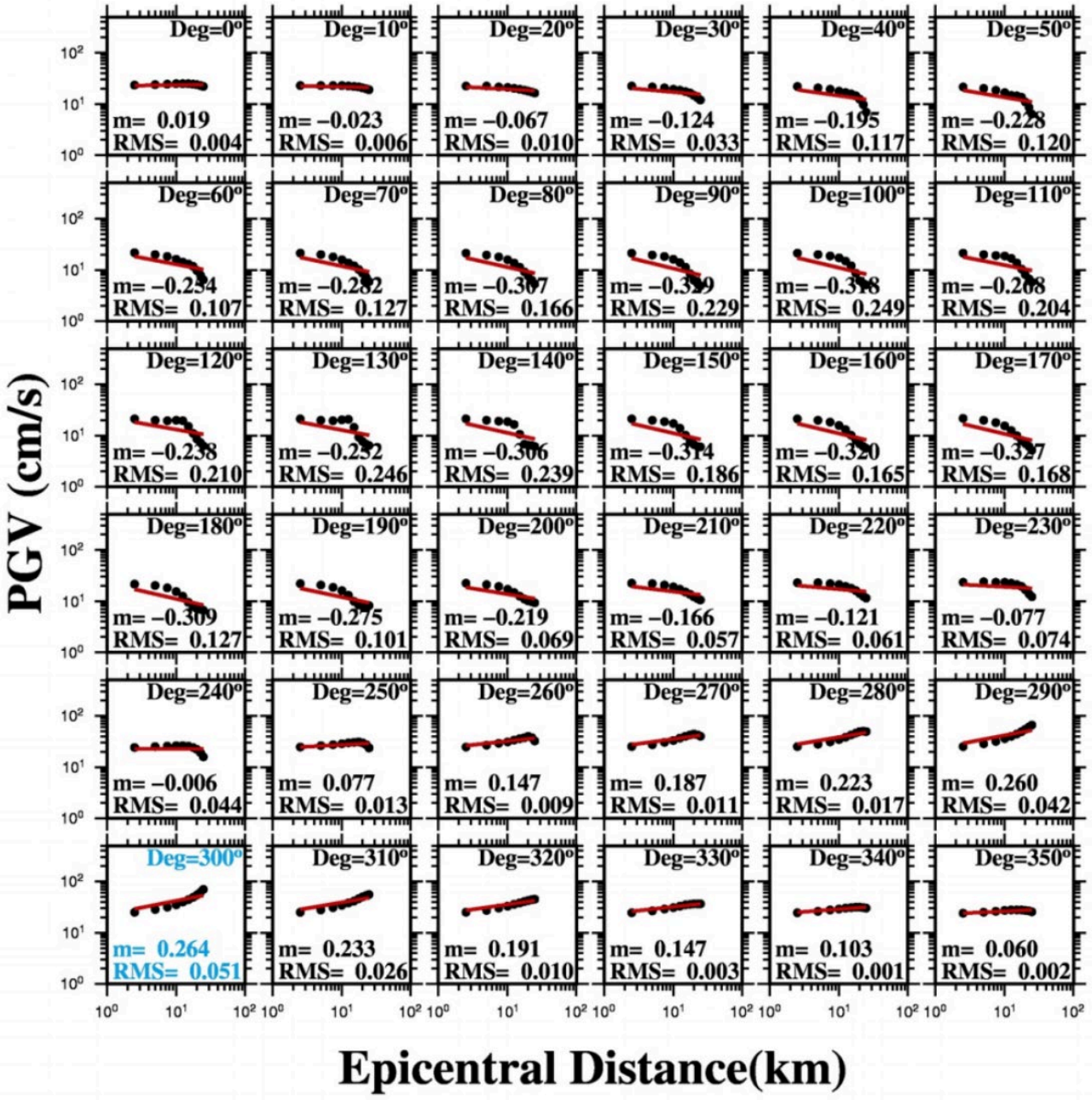

P-Alert Strong Motion Network (https://palert.earth.sinica.edu.tw/)

# **Method** – directional attenuation regression

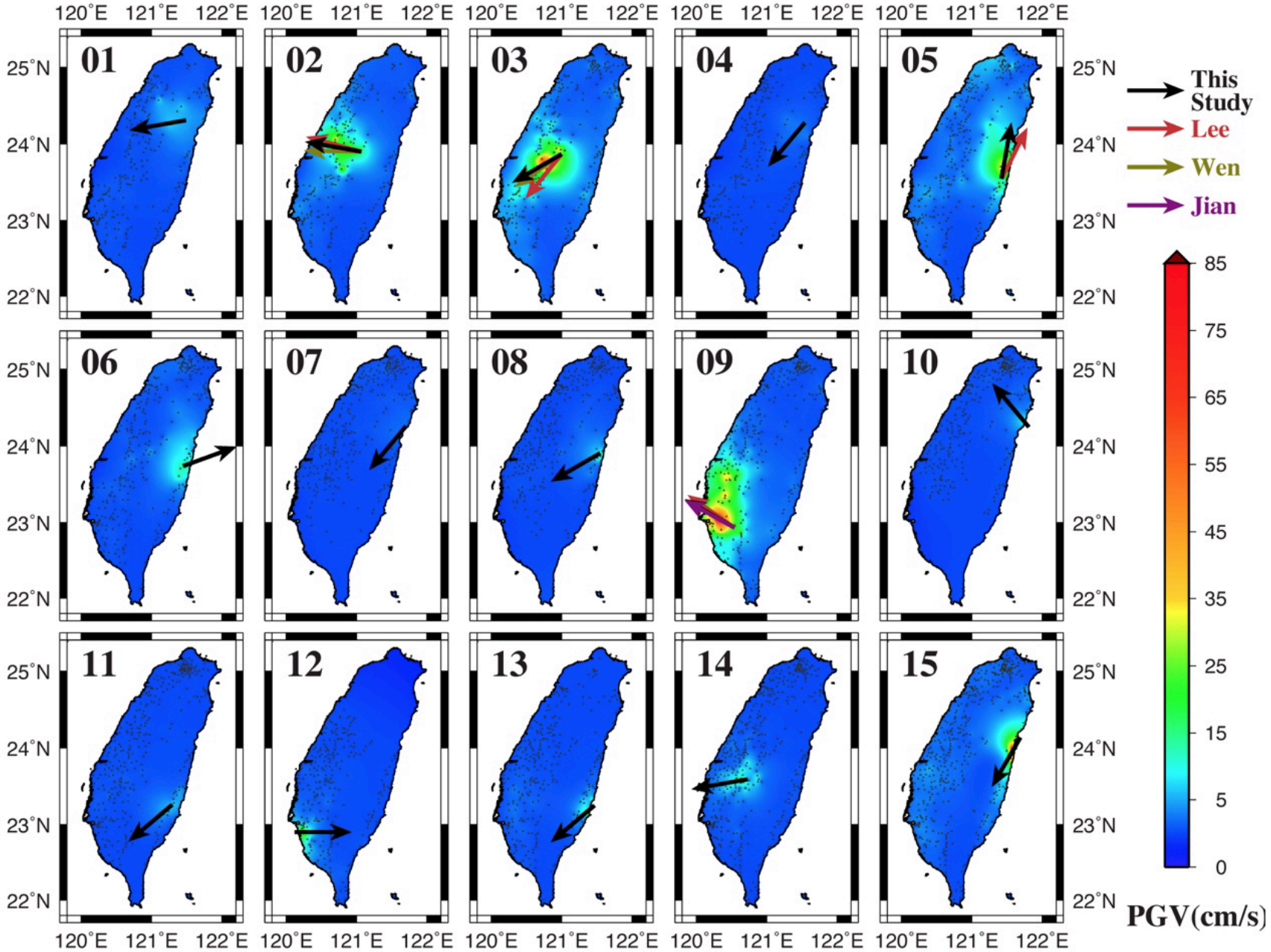
$$log(A) = log(A_0) + m\, log(R)$$




(Jan et al., 2018)



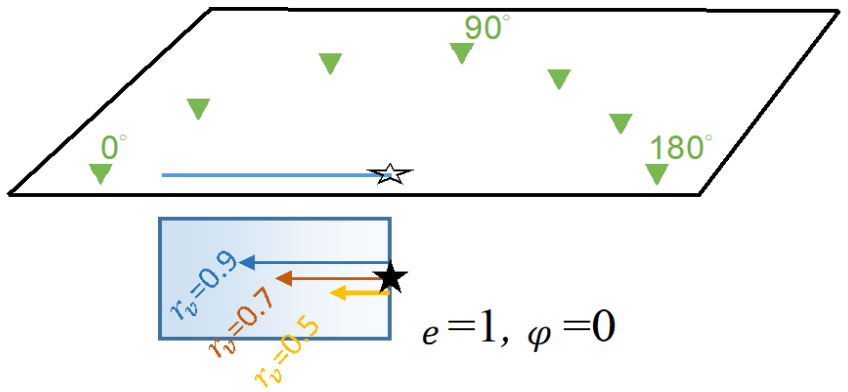
# Directivity results and validation



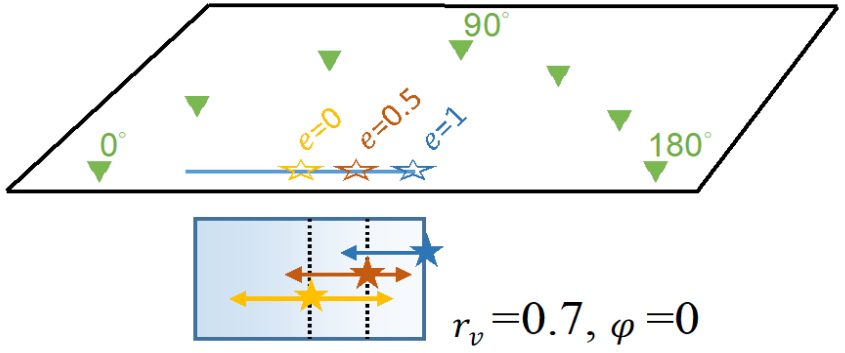
# Directivity function *Cd*

$$C_d = \frac{1}{2}\sqrt{\frac{(1+e)^2}{(1-r_v\cos(\theta))^2} + \frac{(1-e)^2}{(1+r_v\cos(\theta-\varphi))^2}}$$

