Portfolio loss sensitivity to soil conditions, portfolio granularity and its spatial distribution: A case study for TCIP loss estimations for the February 6th Kahramanmaraş Earthquake Sequence

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t-rupt

OUTLINE

01| Overview of Kahramanmaraş Earthquakes

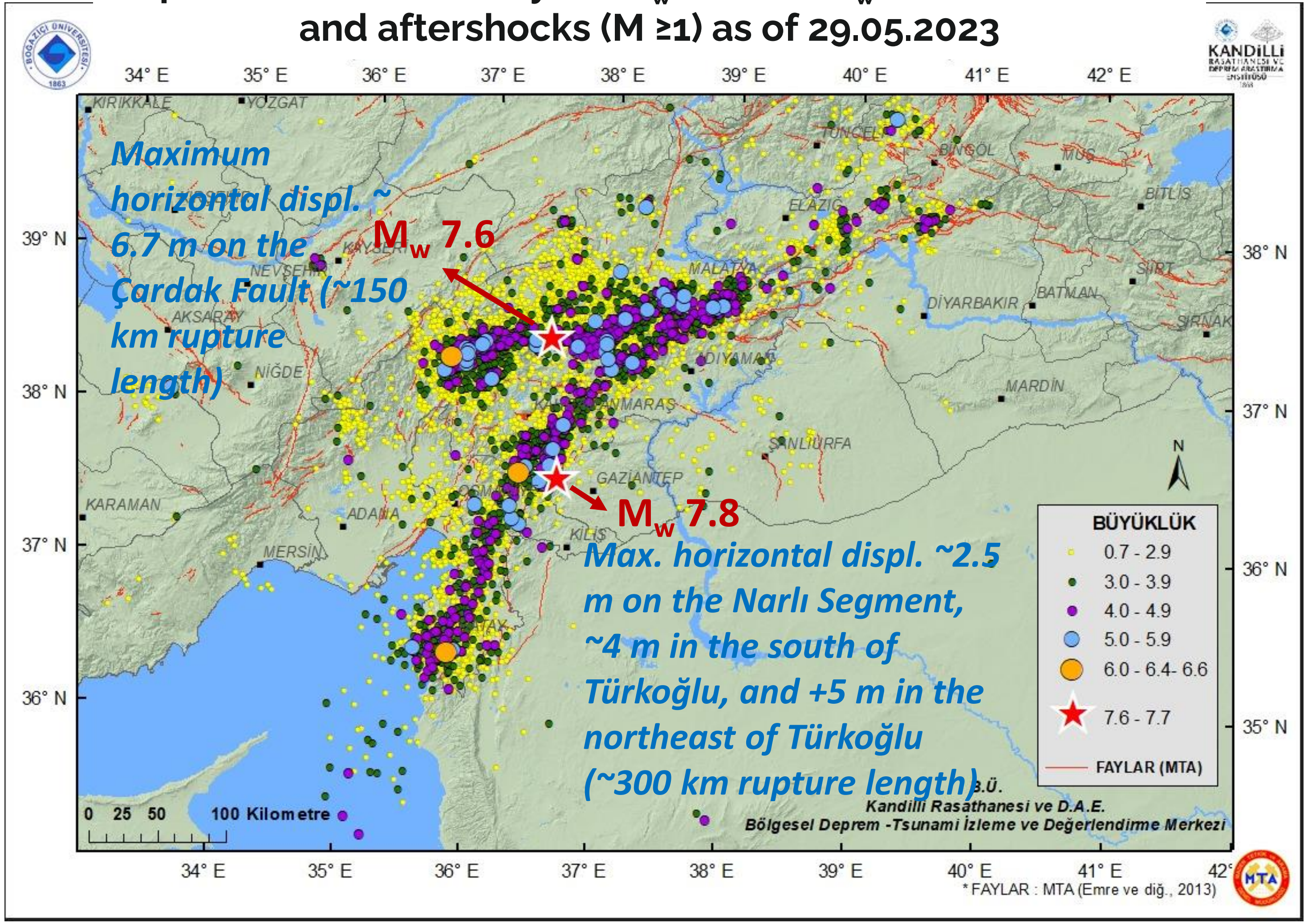
02| Main loss modeling components explored for TCIP insured portfolio losses

03| Case studies and observations

04| Closure

01| Kahramanmaraş Earthquakes

Epicenters of February 6th M_w 7.8 and M_w 7.6 mainshocks and aftershocks (M ≥1) as of 29.05.2023



Southwestern segments of the EAFZ are reactivated during the Feb. 6th, 2023 earthquakes: Narlı segment and EAF are activated during the M_w 7.8 event occurred at 04:17 (local time) Çardak-Sürgü Fault is reactivated during the M_w 7.6 event occurred at 13:24 (local time)

