# EFFECT OF NEAR FIELD GROUND MOTIONS ON FORCE REDUCTION FACTOR AND RESIDUAL DISPLACEMENT

Tokyo Institute of Technology

Ken KIJIMA

Gakuho WATANABE

Kazuhiko KAWASHIMA

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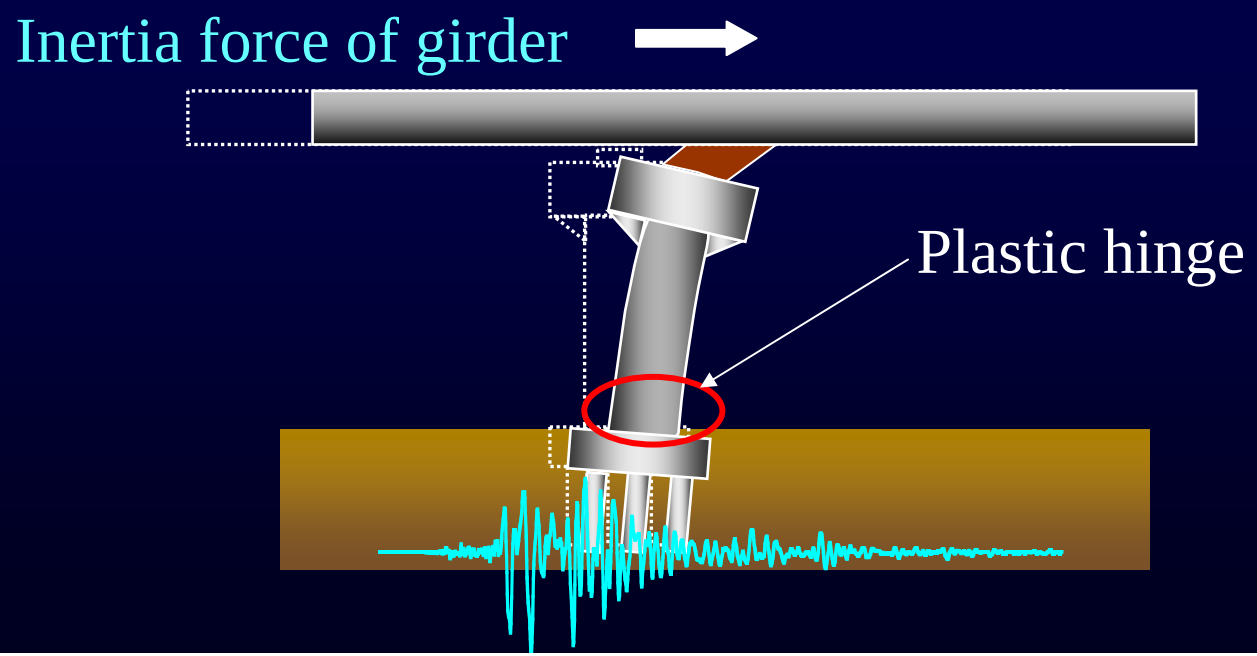
# DUCTILITY DESIGN

- Reduce the acceleration response of bridge, admitting the damage at plastic hinge
- Calculate the elastic force, divide it by Force Reduction Factor (R factor), get the inelastic force