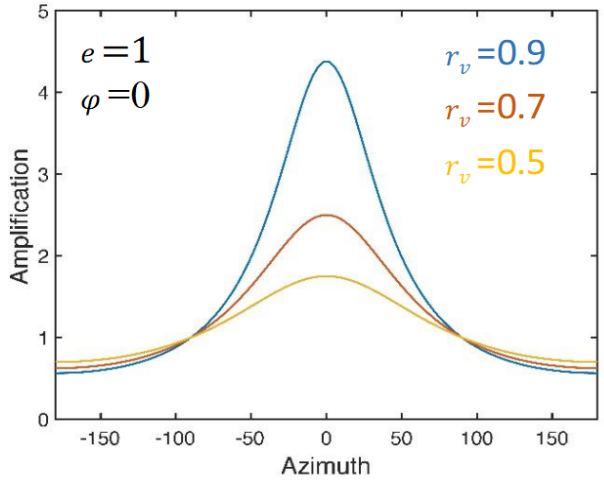
(a) Rupture velocity ratio



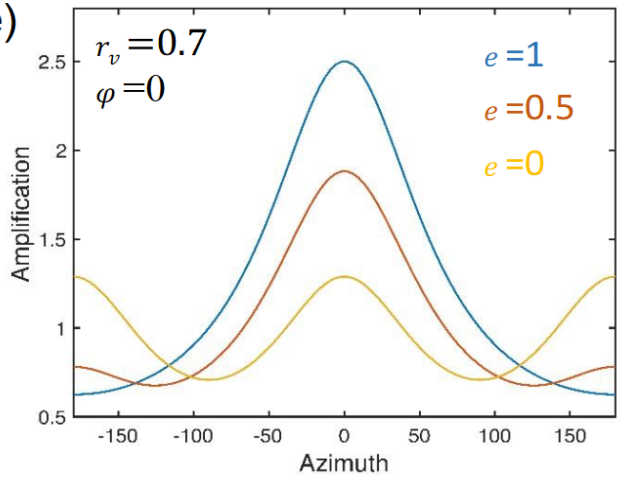

(b) Percent unilateral rupture



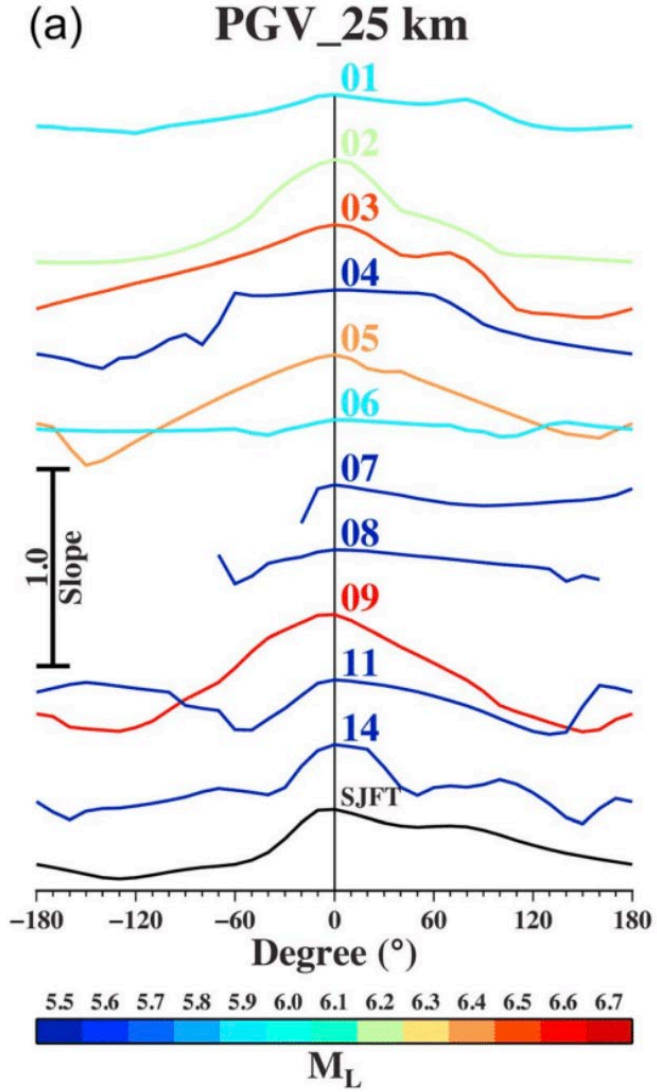

(d)




(e)




(Boatwright, 2007; Convertito et al., 2012)



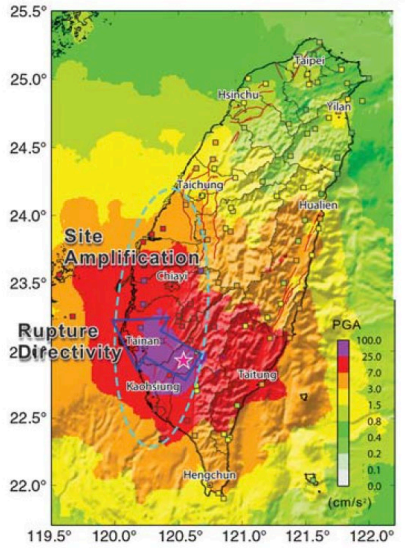

(Jan et al., 2018)

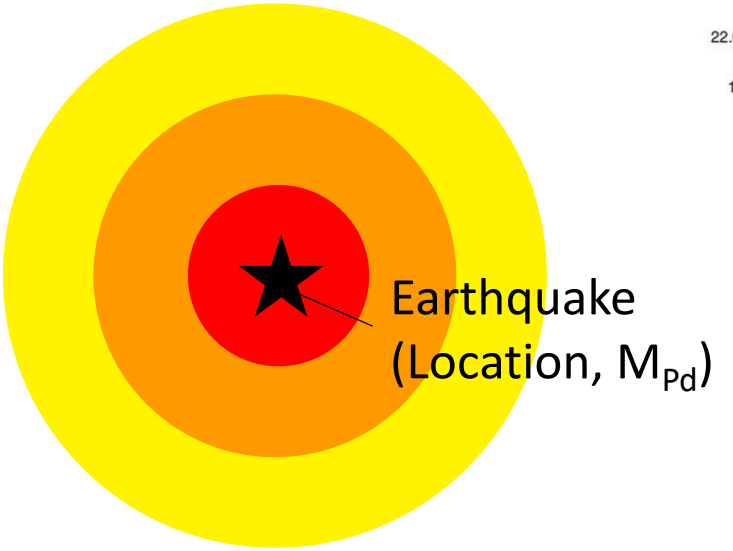
# Near-field ground motion inversion

– EEW gives earthquake location & $M_{Pd}$ (CWA)

– GMPE (Hsiao, 2006)

$$PGA = 1.657 \times e^{1.533 \times M} \times r^{-1.607} \times S_i$$



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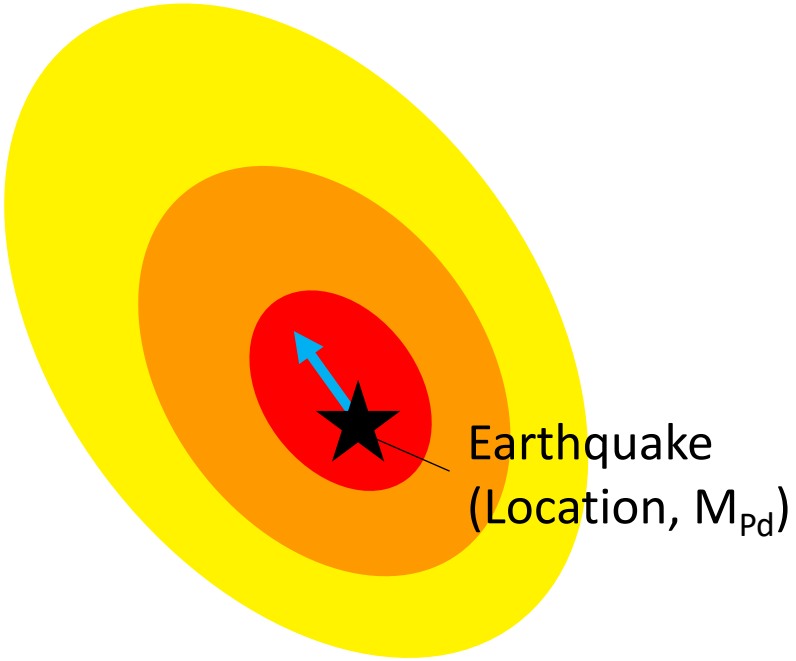
– Search $\theta$ and *rv*

$$PGA' = PGA \times Cd(\theta, rv)$$

$$C_d = \frac{1}{2}\sqrt{\frac{(1+e)^2}{(1-r_v\cos(\theta))^2} + \frac{(1-e)^2}{(1+r_v\cos(\theta-\varphi))^2}}$$



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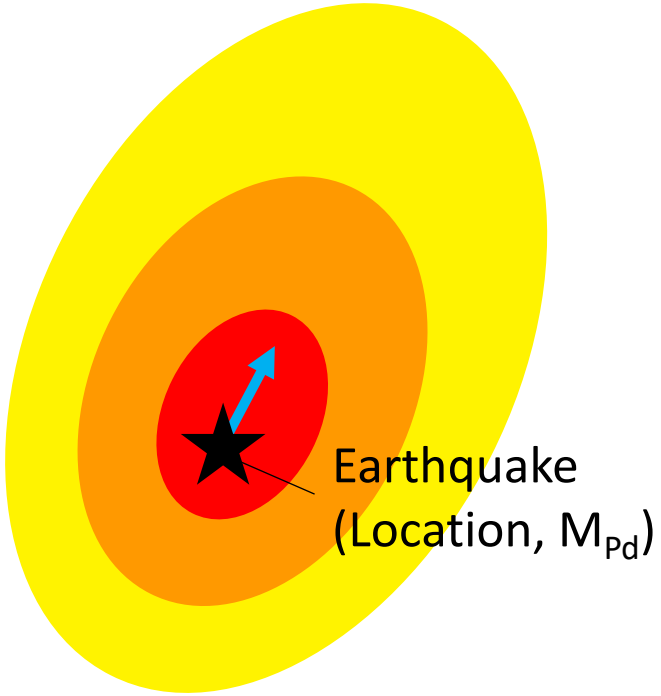

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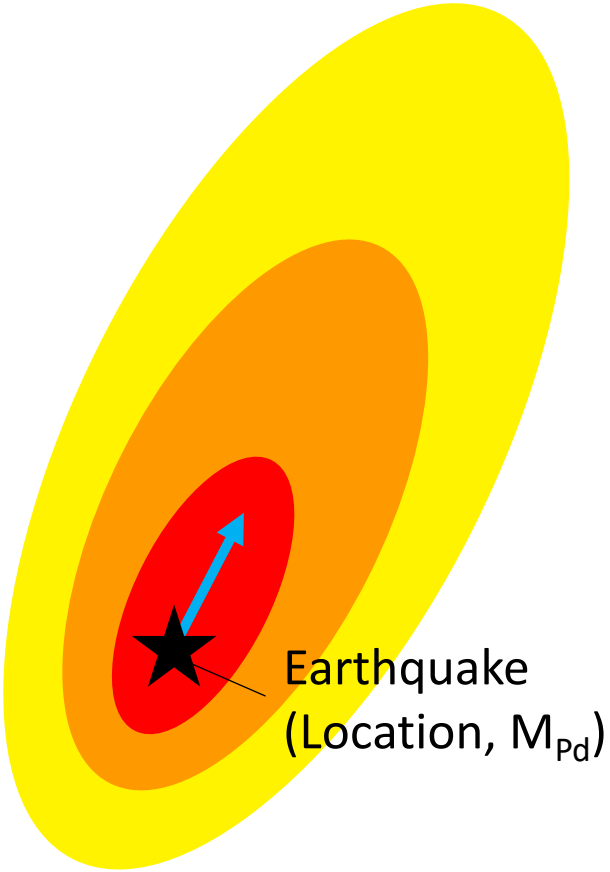
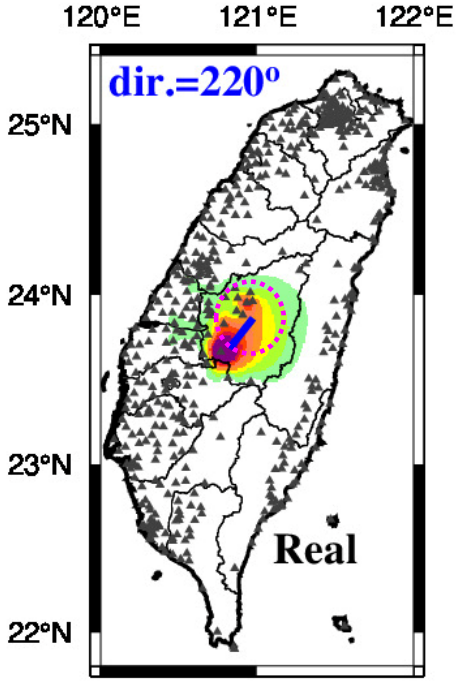
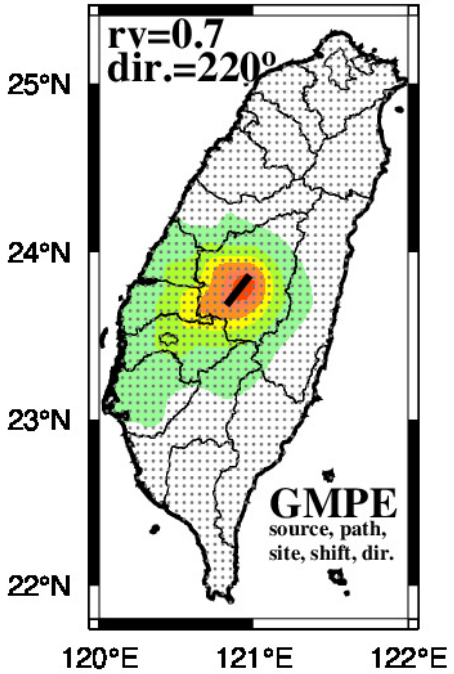
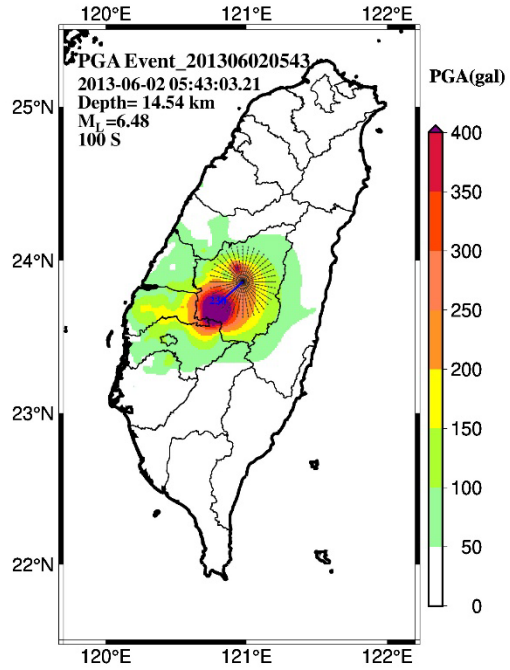