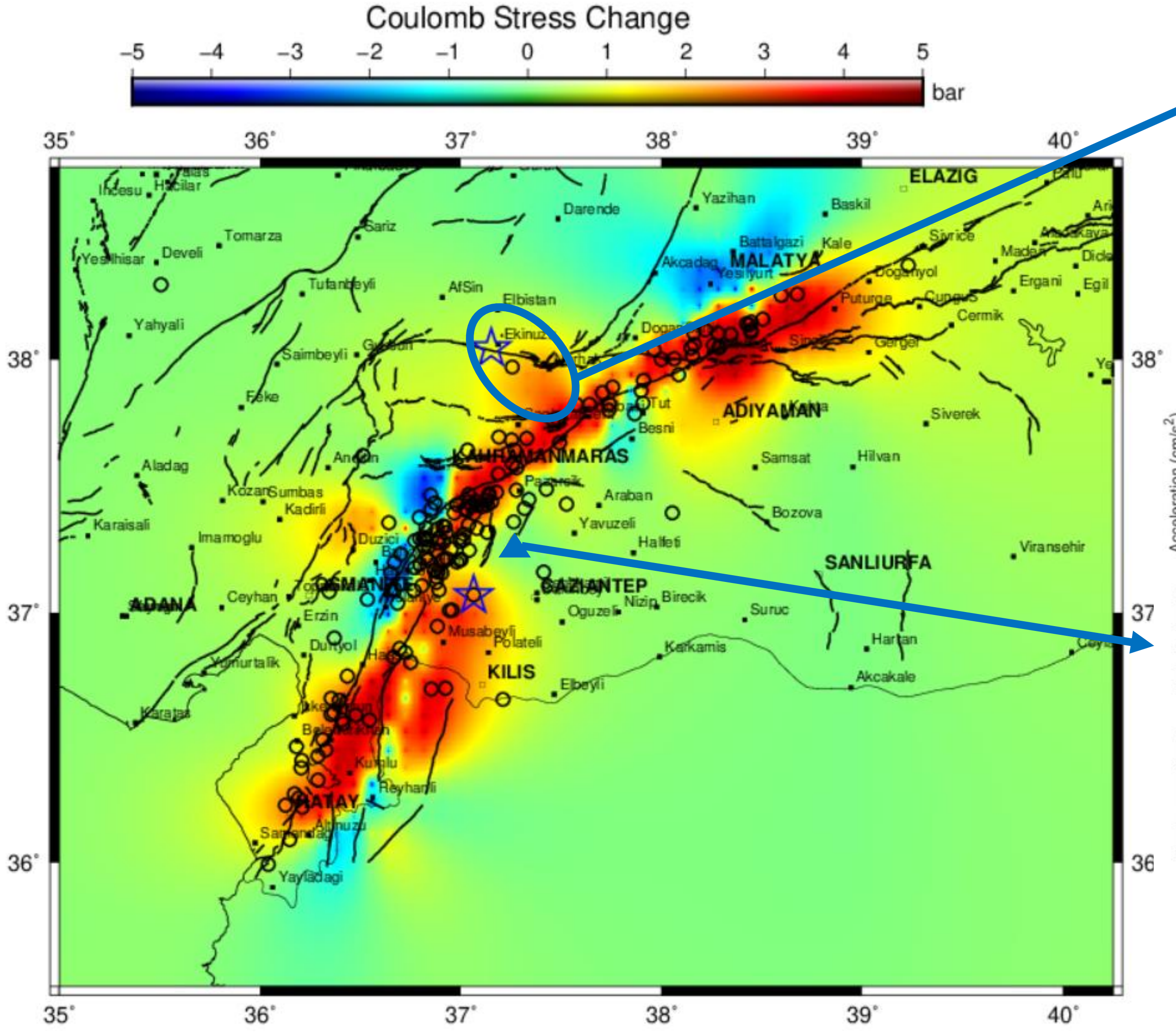
The ruptures occurred on the segments where M +7 earthquakes have not been occurred for several hundred years.

- *The 1513 (M > 7.4) and the 1114 events (M?) are the previous M+7 events on the SW part of EAFZ.*
- *The 1544 (M 6.7) event is the last largest earthquake on the Çardak-Sürgü Fault*

The instrumental data indicate infrequent M_w +4 events on the SW segments of the EAFZ where the M_w 7.8 earthquake occurred. There are no contemporary M_w +4 events reported on the Çardak-Sürgü Fault where the M_w 7.6 event occurred.

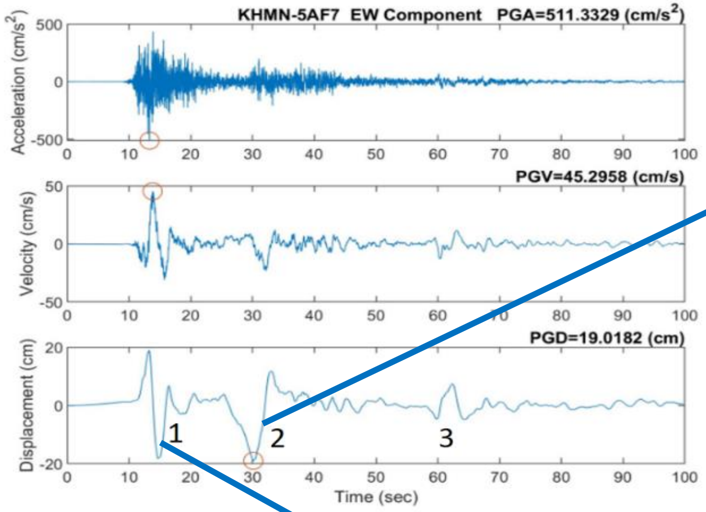
01| Kahramanmaraş Earthquakes *(M_w 7.8 event, Coulomb stress distribution, bilateral rupture)*

Coulomb stress change model of the M_w 7.8 earthquake



The Coulomb stress model of the M_w 7.8 event suggests a stress increase in the Eastern part of the Çardak-Sürgü fault resulting in a rupture on this fault segment (M_w 7.6) nine hours after the first earthquake

Strong-motion data recorded at ~30 km NE of the M_w 7.8 event



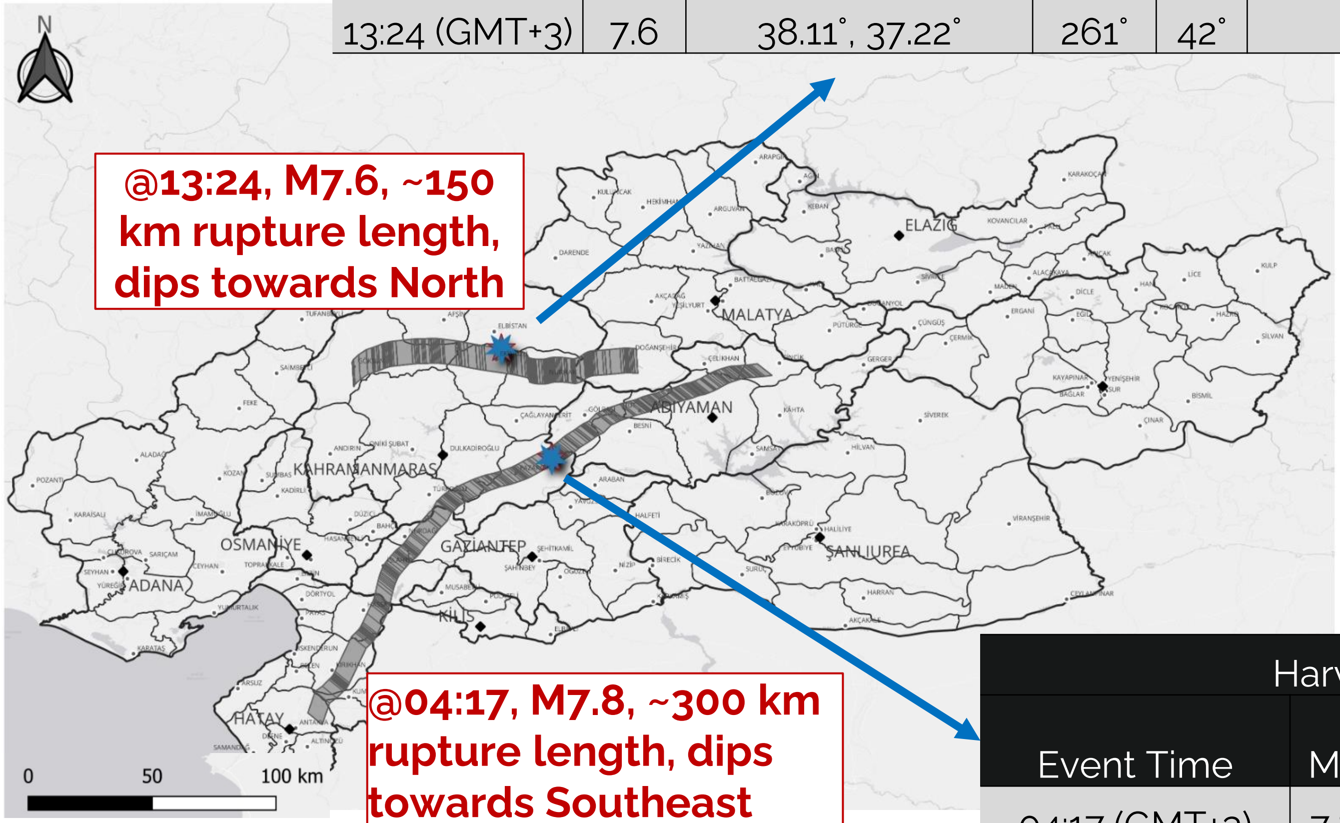
rupture propagation outwards the strong-motion station towards southwest