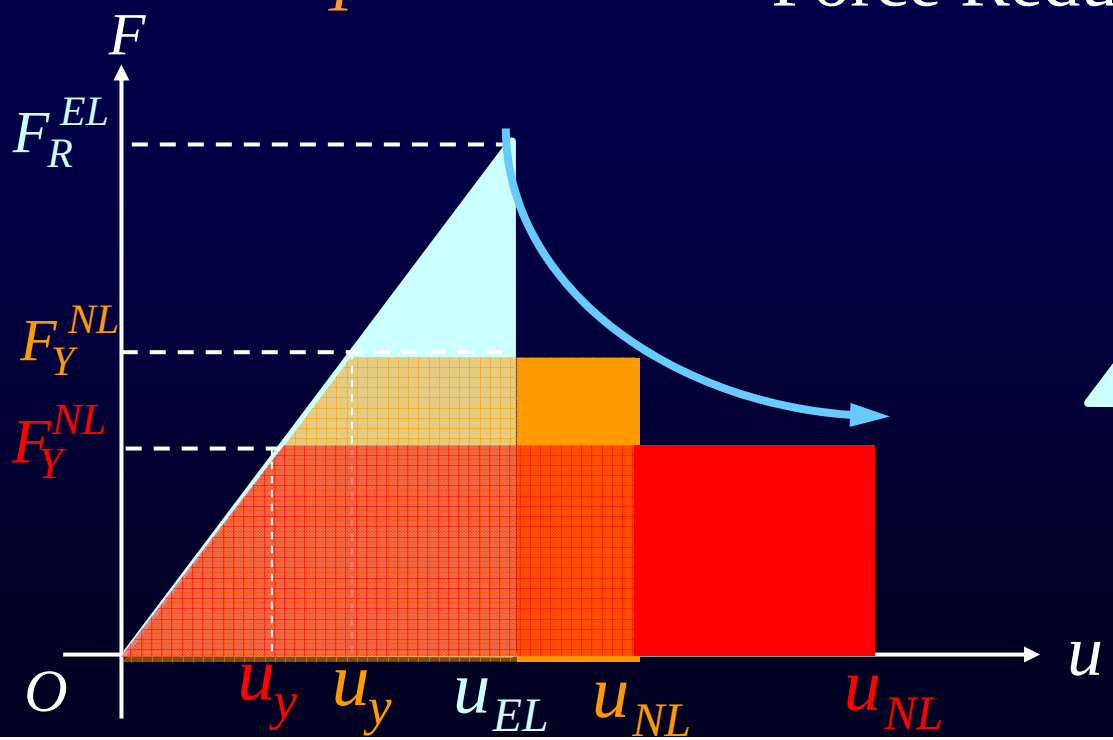


# DUCTILITY DESIGN

High ductility →Can decline the force demand

Relationship between strength and ductility is trade-off

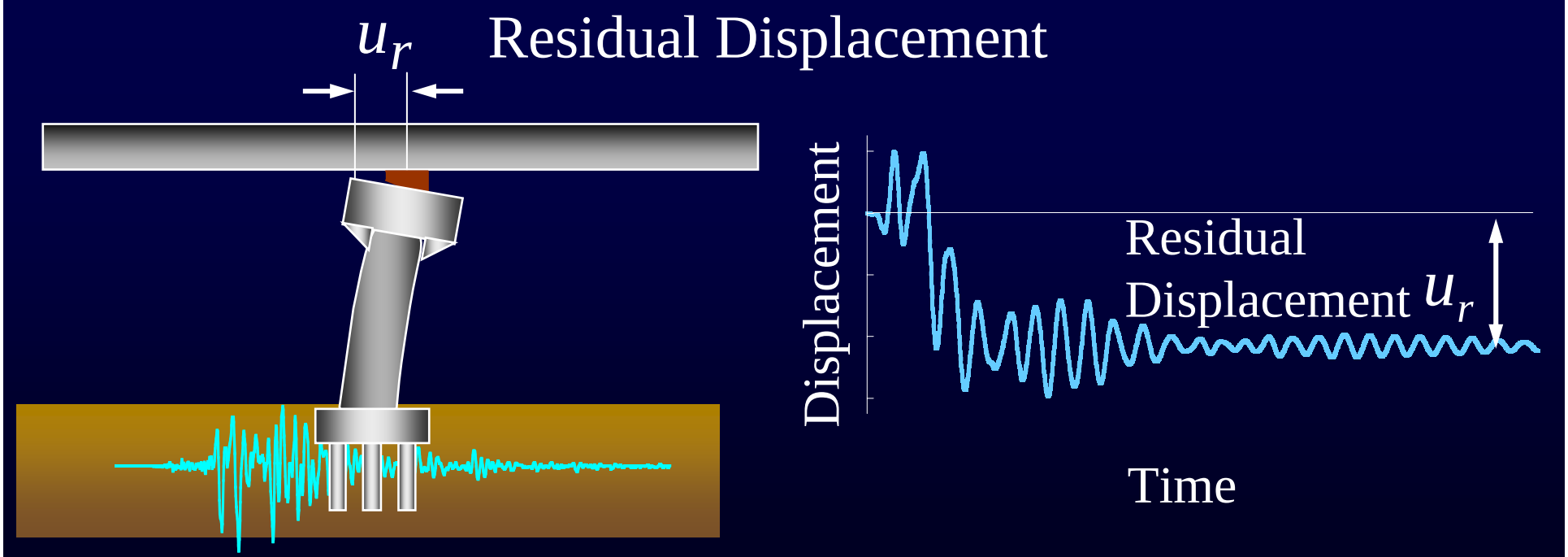
Inelastic force demand $F_Y^{NL}$ = Elastic restoring force $F_R^{EI}$ / Force Reduction Factor $R$




# DUCTILITY DESIGN

If the ductility is high, R factor can be set excessively?

Residual displacement is generated after an earthquake!



# PROBLEM AND OBJECT OF RESEARCH

Kobe earthquake(JPN), Northridge earthquake(USA),Chi-Chi earthquake(TWN),etc, are observed in recent years.

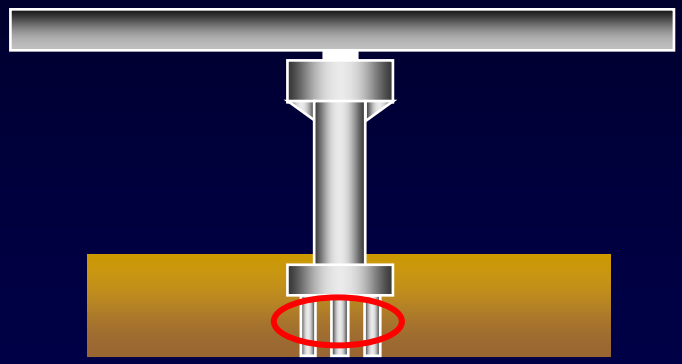
## Problem

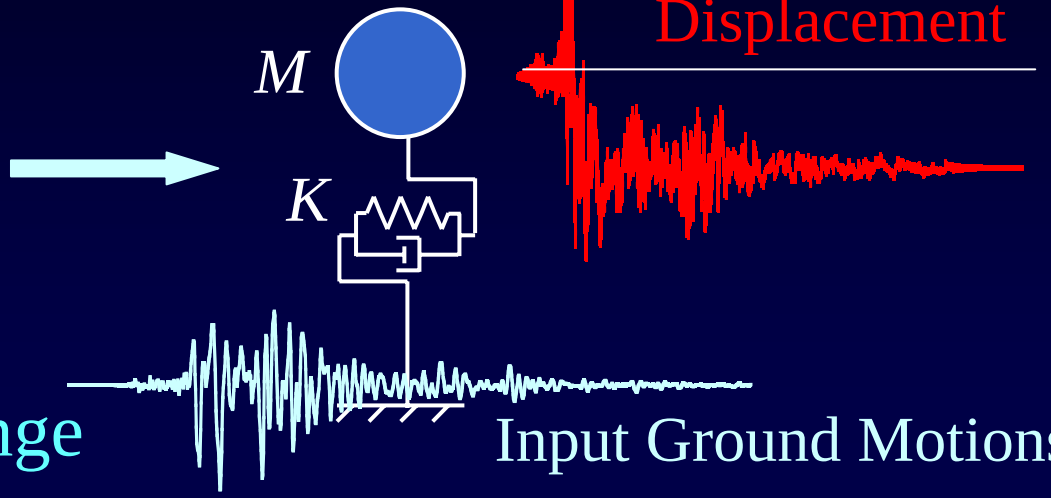
Present seismic codes don’t include the effect of near-field ground motions

## Object

Compared with conventional middle-field and far-field ground motions, research the effect of near-field ground motions on R factor and residual displacement