# Finite source effect

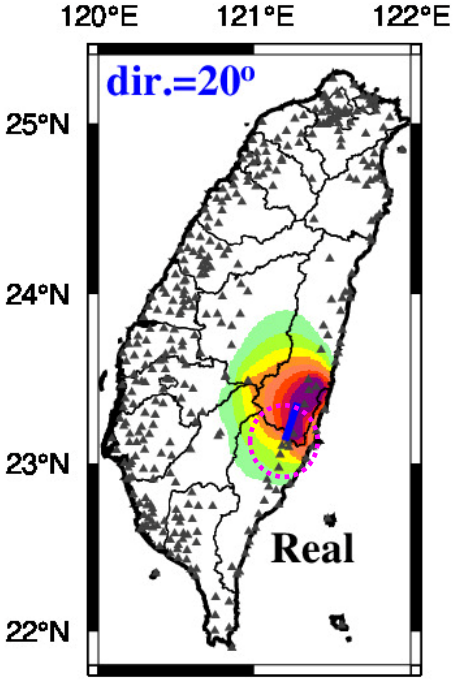
20230602 $M_L$6.4
Nantou Earthquake

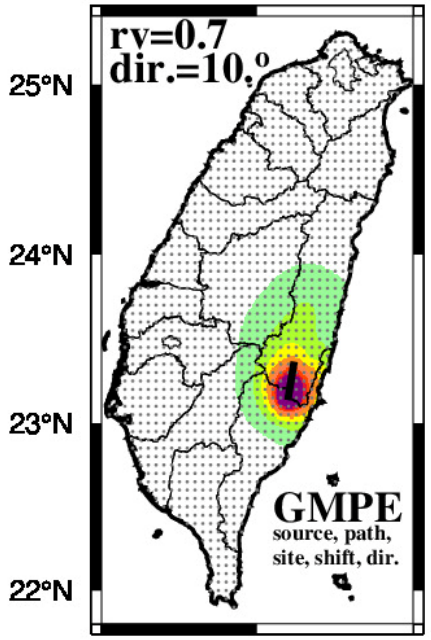


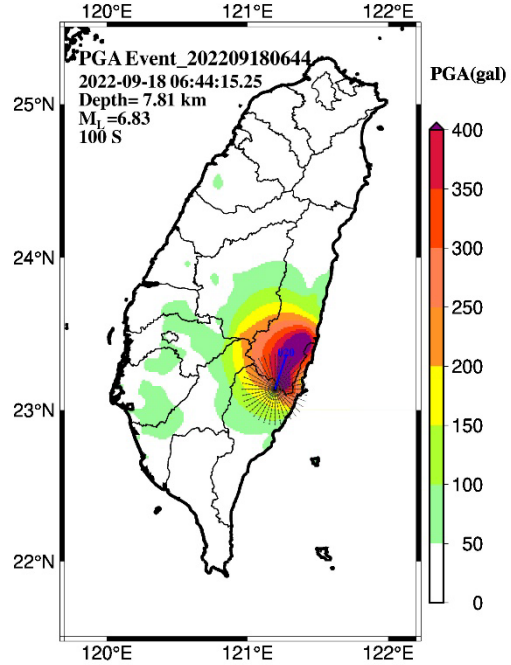




20220918 $M_L$6.8
Chihshang Earthquake



# Line-source Near-field ground motion inversion

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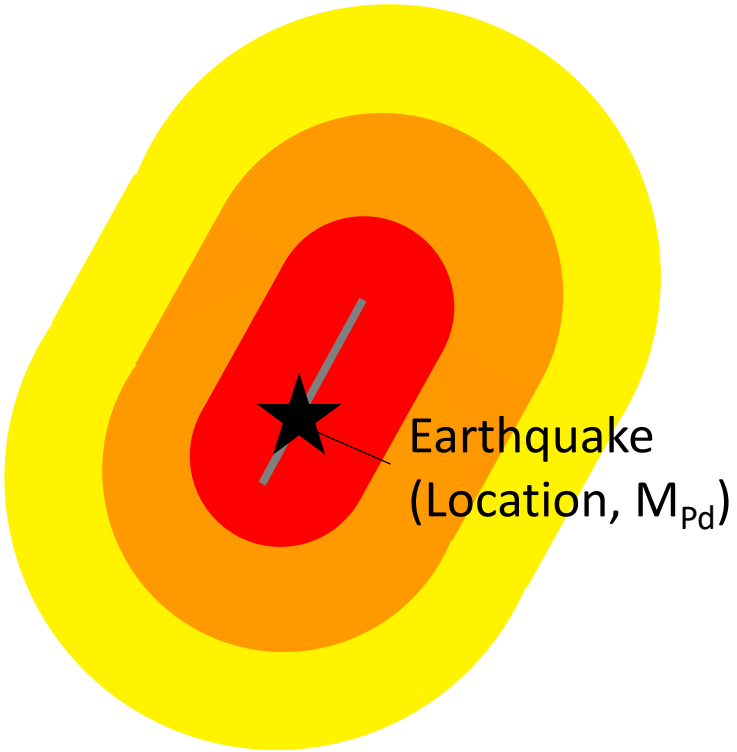
– Finite fault length *L*
(Wells and Coppersmith, 1994)



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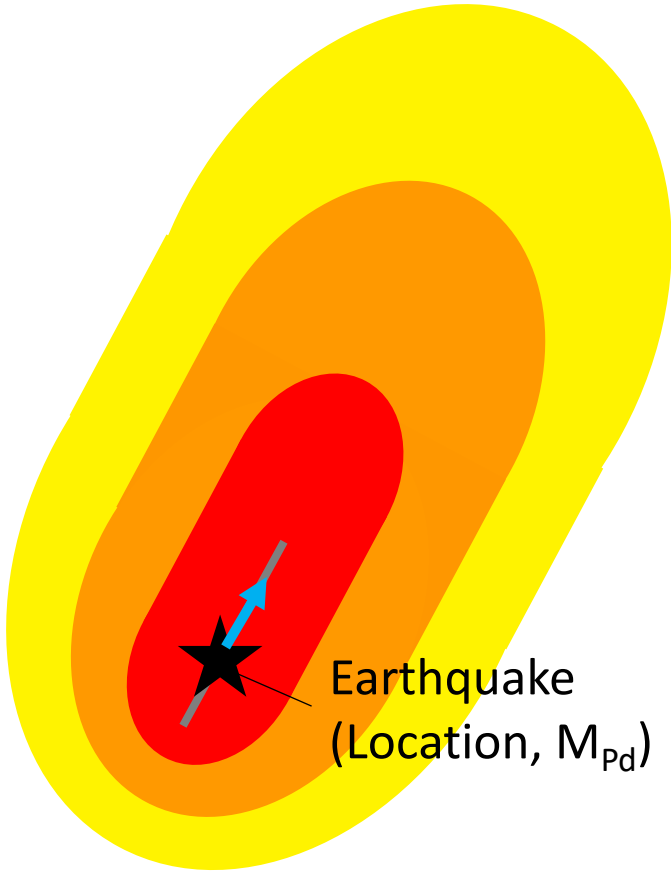
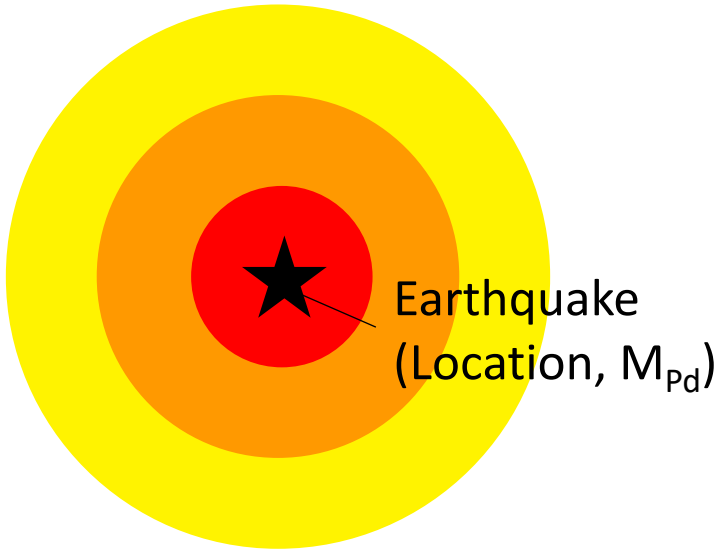
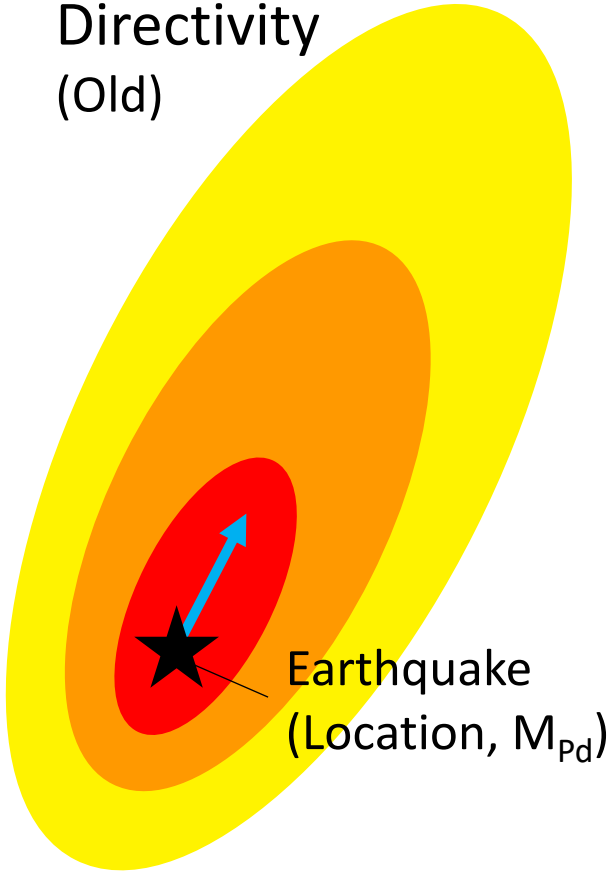


# Line-source Near-field ground motion inversion

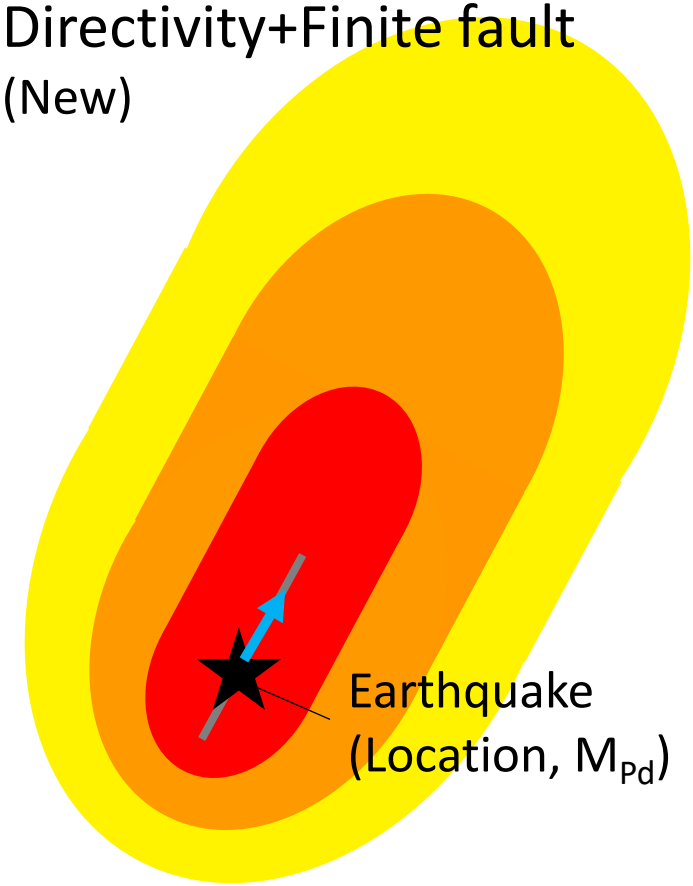
Point source
(Conventional)