rupture propagation towards the strong-motion station

Bilateral rupture oriented towards NE and SW of EAFZ

01| Kahramanmaraş Earthquakes *(Ruptured segments)*

Harvard Centroid Moment Tensor Solution						
Event Time	M_w	Epicenter (Lat-Lon)	Strike	Dip	Depth (km)	L_{rup} (km)
13:24 (GMT+3)	7.6	38.11˚, 37.22˚	261˚	42˚	12	~150 km

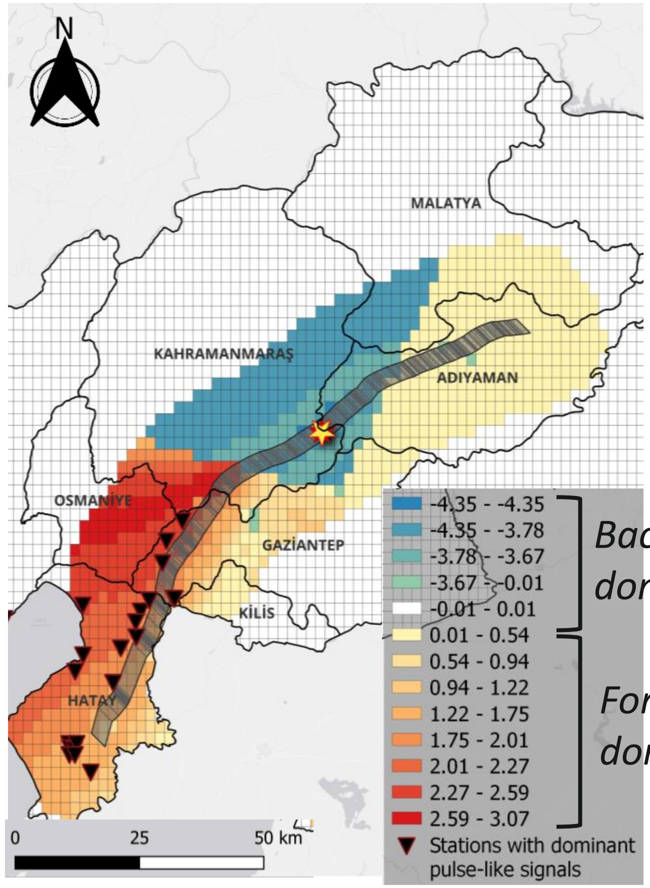


These two major events are recorded by **+379** strong-motion stations with maximum rupture distance of **~630** km. Some of the recorded ground motions feature dominant directivity effects. The most significant aftershocks of the Kahramanmaraş earthquakes are the **Nurdağı (M_w6.8)** and **Yayladağı (M_w6.3)** events

Harvard Centroid Moment Tensor Solution						
Event Time	M_w	Epicenter (Lat-Lon)	Strike	Dip	Depth (km)	L_{rup} (km)
04:17 (GMT+3)	7.8	37.56˚, 37.47˚	54˚	70˚	14.9	~292 km

01 | Kahramanmaraş Earthquakes *(Directivity from Chiou and Spudich, 2013)*

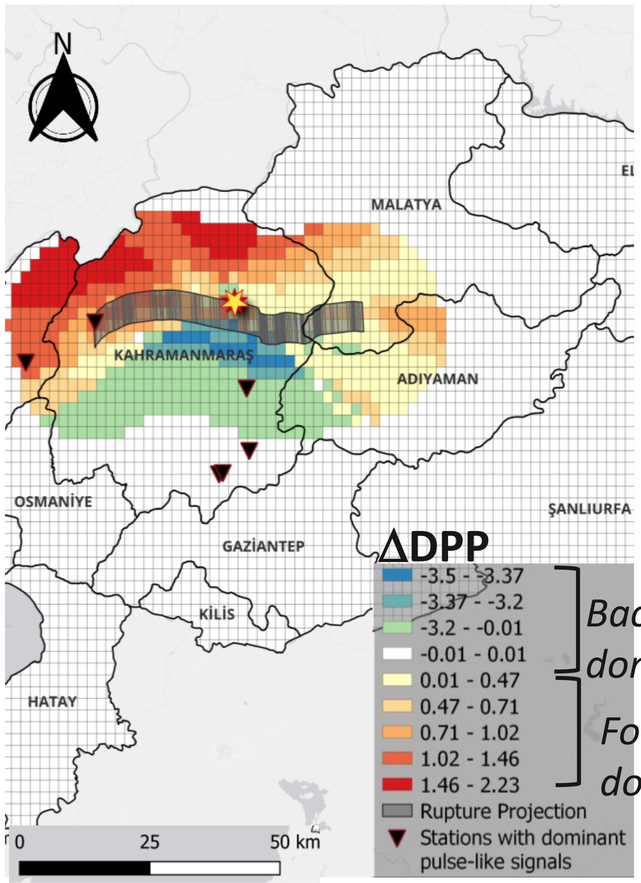
M_w 7.8 earthquake at 04:14 on Feb. 6th



Backward directivity dominant regions

Forward directivity dominant regions

M_w 7.6 earthquake at 13:24 on Feb. 6th



Backward directivity dominant regions

Forward directivity dominant regions

- Mostly Hatay, Gaziantep as well as Adıyaman provinces are subject to forward directivity in the first event (M_w 7.8).
- The forward directivity is prominent at Adıyaman and the North of Kahramanmaraş in the second event (M_w 7.6).