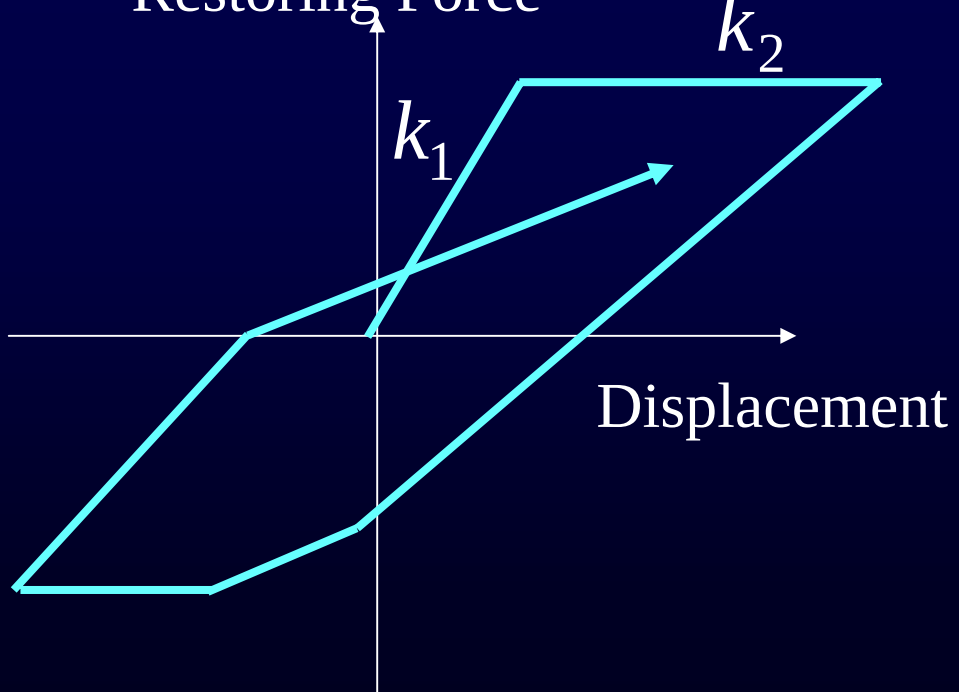
# MODELING AS SDOF






## Modeling of Plastic Hinge

Restoring Force




Takeda
degrading stiffness
model

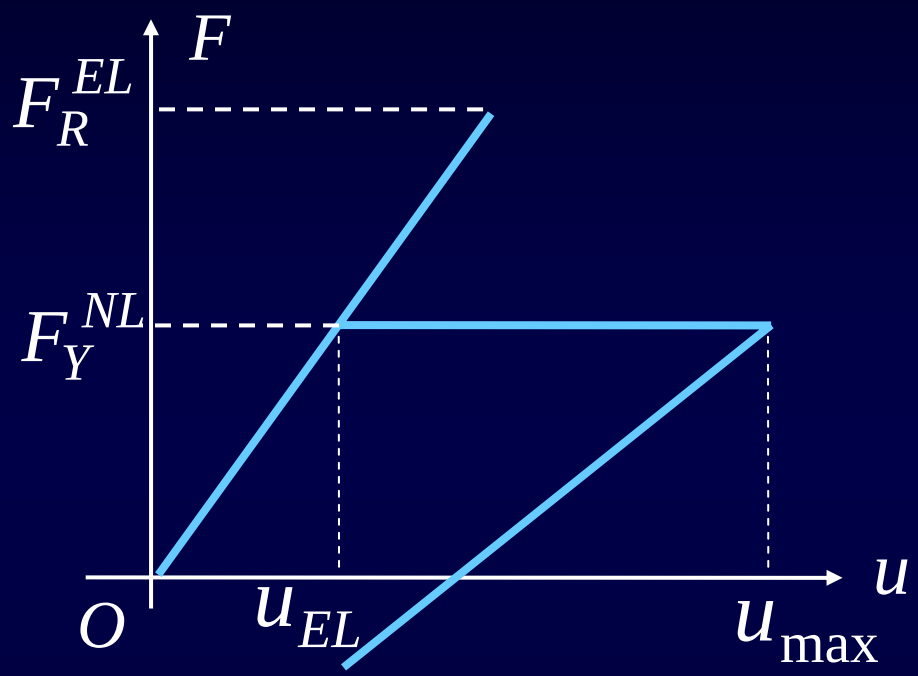
Post-yield stiffness

$$k_2 = 0$$

# DEFINITION OF R FACTOR

Force Reduction Factor $R$

$$R(\mu, \xi_{EL}, \xi_{NL}, T) = \frac{F_R^{EL}(\xi_{EL}, T)}{F_Y^{NL}(\mu, \xi_{NL}, T)}$$




$\xi_{EL}$ : Linear Viscous Damping Ratio

$\xi_{NL}$ : Nonlinear Viscous Damping Ratio

$T$ : Natural Period

$\mu$ : Ductility

$\xi_{EL} = 5\%$ $\xi_{NL} = 2\%$

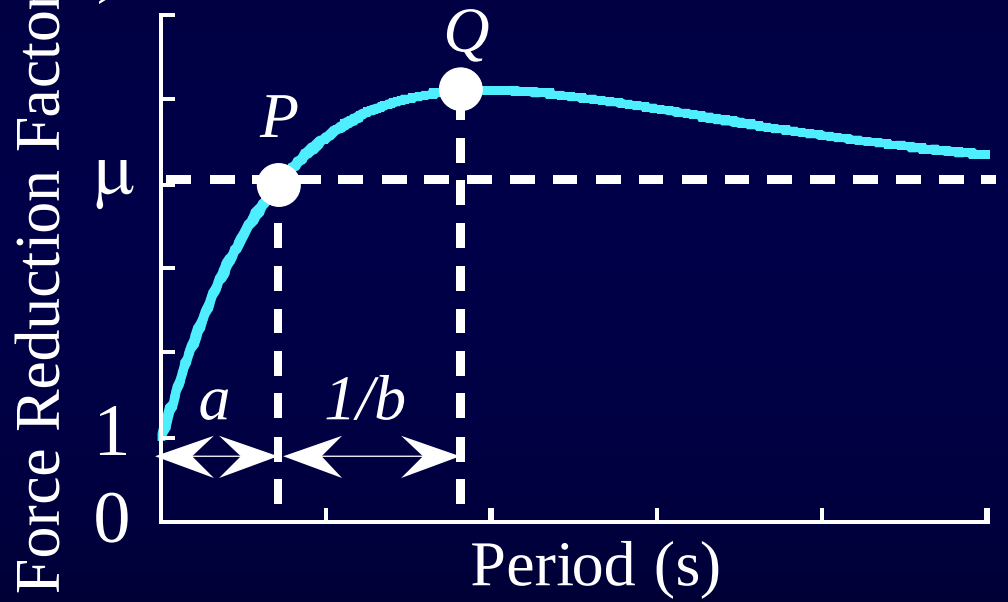
# ESTIMATE FORMULA

## Watanabe and Kawashima

$$R(T,\mu) = (\mu - 1)\left(\frac{T-a}{ae^{bT}} + 1\right) + 1$$

$a$ ; Natural period where $R = \mu$

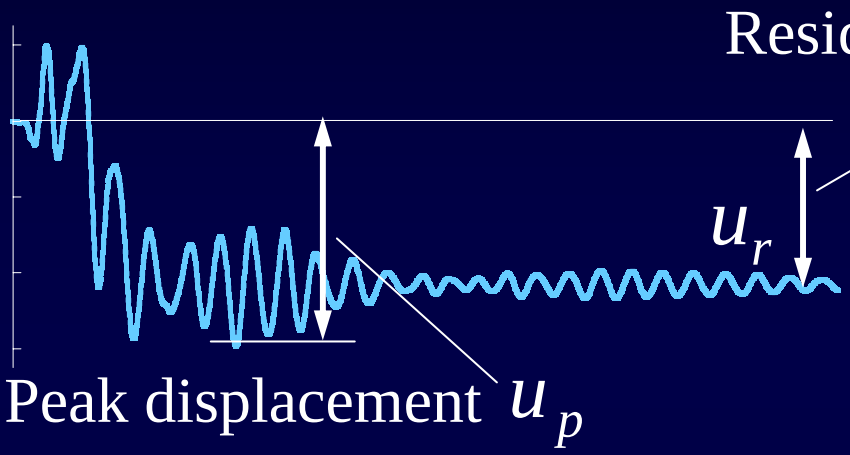
$1/b$ ; Period between $P$ and $Q$




Parameters have physical meaning

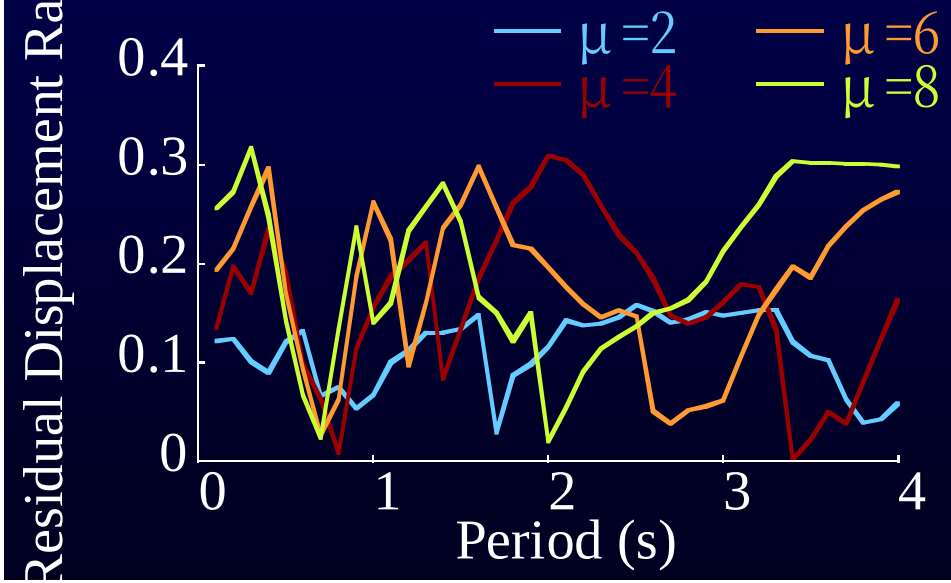
# DEFINITION OF RESIDUAL DISPLACEMENT RATIO