Directivity
(Old)



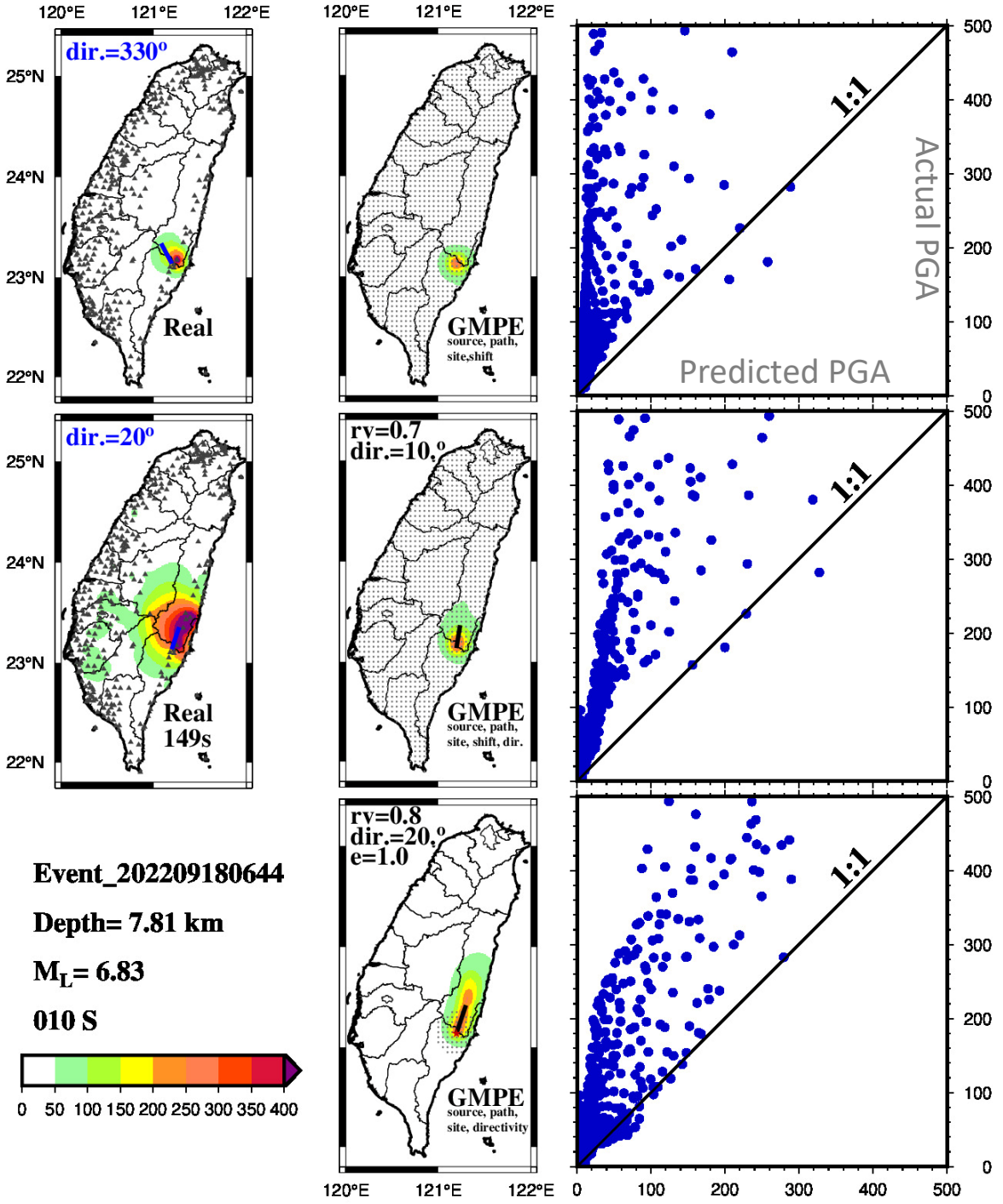

Directivity+Finite fault
(New)



# Ground motion prediction

– 20220918 $M_L$6.8 ChihShang EQ

– 10-s snapshot




Point source (Conventional)

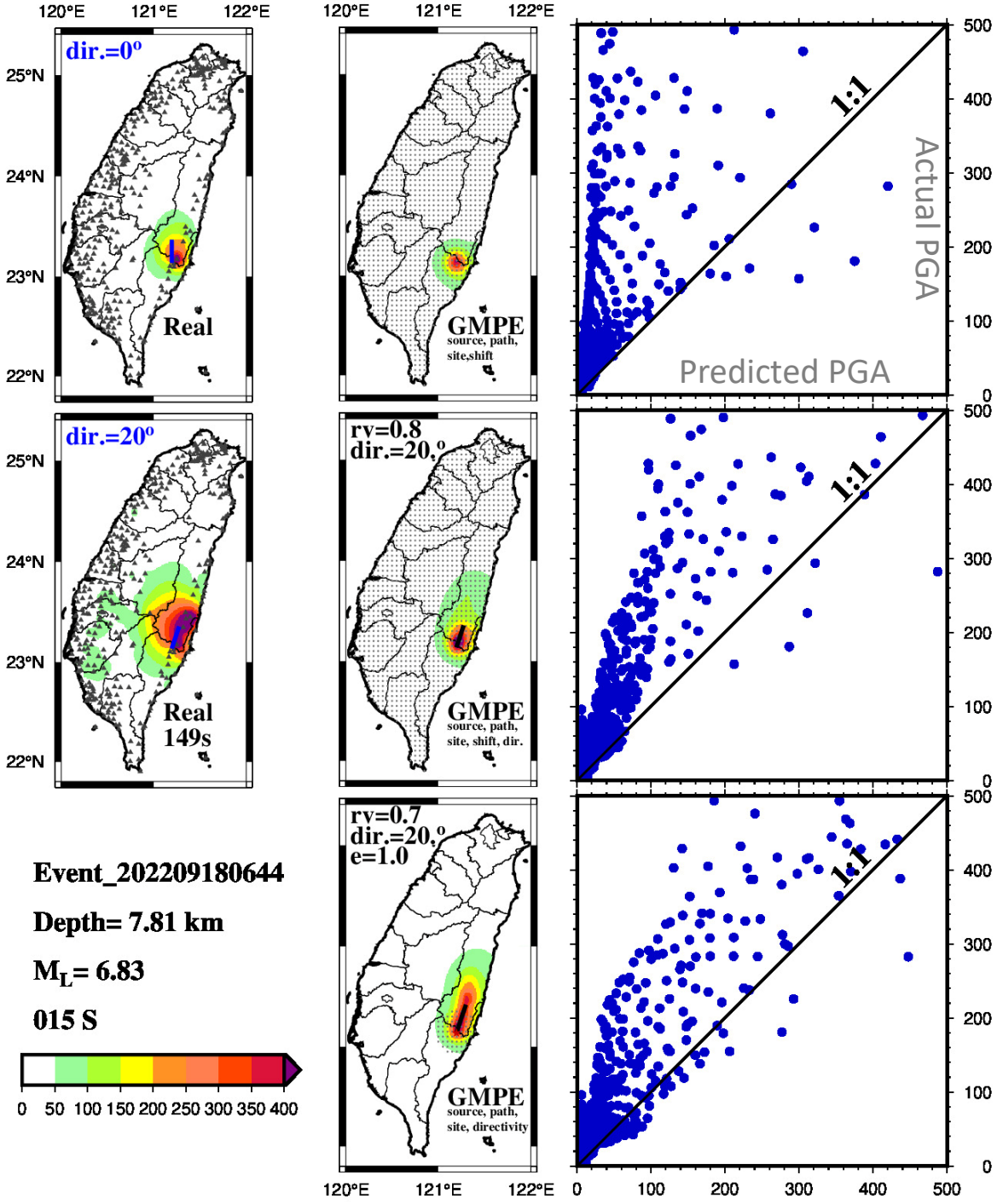
Directivity

Directivity+Line source

# Ground motion prediction

– 20220918 $M_L$6.8 ChihShang EQ

– 15-s snapshot




Point source (Conventional)

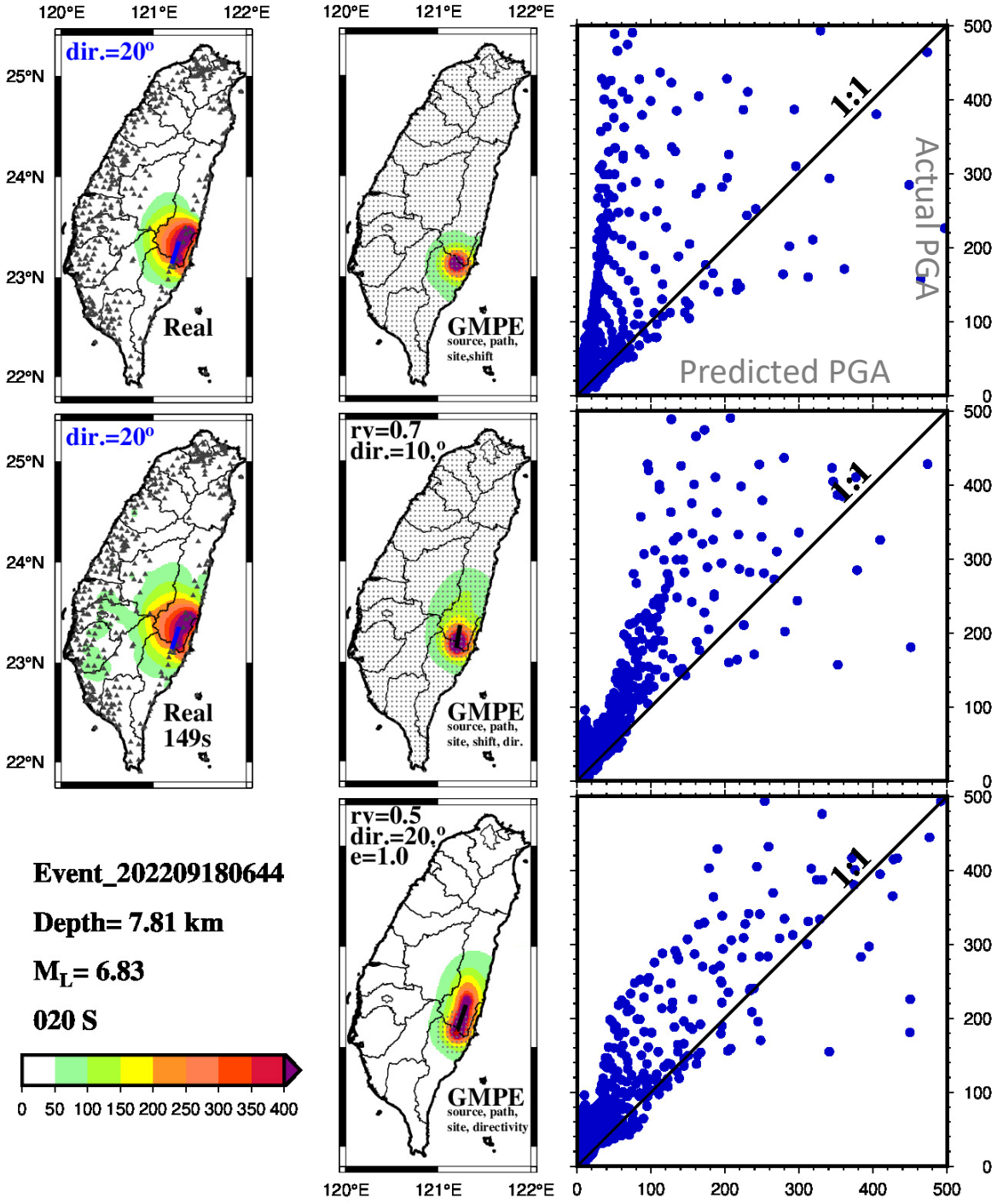
Directivity

Directivity+Line source

# Ground motion prediction

– 20220918 $M_L$6.8 ChihShang EQ

– 20-s snapshot




Point source (Conventional)