02| Loss model components investigated

Given a specific event with magnitude $M_W = m_w$ and a single risk at a site $R_{RUP} = r_{rup}$ km from the ruptured fault segment, the probability of loss exceeding a specific threshold l ($P(L \geq l)$) is

$$P[L \geq l] = \sum_i \sum_j \underbrace{P\left[L \geq l | IM = im_i, V_{s30} = v_j\right]}_{\text{Loss conditioned on ground motion (vulnerability)}} \cdot \underbrace{P\left[IM = im_i | V_{s30} = v_j\right]}_{\text{Ground motion conditioned on } V_{S30}} \cdot \underbrace{P\left[V_{s30} = v_j\right]}_{\text{Soil condition } (V_{S30})}$$

Loss conditioned on ground motion (vulnerability)

Ground motion conditioned on V_{S30}

Soil condition (V_{S30})

The above expression indicates that the uncertainty in

a. Vulnerability model and
b. soil conditions at the site of interest (provided that the ground-motion model as well as the ground-motion intensity metric used in the loss analyses can unbiasedly represent the hazard and can rationally correlate with damage)

If the loss estimations are for a building portfolio, the uncertainty in the spatial distribution of portfolio as well as its granularity (in terms of structural types) will also be the other points of concern in loss modeling

In the case of Kahramanmaraş earthquake sequence the loss modeling is challenged by the two sequential major earthquakes, occurring with nine hours of difference, that amplify the damage of the insured assets in the portfolio

02| Loss model components investigated

Under the explanations given in the previous slides, this presentation focuses on the uncertainties in

V_{S30} (parameter describing the soil conditions at portfolio sites)

- *Median V_{S30} vs. V_{S30} as a distribution at each portfolio site*

Spatial distribution of portfolio

- *Portfolios lumped at the subprovince centers*
- *Portfolios distributed at 0.1, 0.05 and 0.025-degree cells within the provinces*

Vulnerability models

- *Mean damage vs. damage as a distribution*

Granularity of portfolio

- *Policies as is (distributed over geological coordinates)*
- *All policies in the portfolio are mid-rise (4 to 9 story buildings) and are lumped at the district centers*
- *All policies in the portfolio are low-code (built before 1975) and are lumped at the district centers*
- *All policies in the portfolio are mid-rise (4 to 9 story buildings) and low-code (built before 1975). They are lumped at the district centers*

Modeling of two sequential events

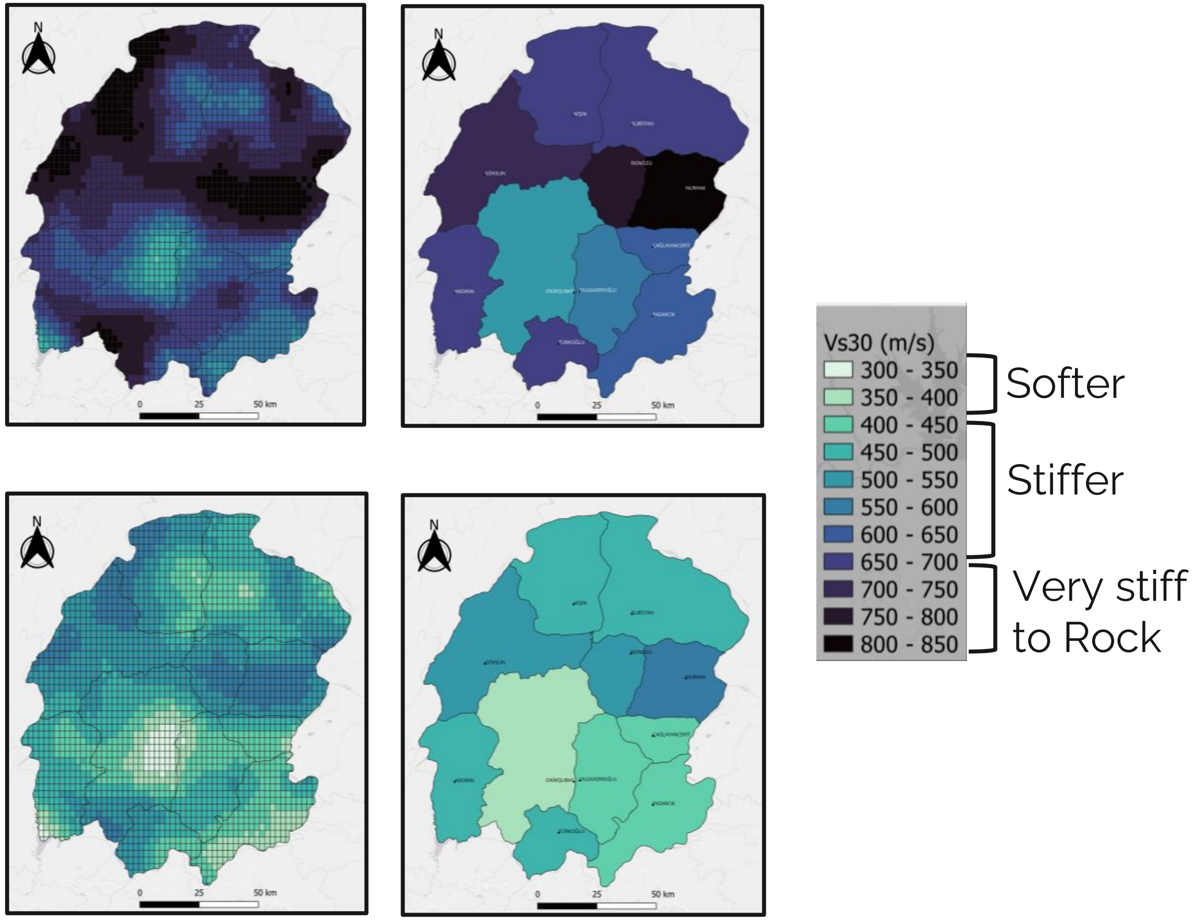
- *Two events separately*
- *Aggregate the damaging effects of two sequential events with alternative damage models*