## Residual displacement and residual displacement ratio



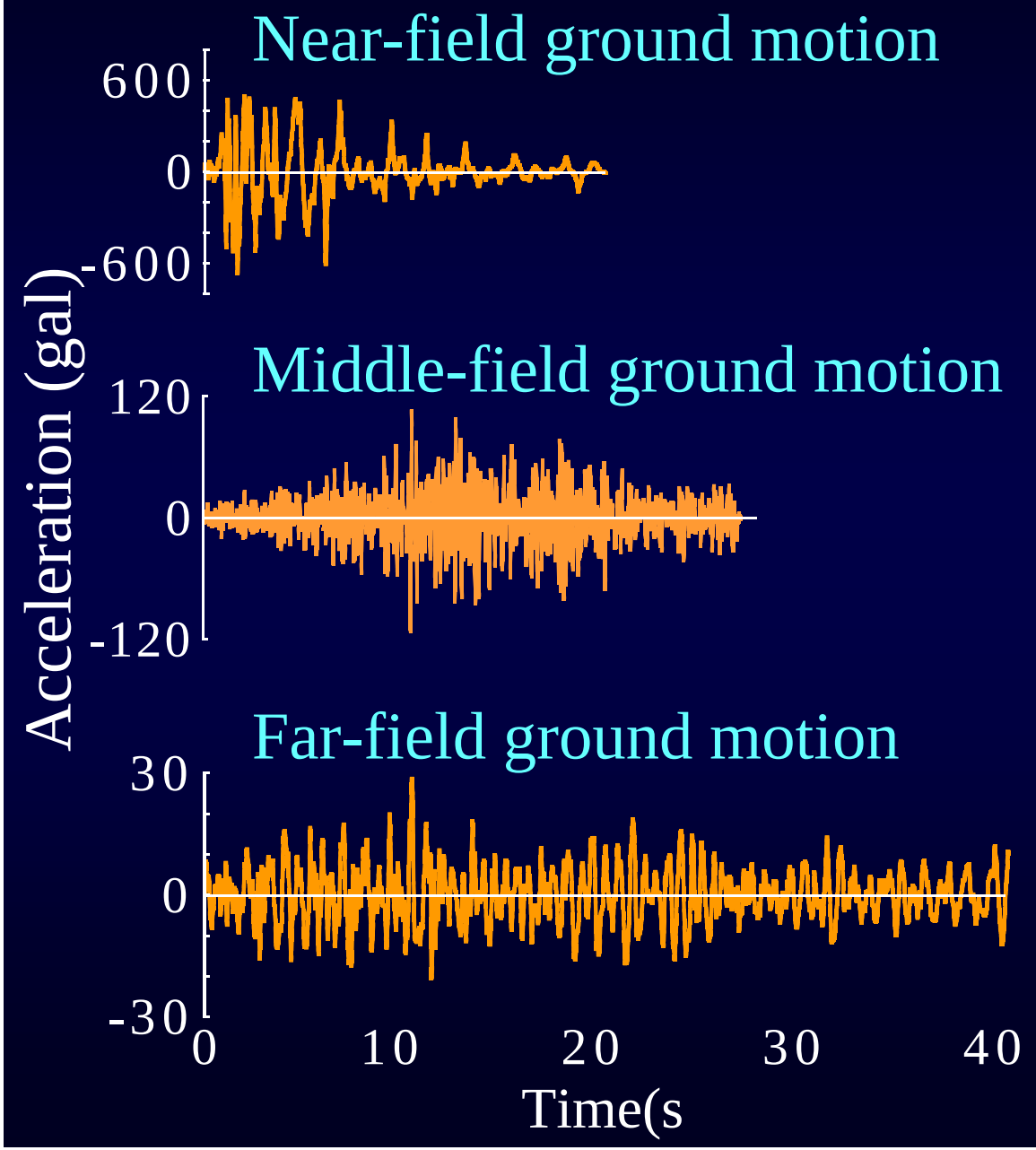

Residual Displacement Ratio

$$r_r = \frac{u_r}{u_p}$$




Residual displacement ratio response spectrum

# INPUT GROUND MOTIONS

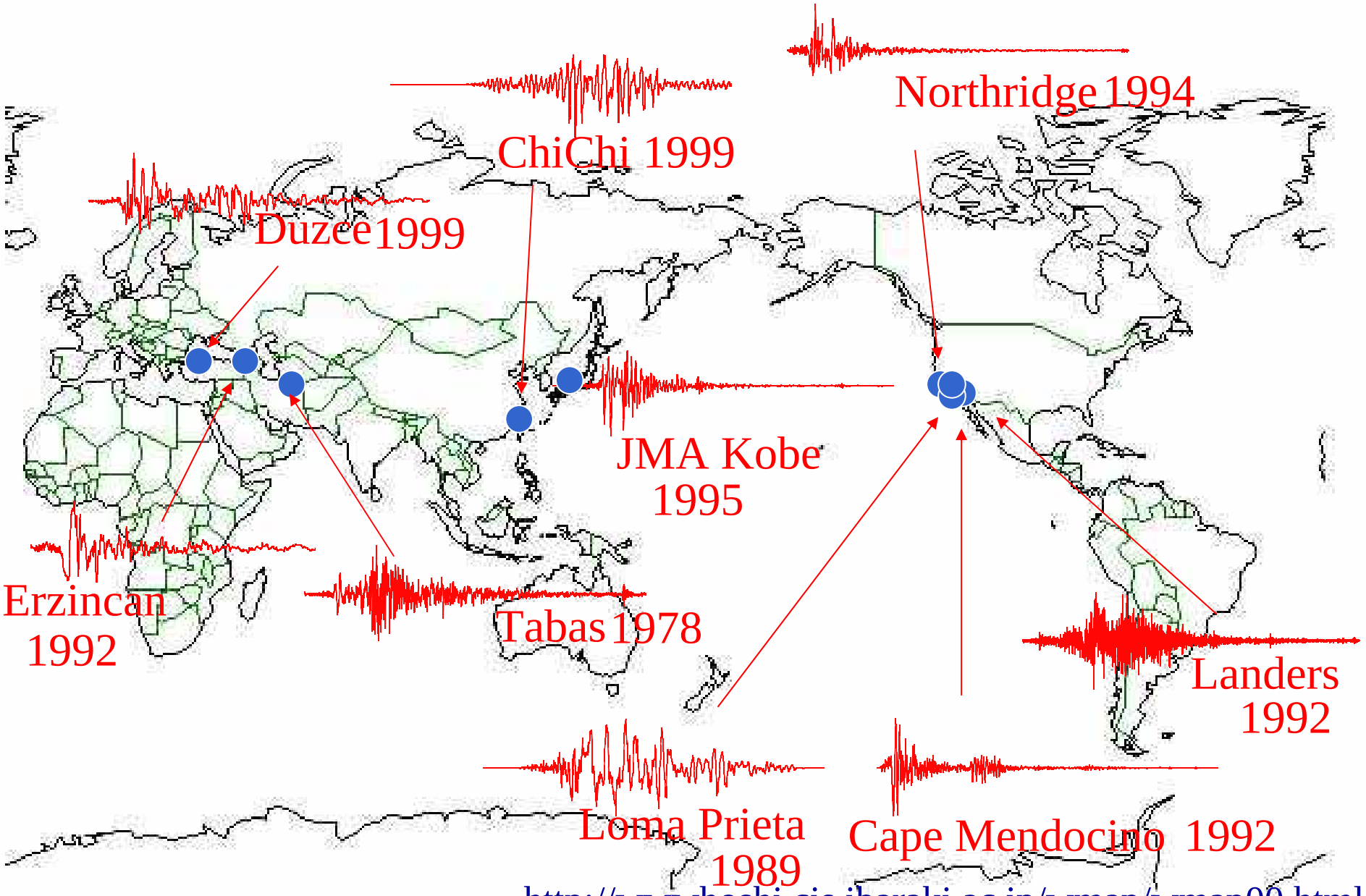