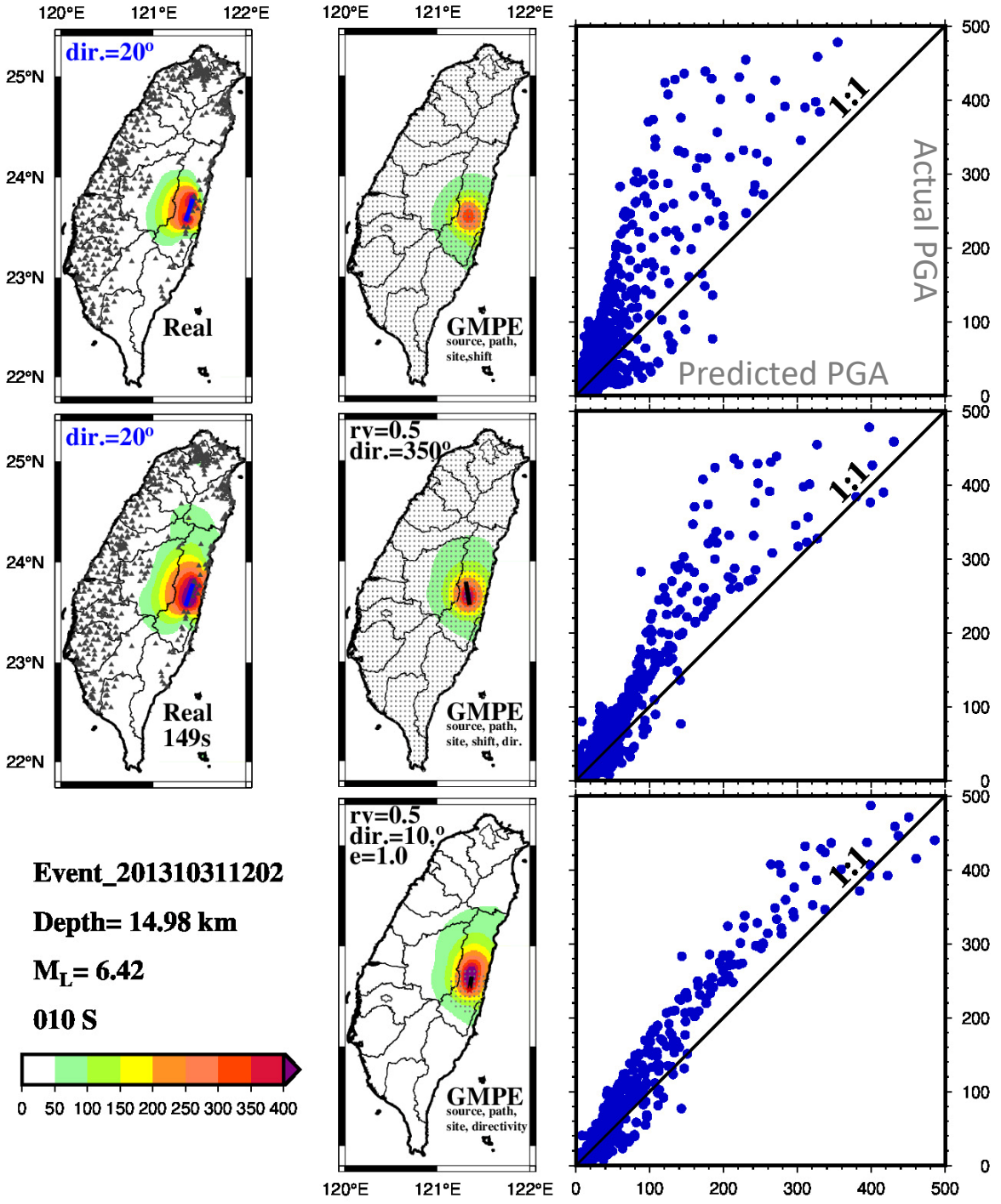
Directivity

Directivity+Line source

# Ground motion prediction

– 20131031 $M_L$6.4 Ruisui EQ

– 10-s snapshot




Point source (Conventional)

Directivity

Directivity+Line source

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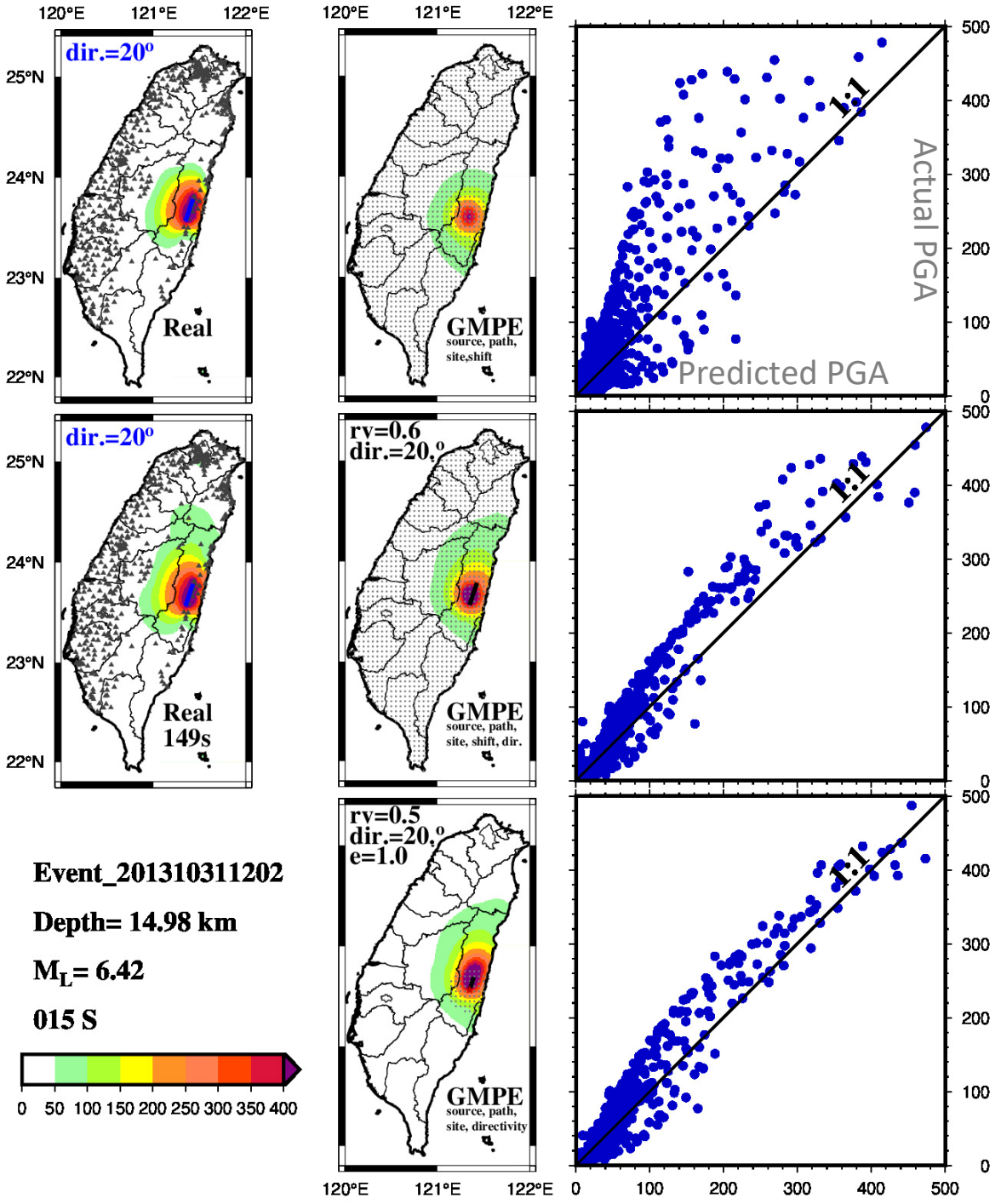
– 15-s snapshot




Point source (Conventional)

Directivity

Directivity+Line source

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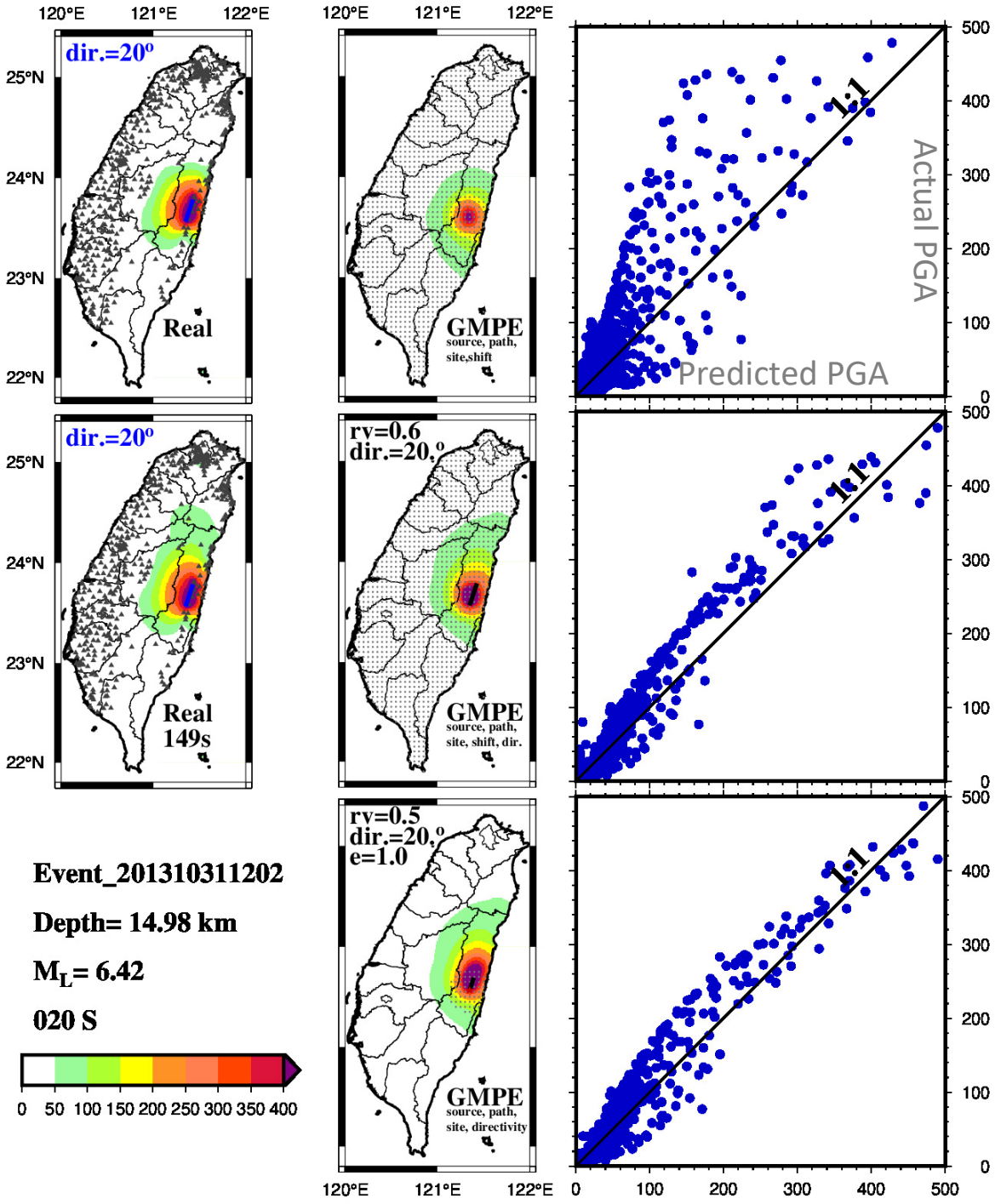



Point source (Conventional)