02| Loss model components investigated *(Uncertainty in V_{S30} and consequences on spatial distribution)*

Grid size: 0.025° | Subdistrict centers

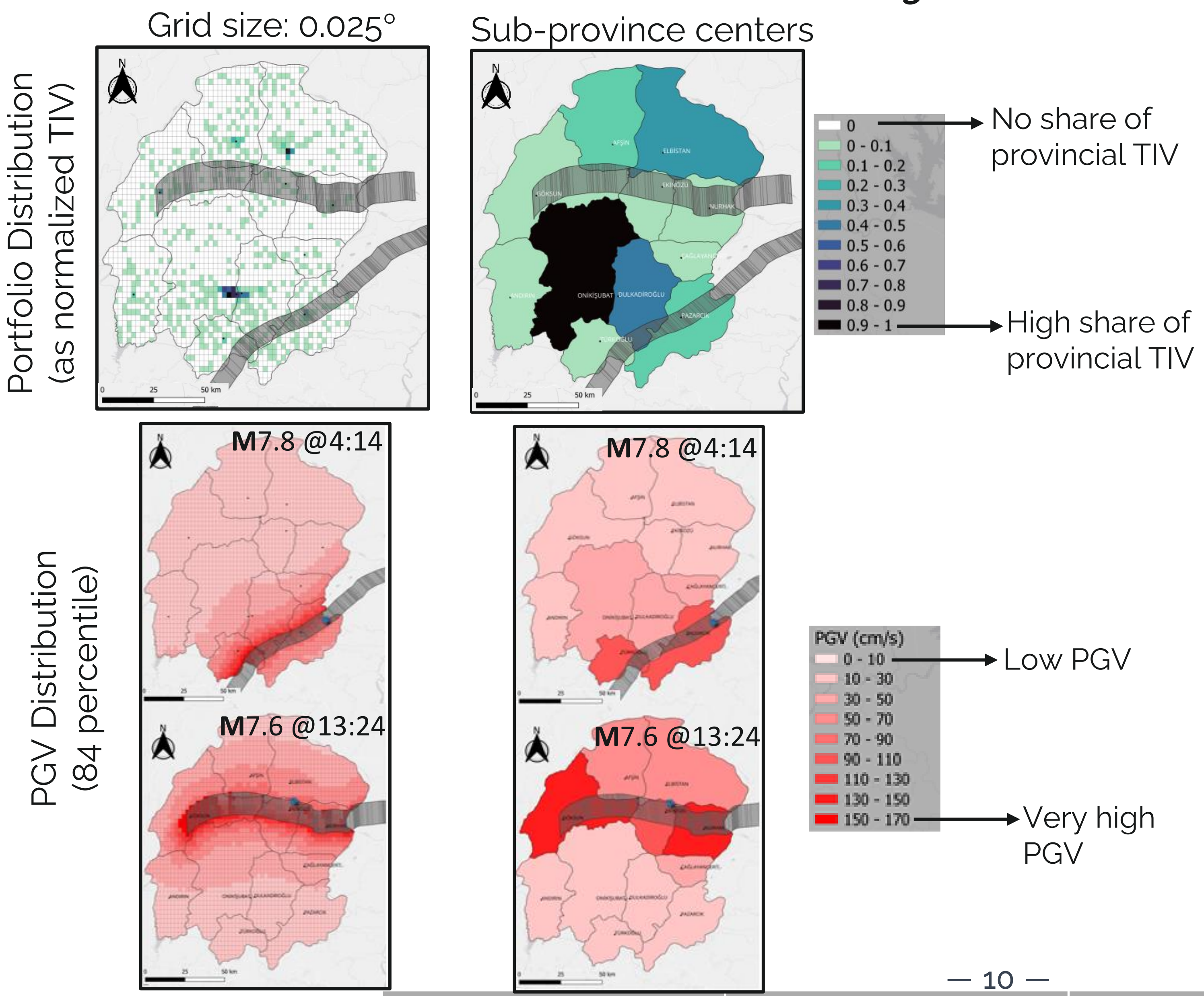
84 prc. V_{S30}

Median V_{S30}

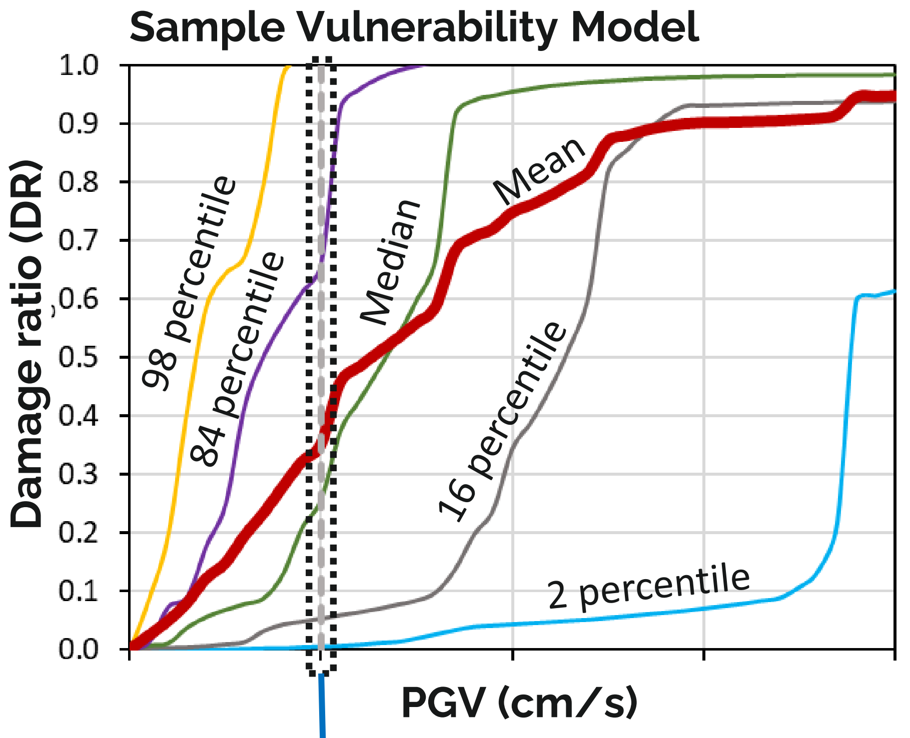


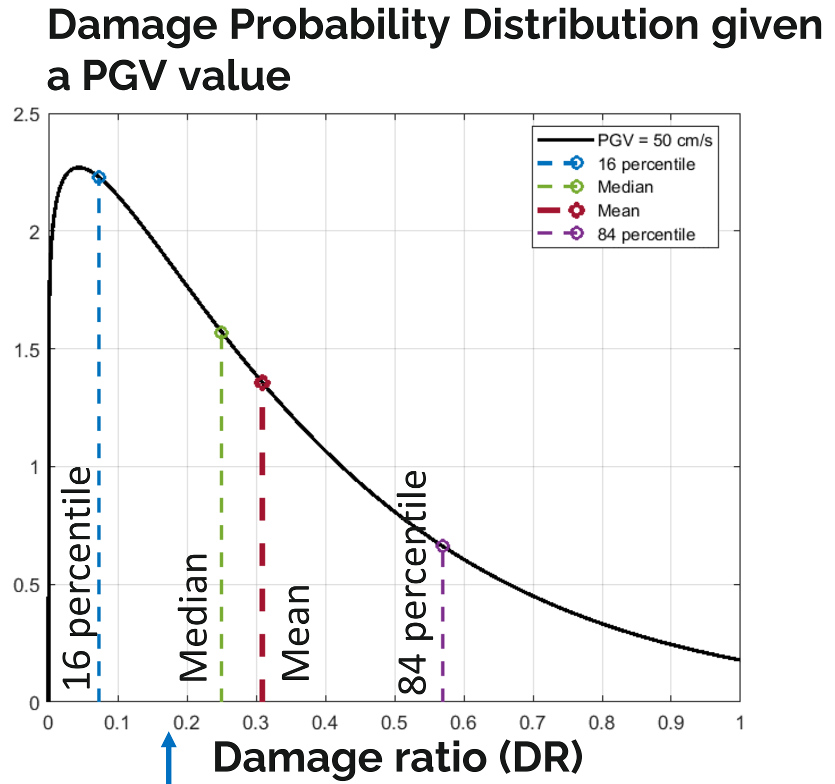
- From fine-to-gross grid structure the variation in soil conditions is captured at different levels
- The uncertainty in V_{S30} (median ± σ) leads to variations in site conditions from soft to very stiff soil conditions (or vice versa)

02| Loss model components investigated *(Portfolio distribution and consequences on grid size - emphasis on ground-motion distribution-)*