Record of 0～40km
20components

Record of 40～200km
20components

Record over 200km
14components

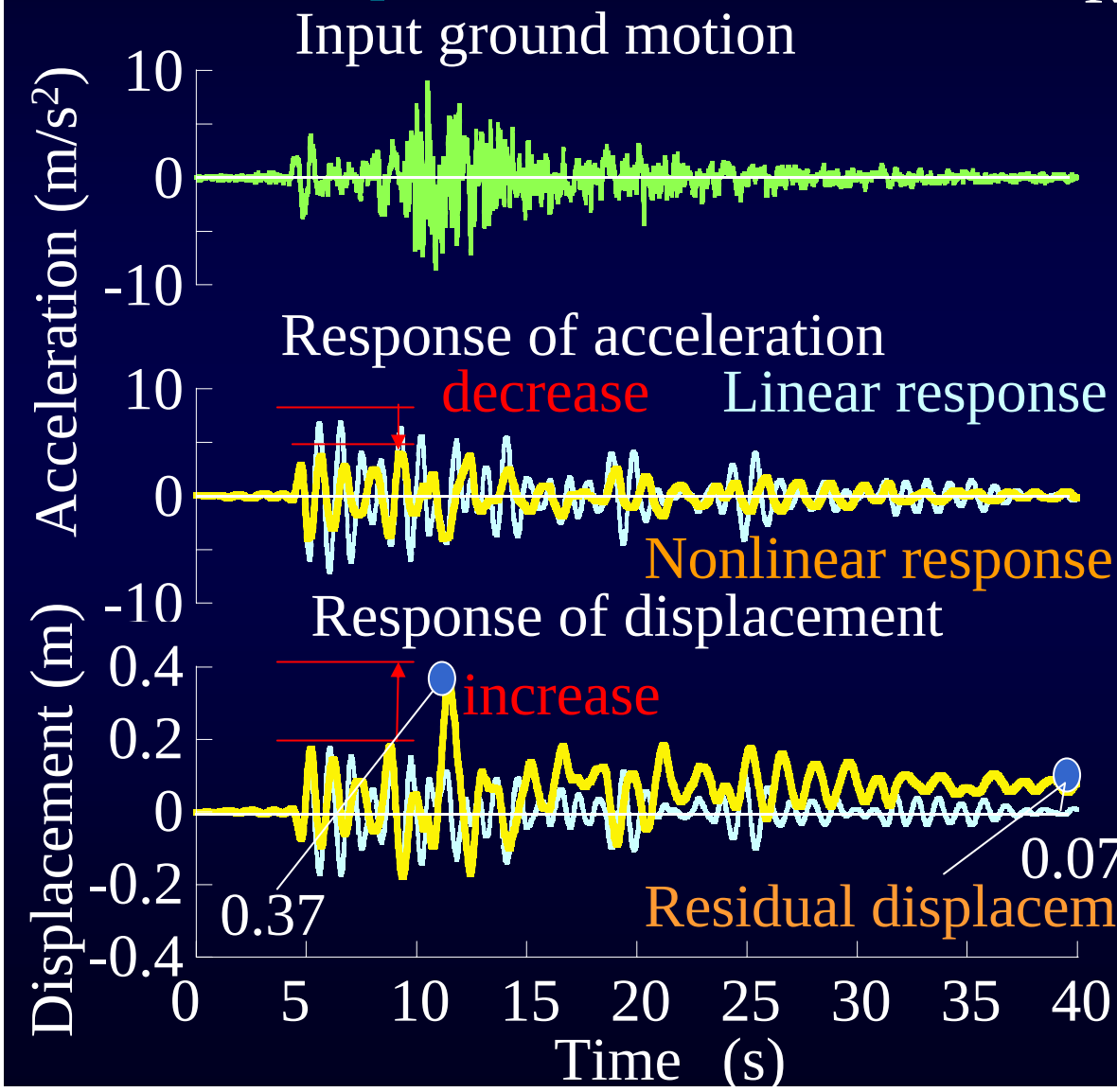
# Near-Field Ground Motions

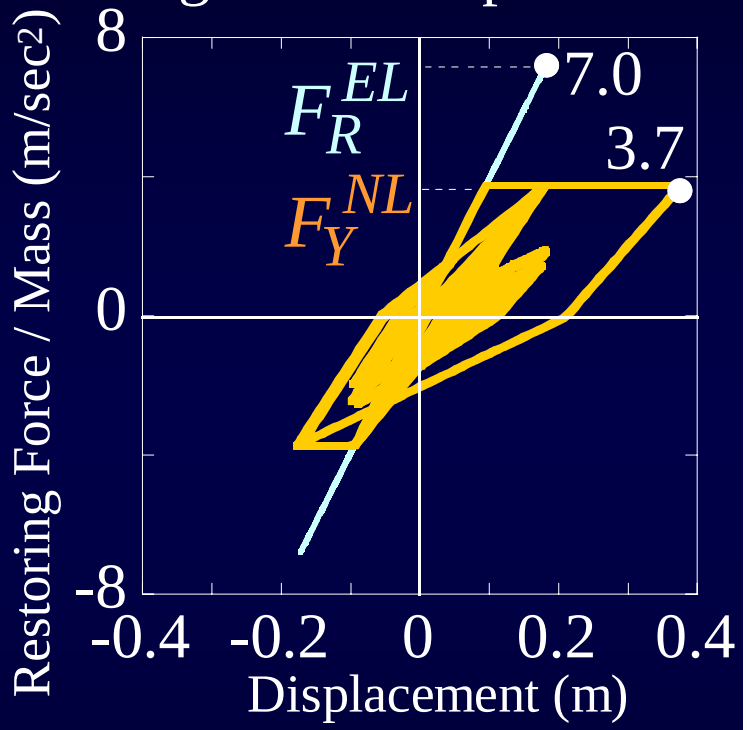



http://wwwhoshi.cis.ibaraki.ac.jp/wmap/wmap00.html