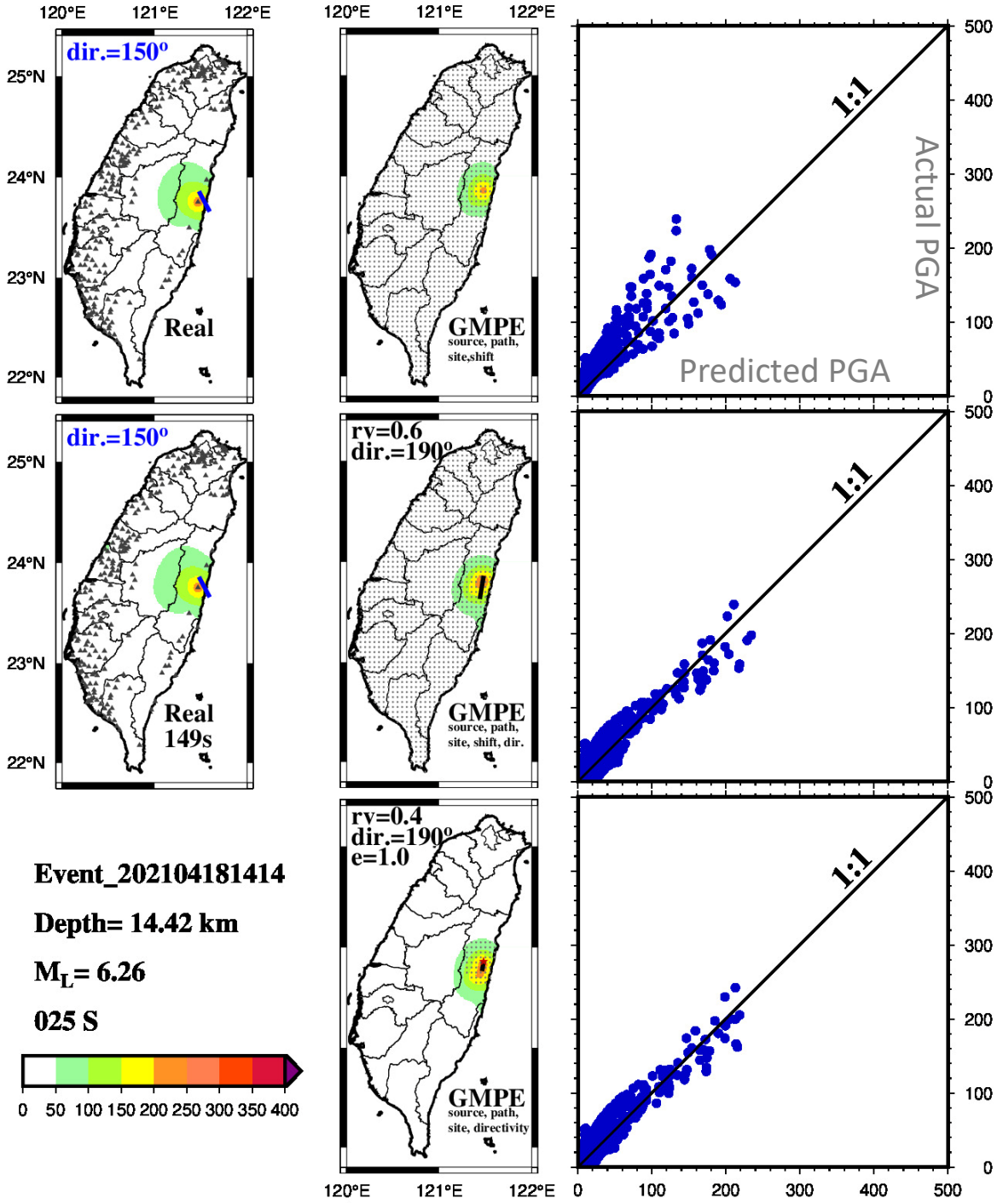
Directivity

Directivity+Line source

# Ground motion prediction

– 20210418 $M_L$6.2 Hualien EQ

– 25-s snapshot



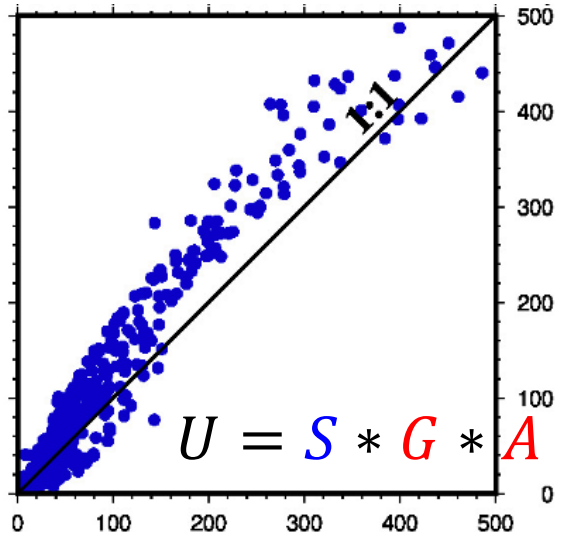

Point source (Conventional)

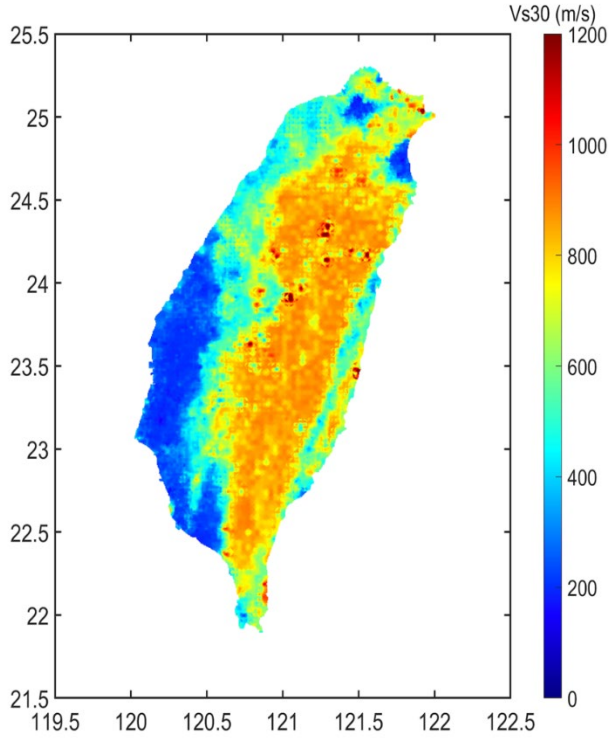
Directivity

Directivity+Line source

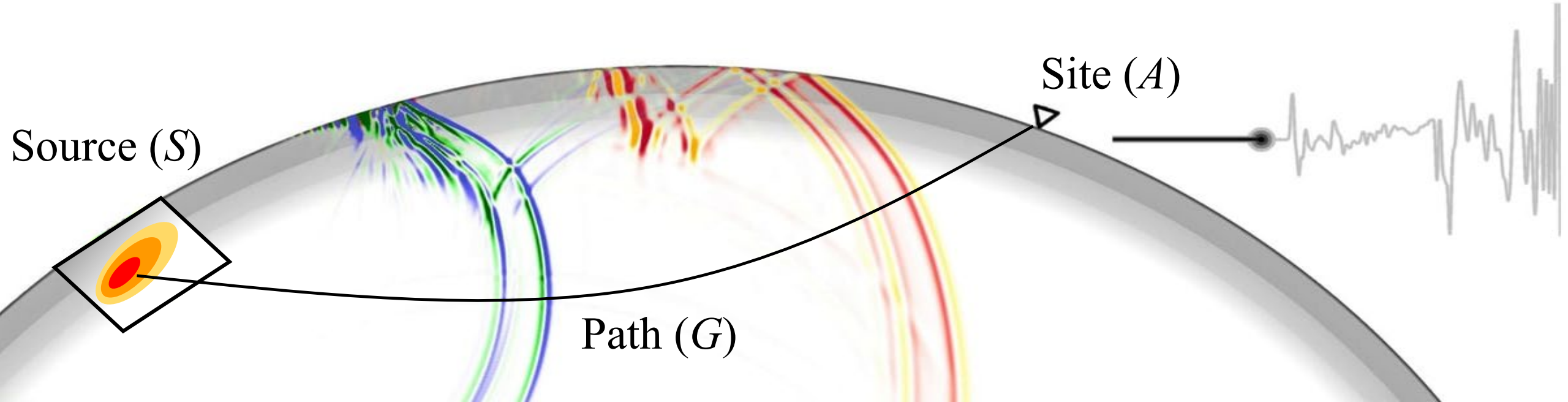
# Summary and future works

- Rupture directivity could be rapidly estimated by near-field ground motion inversion and incorporated into EEW system
- Including finite source effect performs better for the events with $M_L \geq 6.5$ in general
- Further analyses of ground motion prediction results are needed (e.g. intensity, district prediction, different GMPEs)
- New GMPE with built directivity and latest high-resolution Vs30 data will be performed
- Practical validation of EEW offline tests