Fine-to-coarse spatial distribution of portfolio (when considered together with the spatial ground-motion distribution) can be the indicators of different levels of monetary loss in total insured value (TIV)



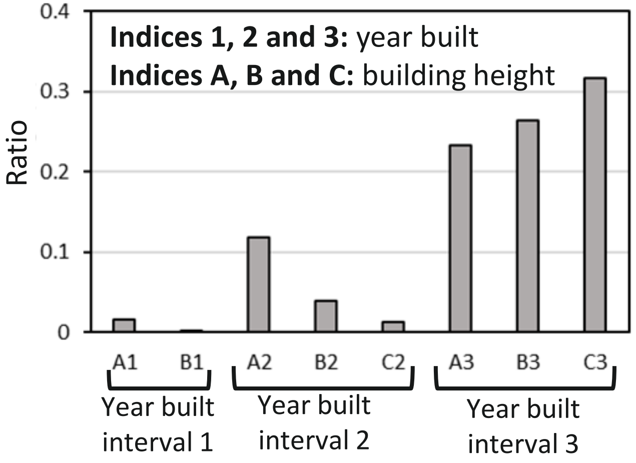


Consideration of mean damage (loss) disregards the model uncertainty in vulnerability

02| Loss model components investigated *(Portfolio granularity and consequences on damage modeling of portfolio)*

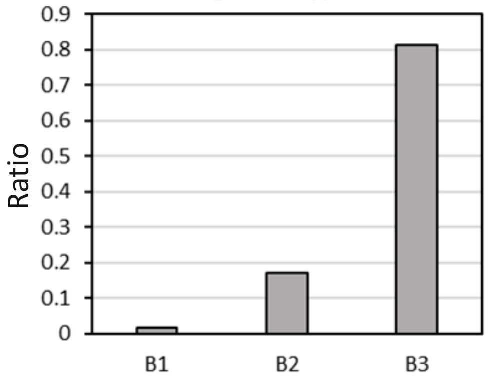
Original portfolio

Portfolio “as is”

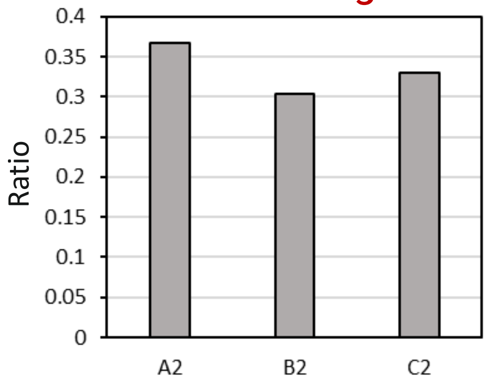


Portfolios derived from original portfolio at different levels of granularity

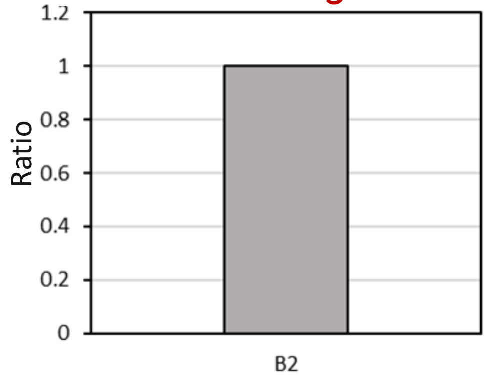
Building height variation is disregarded