# RESPONSE OF REPRESENTIVE NEAR-FIELD GROUND MOTIONS

## Tabas earthquake (Iran, 1978)



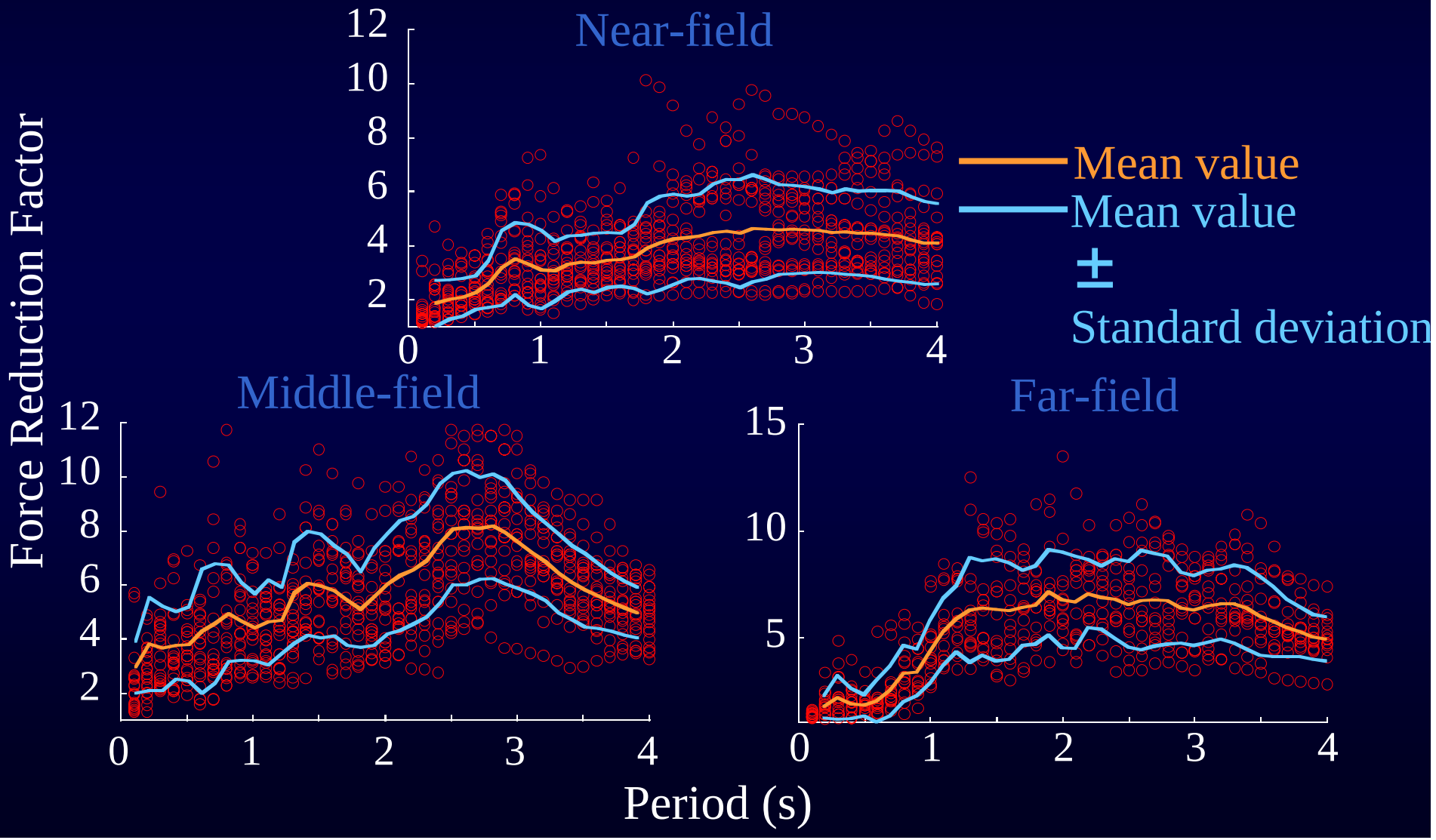




$$R = \frac{F_R^{EL}}{F_Y^{NL}} = \frac{7.0}{3.7} \approx 1.9$$

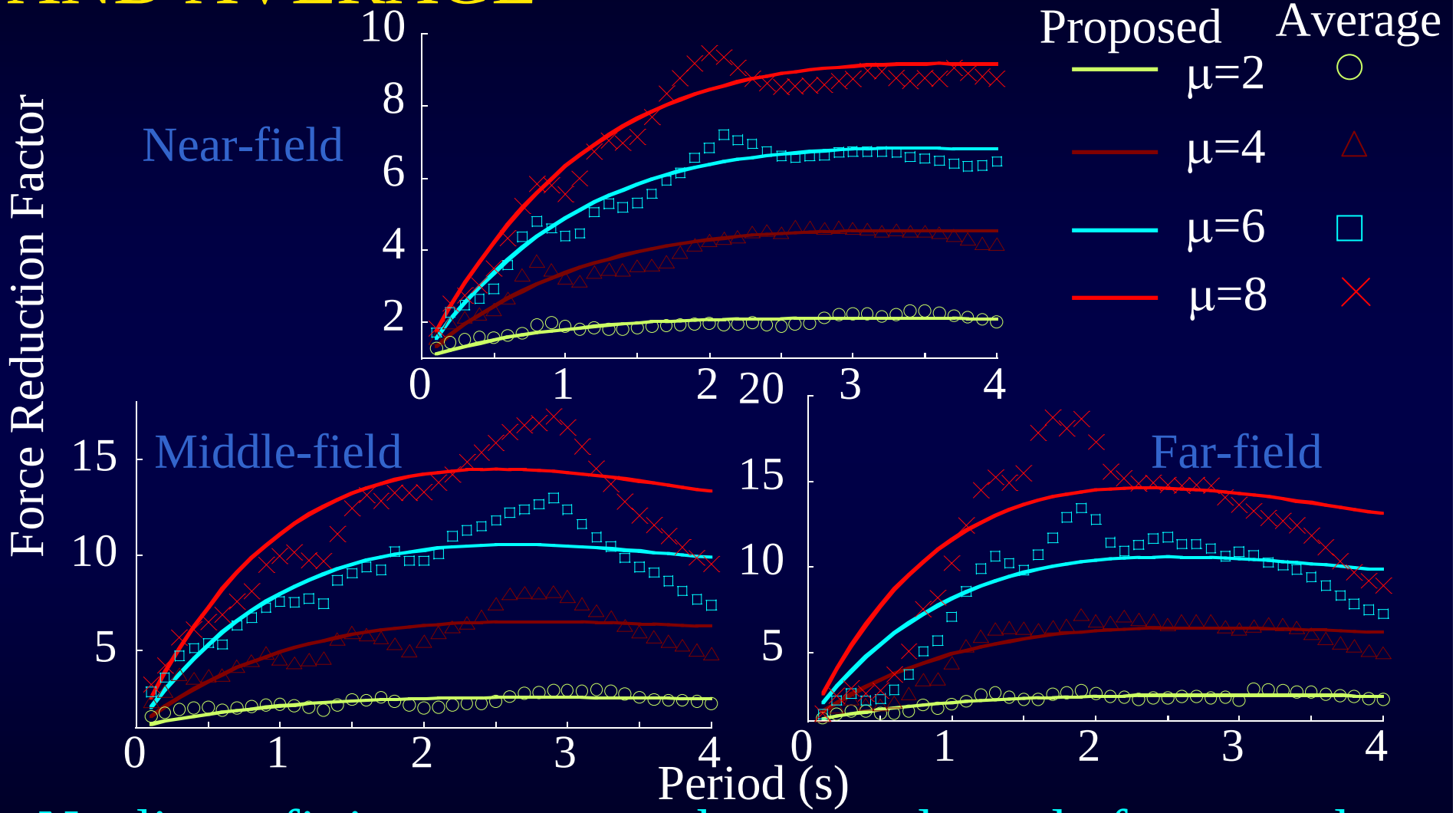
$$r_r = \frac{u_r}{u_{\max}} = \frac{0.07}{0.37} \approx 0.19$$