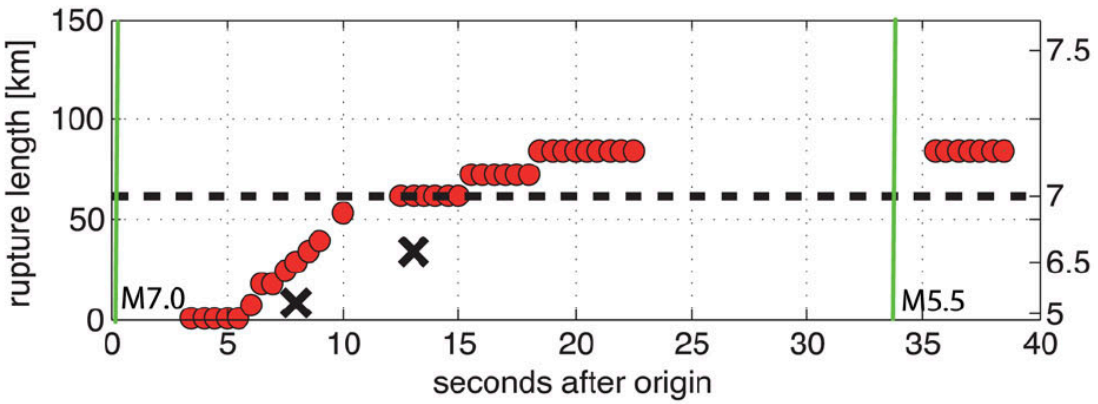



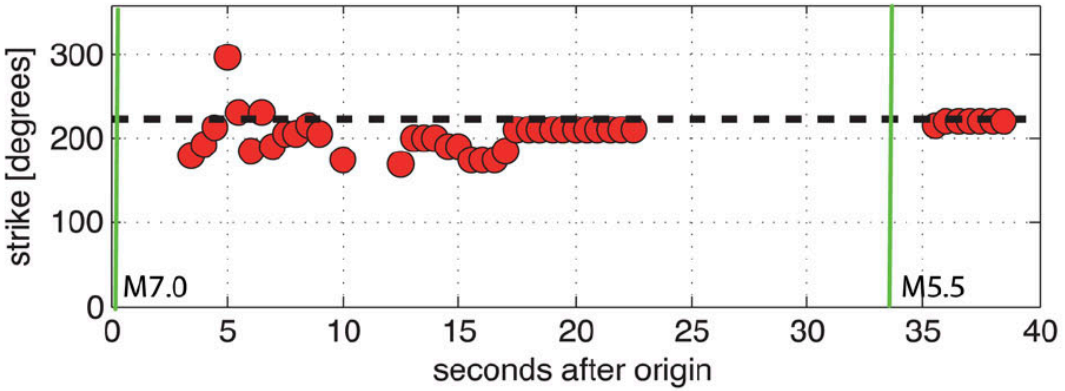
# *Thanks for your attention!*



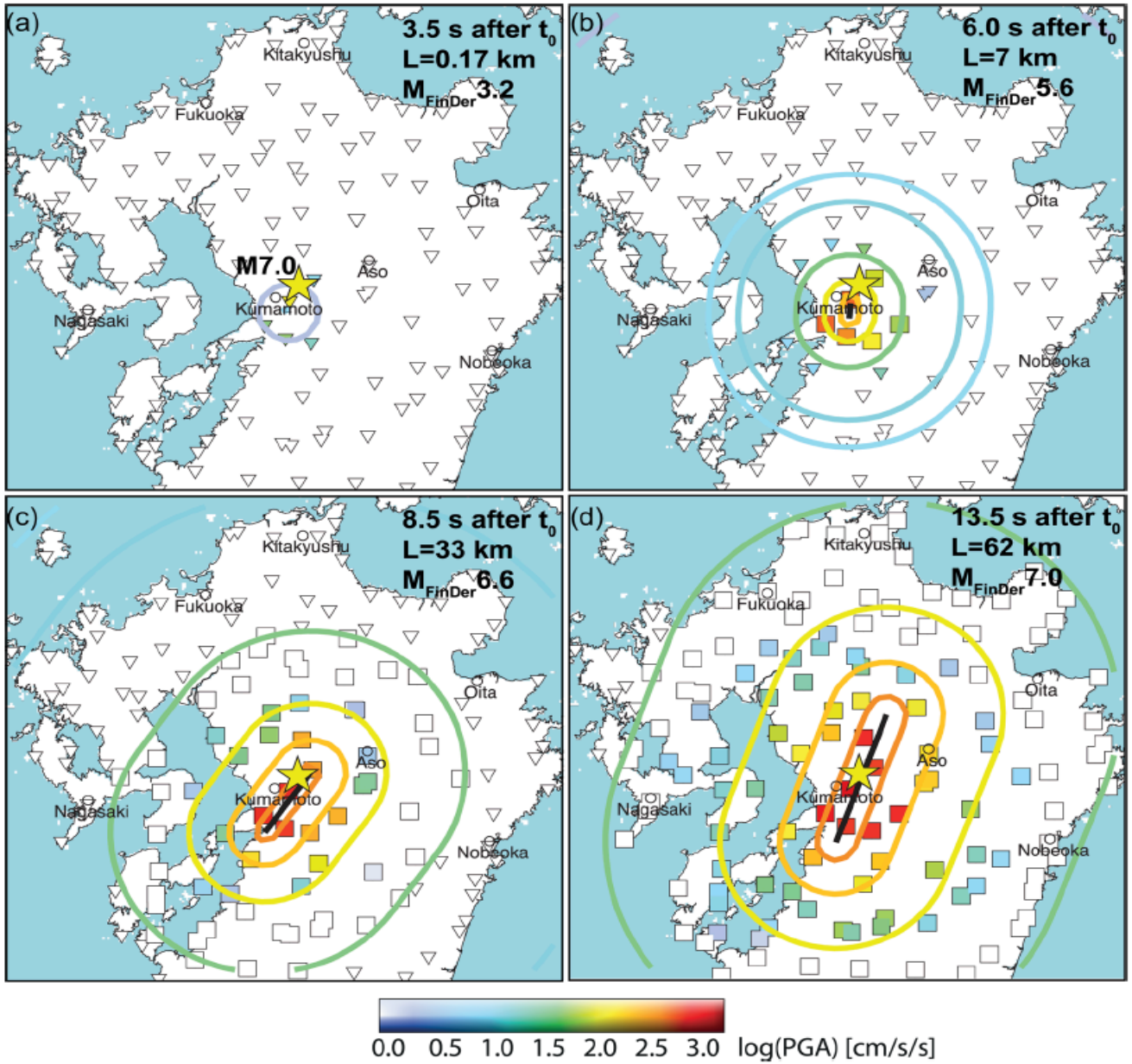
# Finite source effect on the ground shaking

2016 $M_W$7.0 Kumamoto earthquake

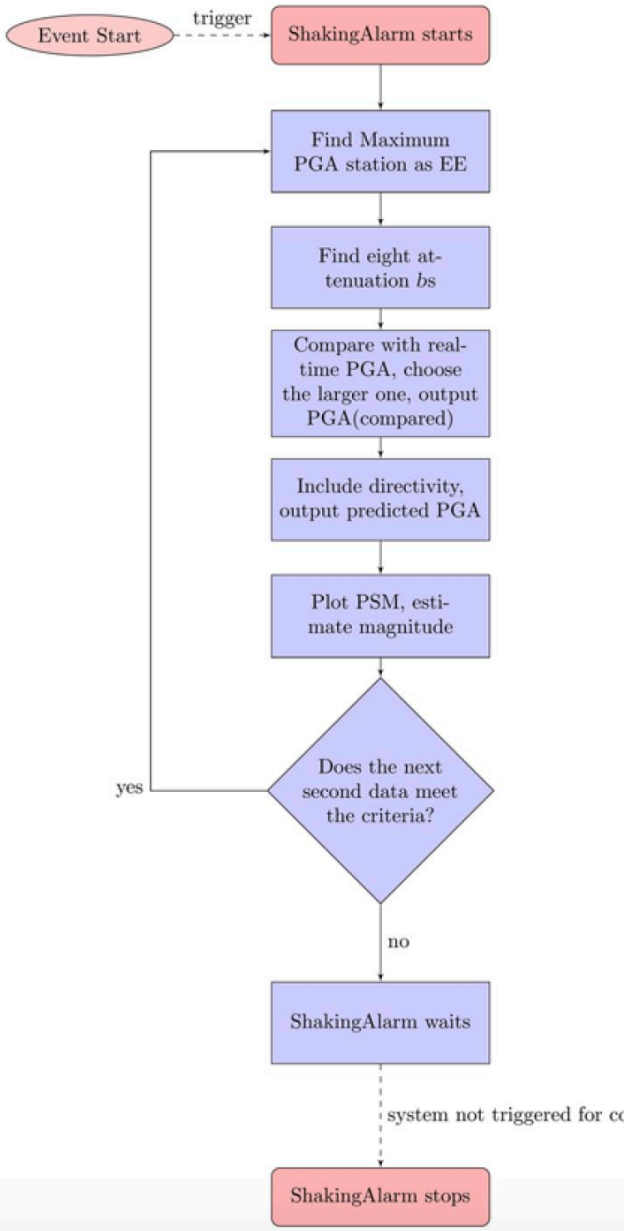


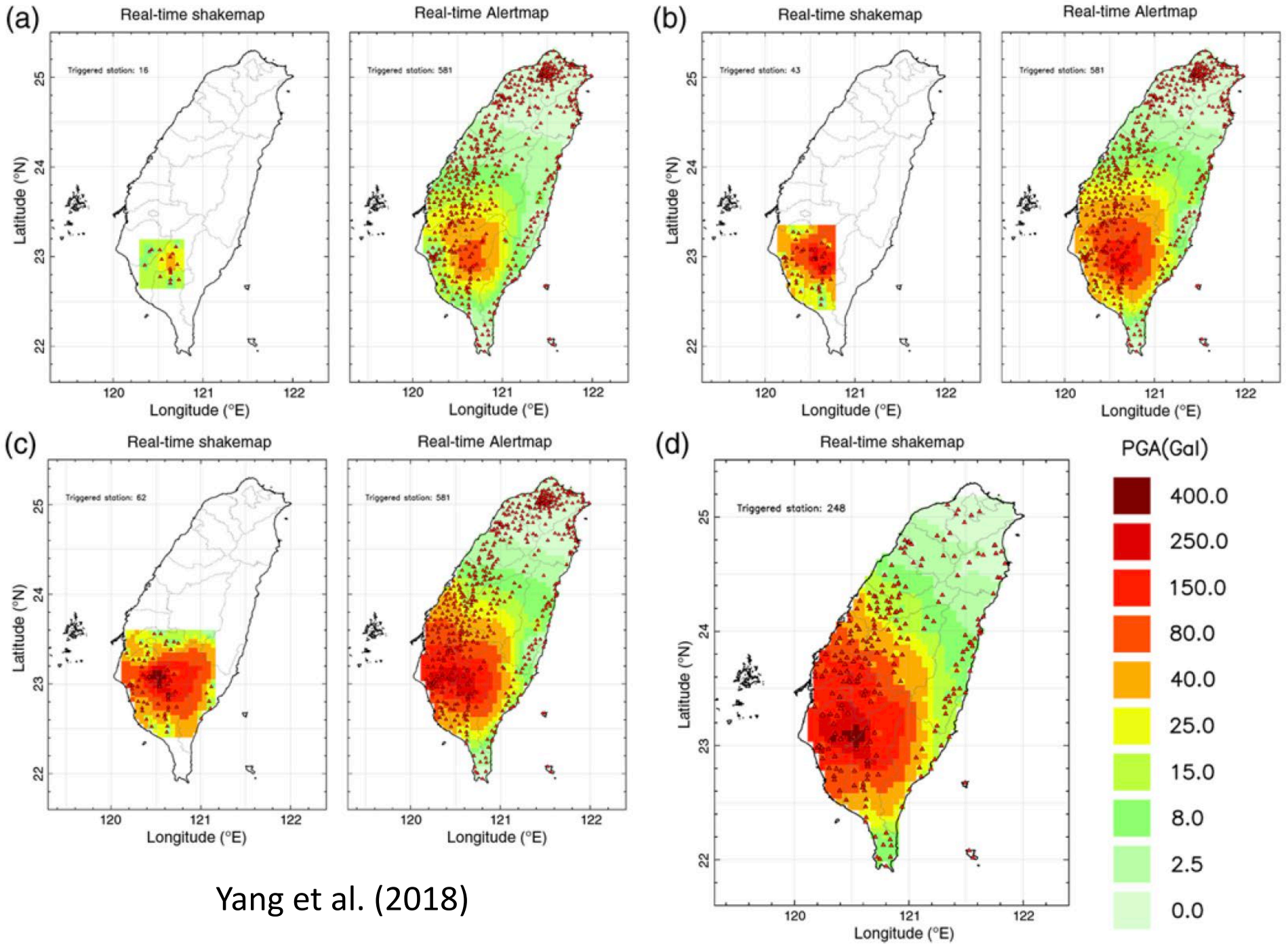




(Bose et al., 2015; 2018)



# ShakingAlarm



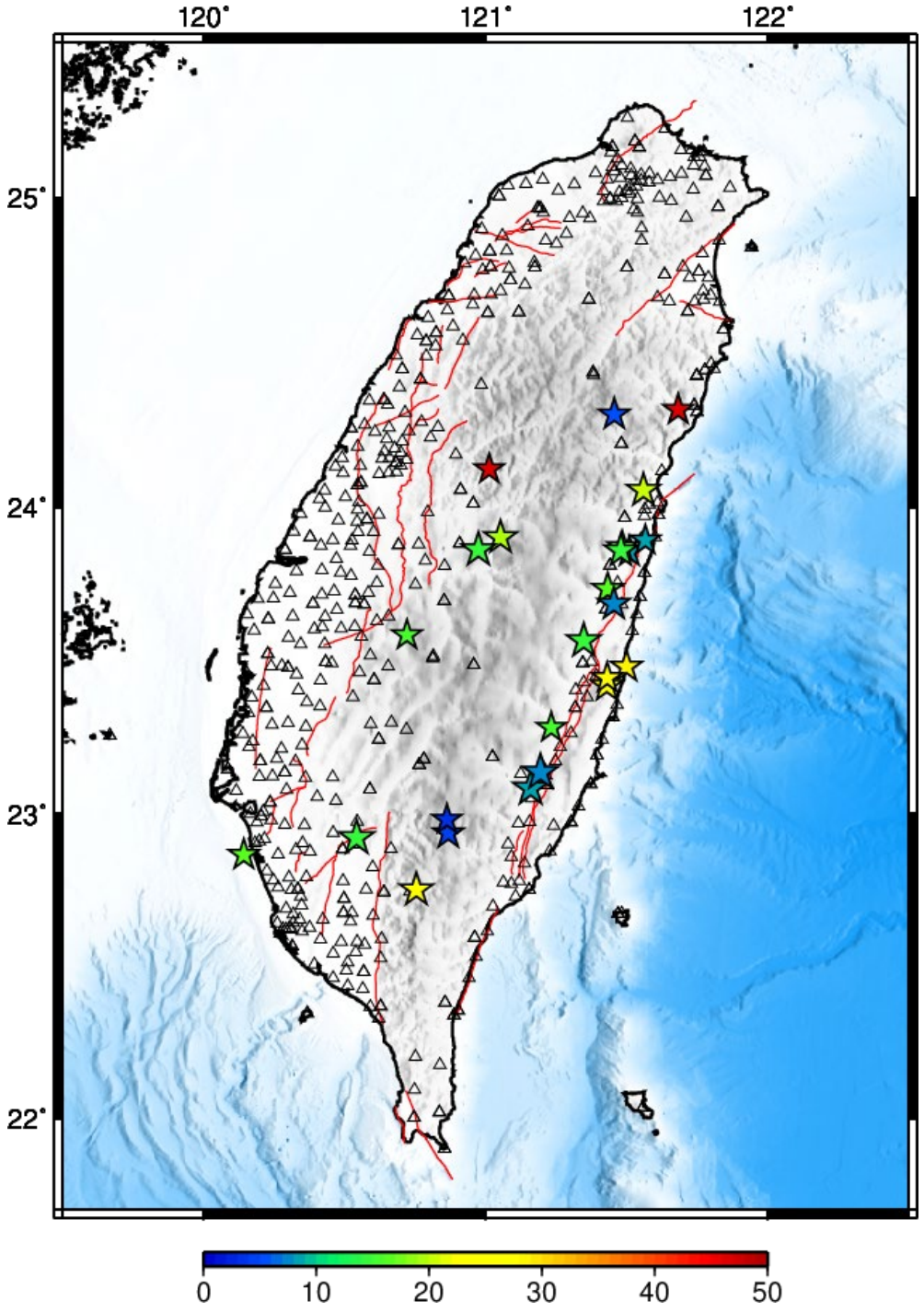




Yang et al. (2018)