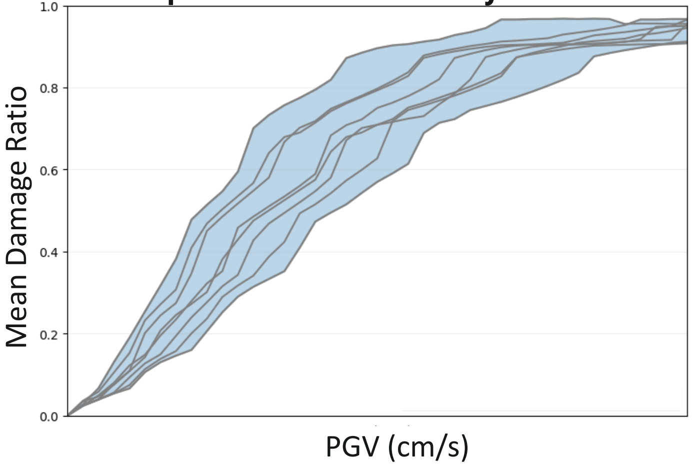
Year built is disregarded



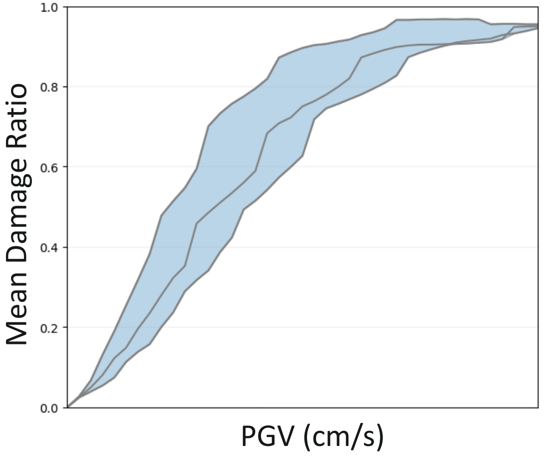
Building height and year built are disregarded