# SIGNIFICANT SCATTERING OF R FACTOR

Difference when classified as types of ground motions

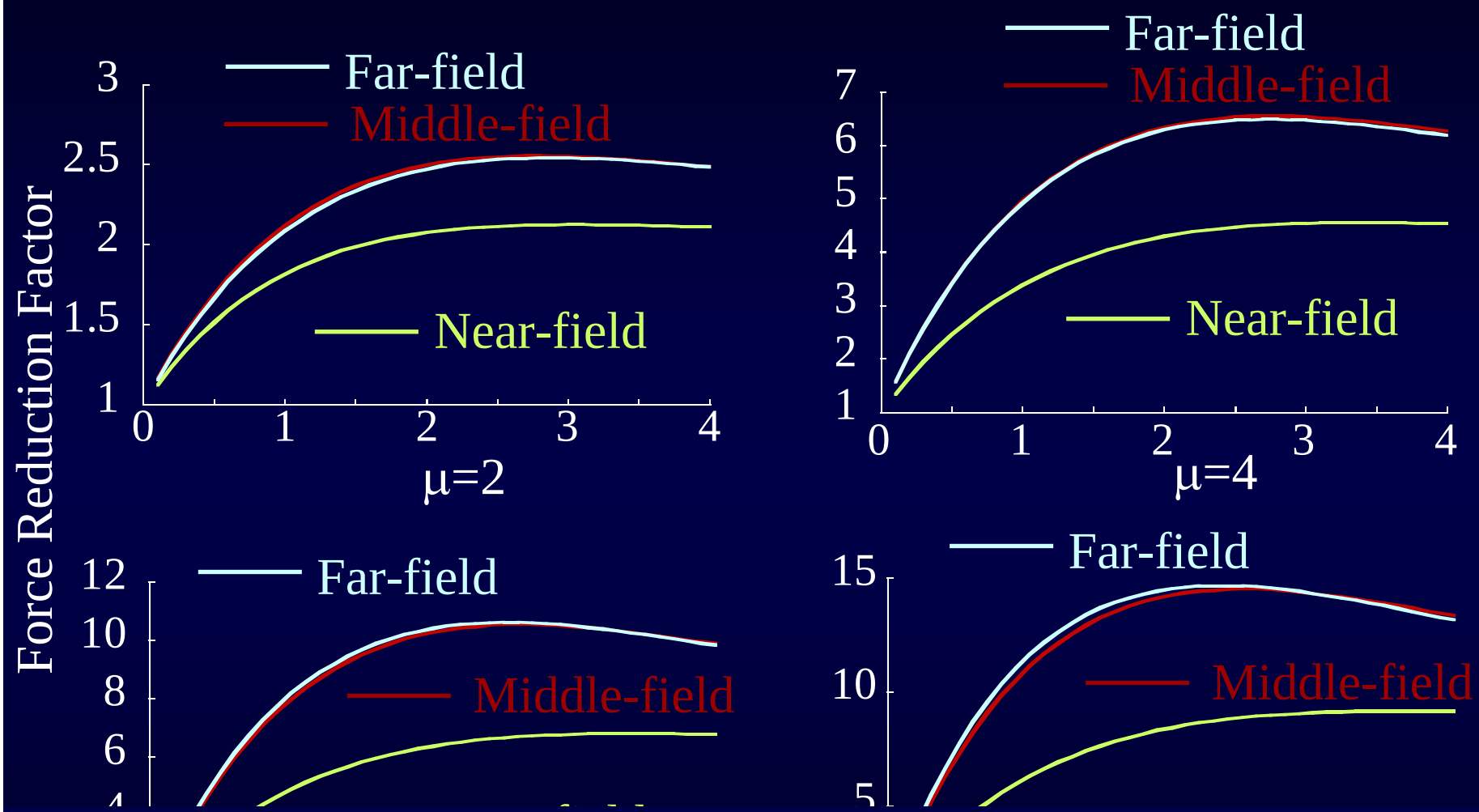


# COMPARISON OF NONLINEAR FITTING AND AVERAGE



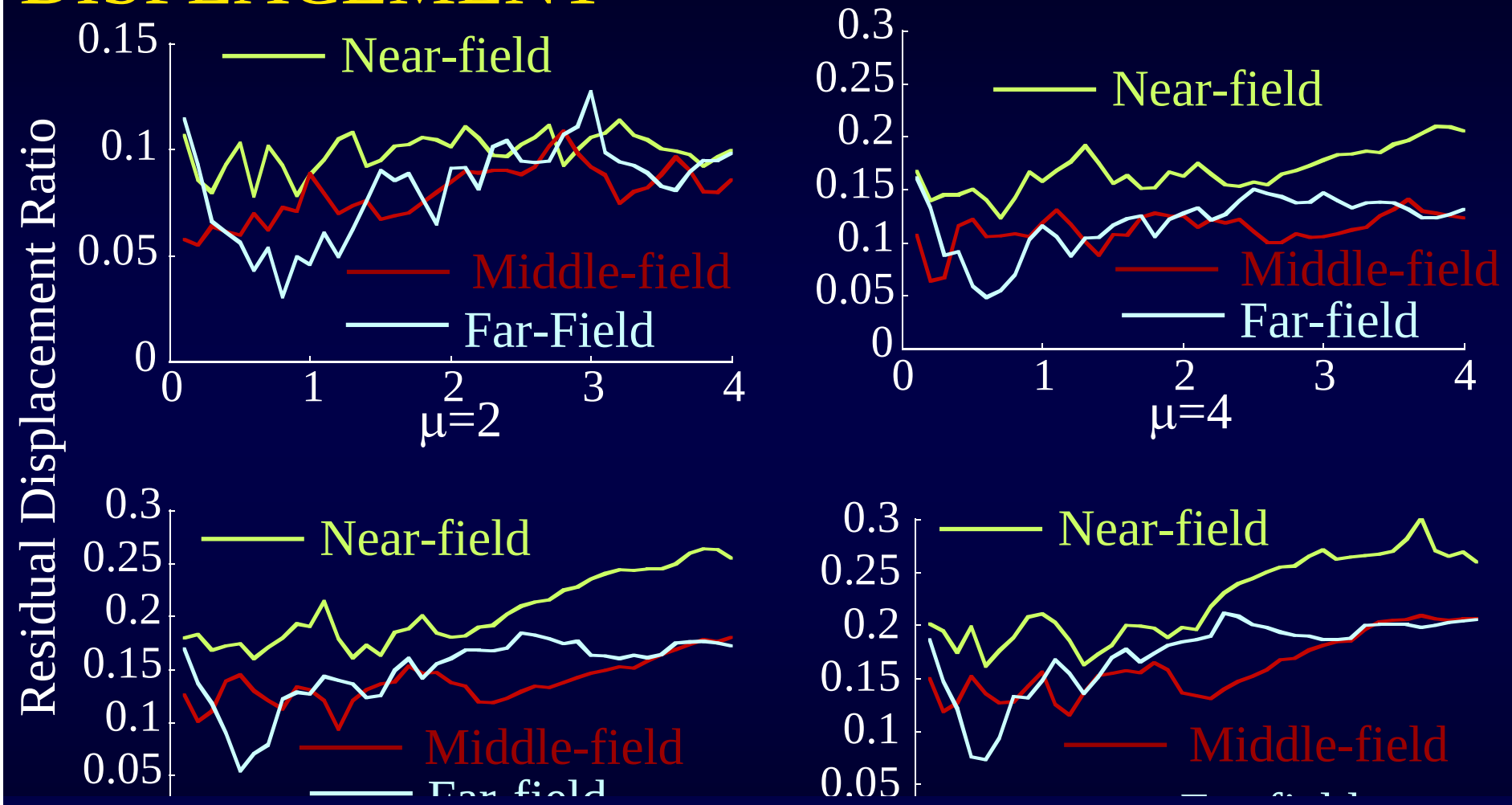

Nonlinear fitting represents the general trend of mean value of R factor

# EFFECT OF DISTANCE ON R FACTOR



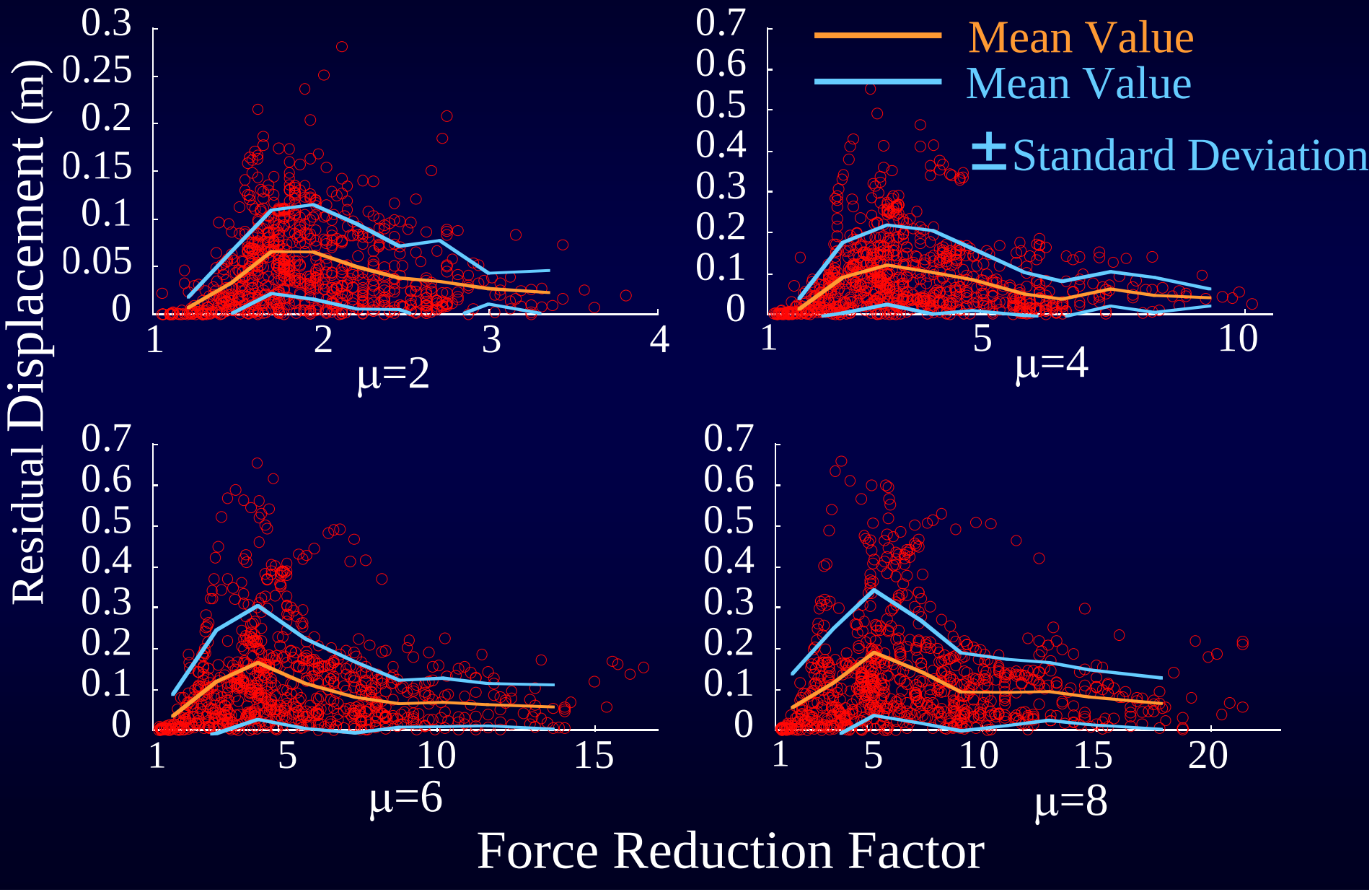

R factors depend on the types of ground motion. R factors for near-field ground motion are smaller than middle and far-field ground motions.

# EFFECT OF DISTANCE ON RESIDUAL DISPLACEMENT




Residual displacement ratio depend on the types of ground motions. The residual displacement ratios for near field ground motions are larger than middle and far-field.

# R FACTOR VS. RESIDUAL DISPLACEMENT



# CONCLUSION

- R factors depend on the types of ground motions. R factor for near-field ground motions are smaller than middle and far-field ground motions
- The residual displacement ratios depend on types of ground motions. The residual displacement ratios for near-field ground motions are larger than middle and far-field ground motions.
- There is not an apparent relation between R factors and residual displacements. It seems that residual displacement are independent of R factors.