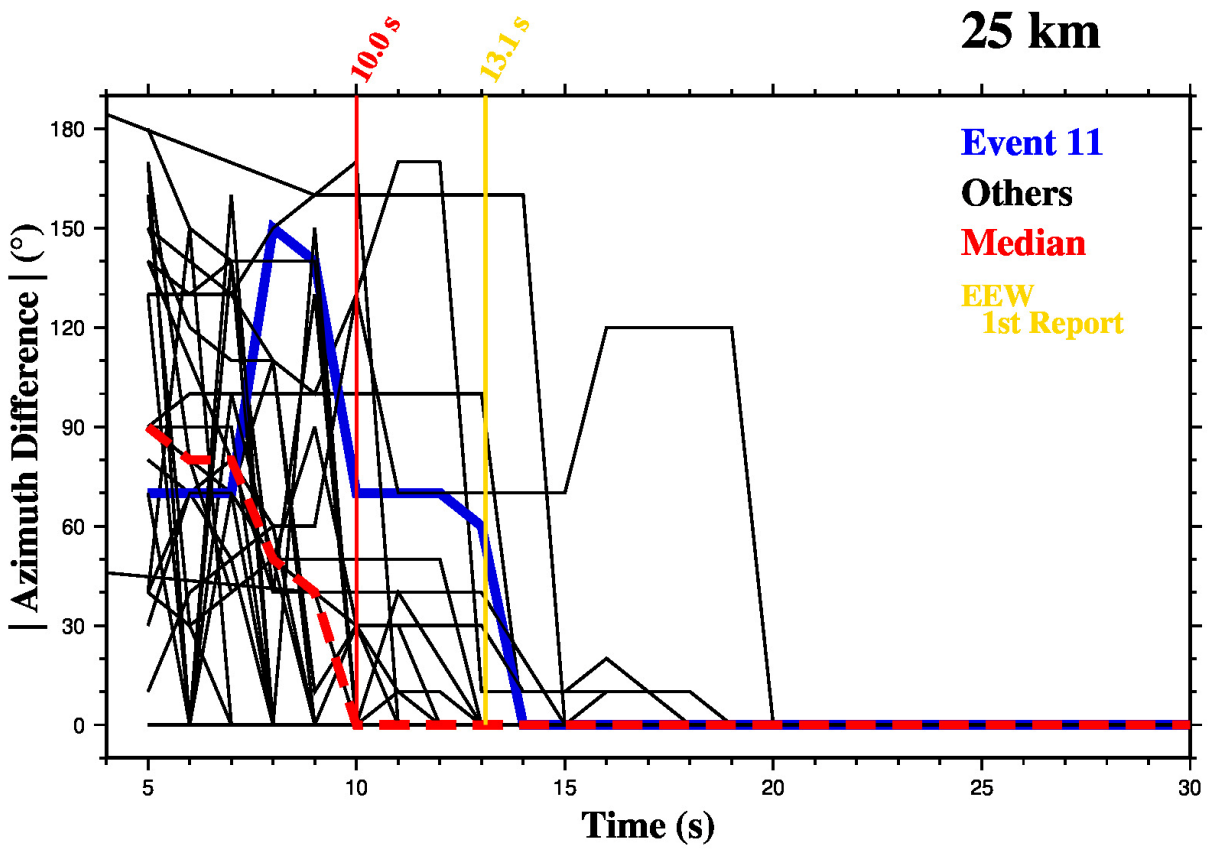
# Applications to CWB new real-time network

- 2012-2022
- 540 stations
- $M_L \geq 5.5$
- Focal depth $\leq$ 50 km
- Gap angle $\leq$ 180°

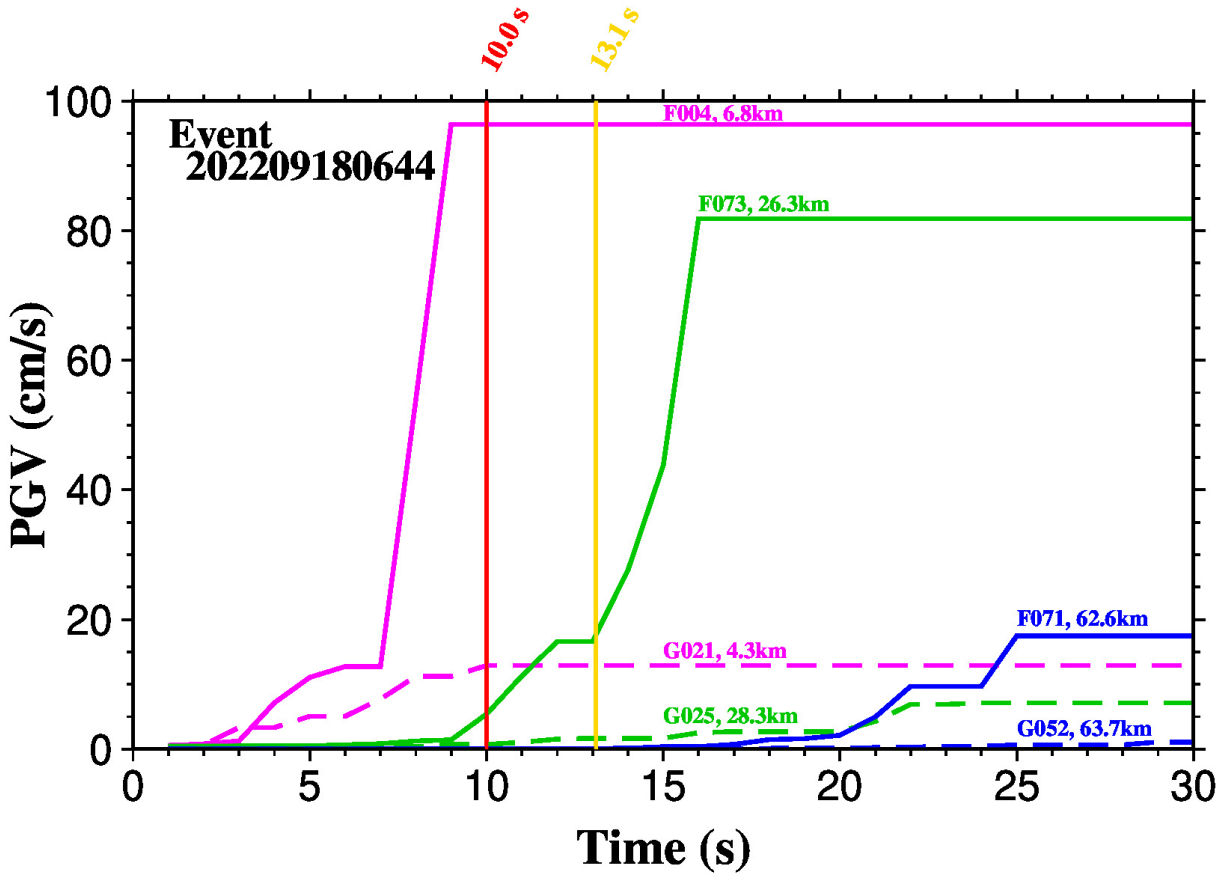
→ 25 events



# Summary of rupture directivity

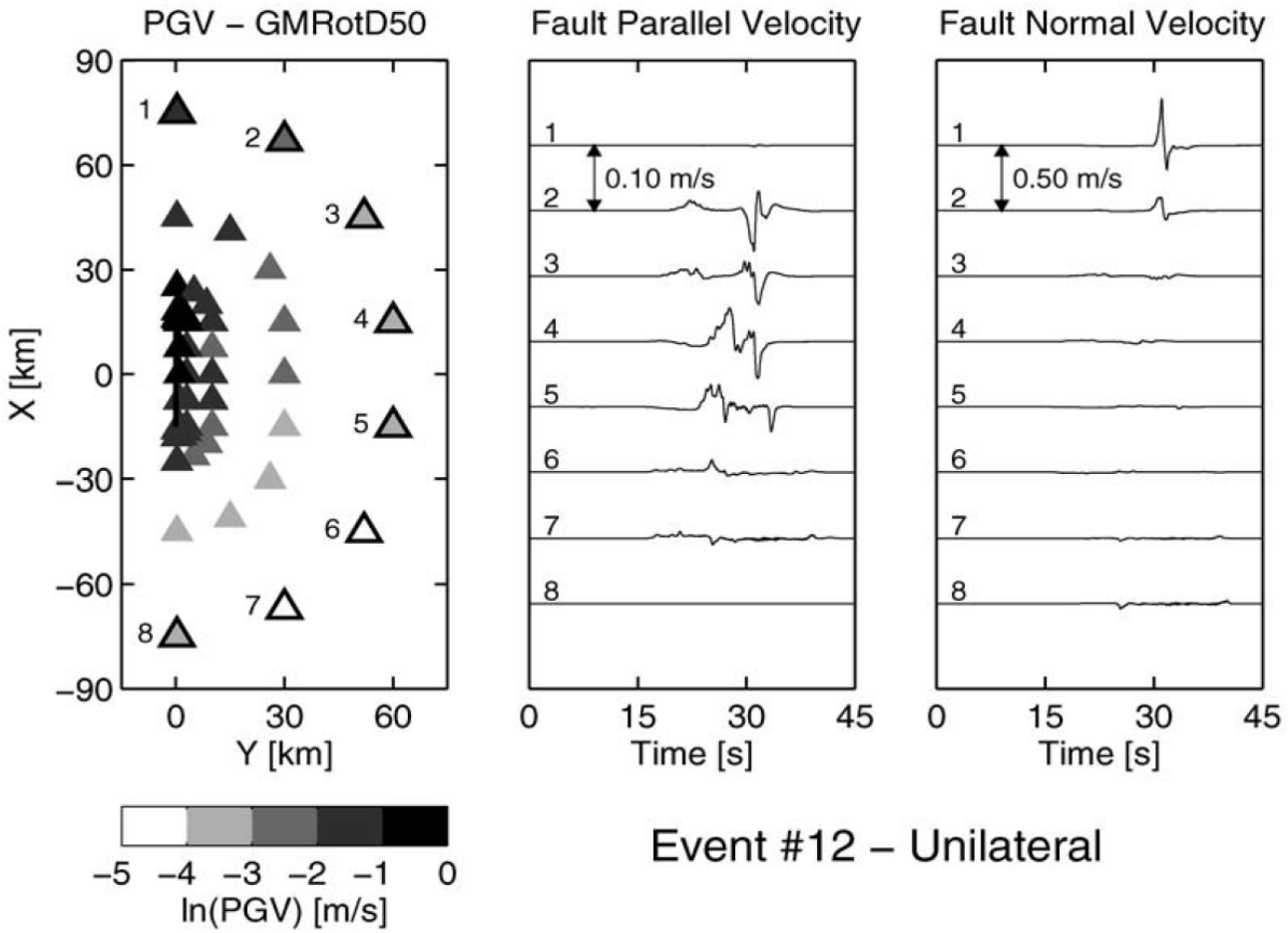



0918 Chihshang earthquake



# Near-field ground motion simulations

– radiation pattern & rupture directivity




(Ripperger et al., 2008)