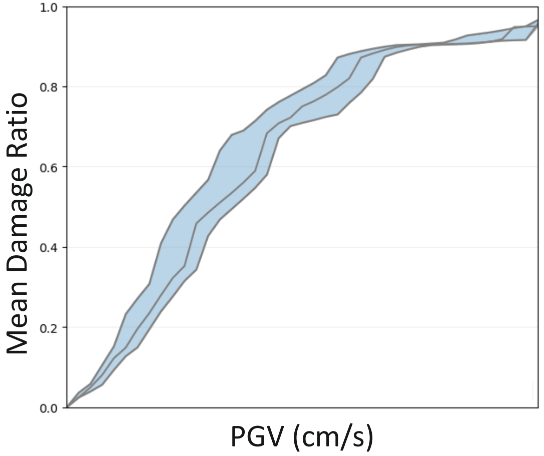
Mean portfolio vulnerability



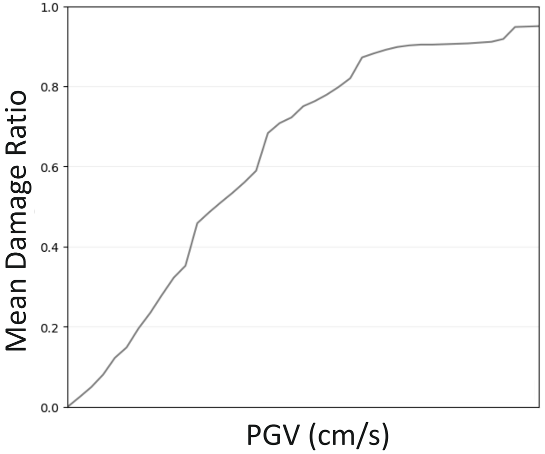
Mean portfolio vulnerability



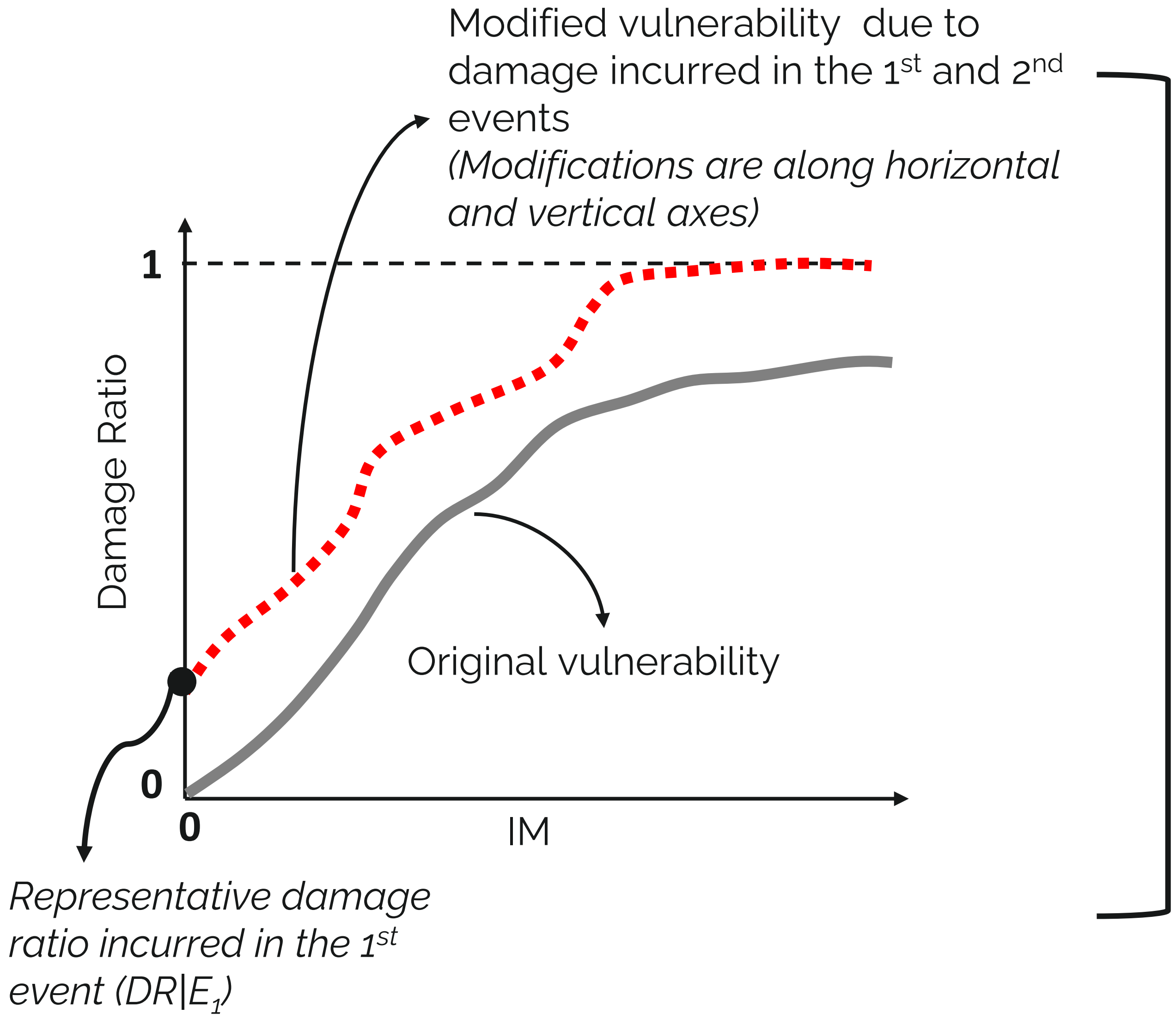
Mean portfolio vulnerability



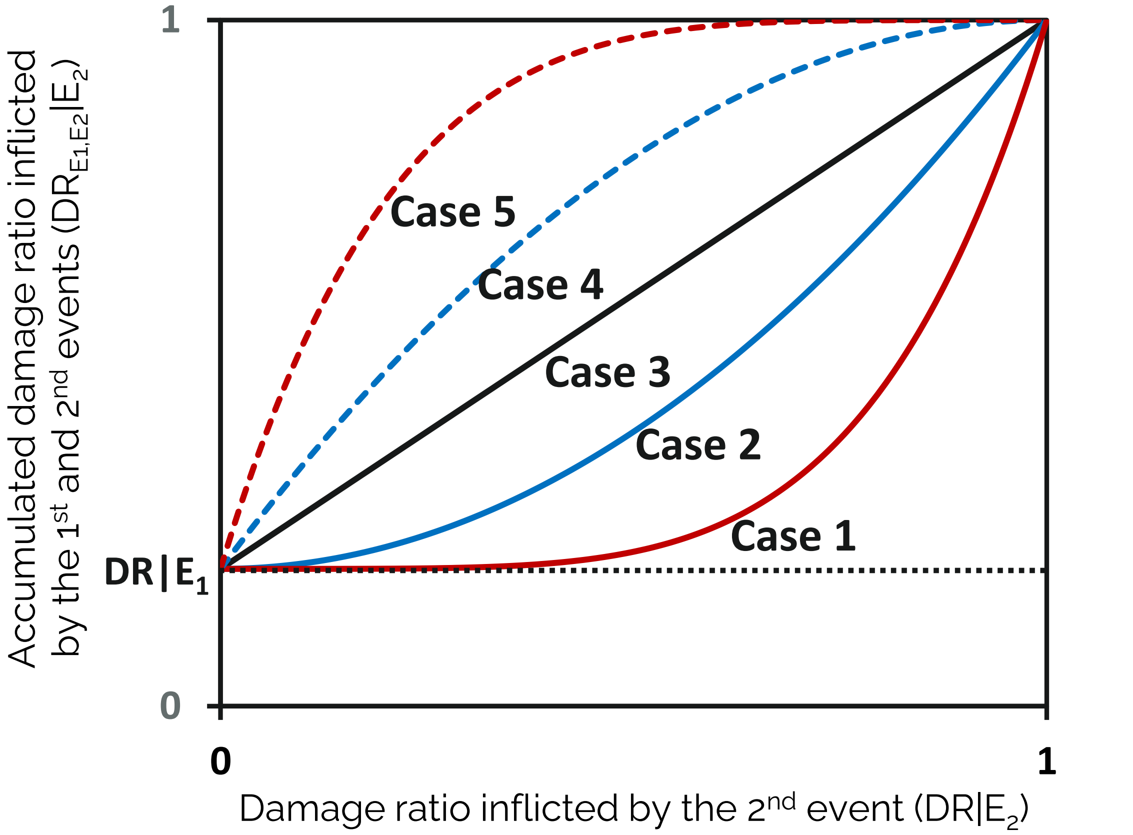
Mean portfolio vulnerability



02| Loss model components investigated *(Consideration of sequential earthquakes on loss)*



Sample cases of modifying models used to account for damage incurred in the 1st and 2nd events together

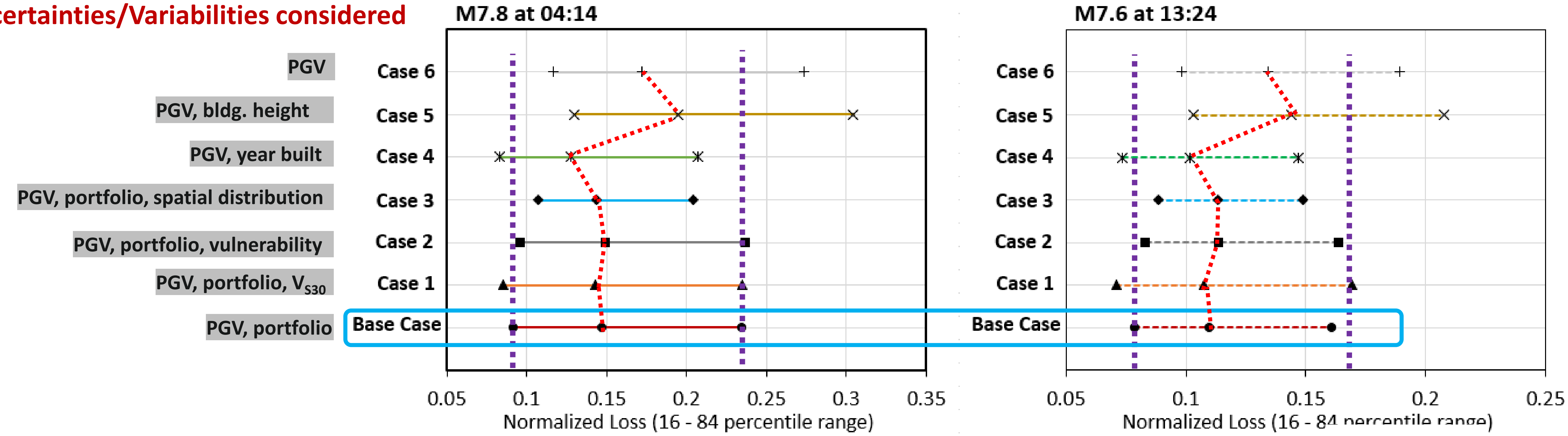


There can be different models to describe different damage modalities

03 Observations *(Influence of V_{S30}, vulnerability modeling, spatial distribution of portfolio and portfolio granularity on estimated loss)*

Case	Portfolio granularity	Portfolio spatial distribution	Vulnerability	V_{S30}
Base Case	**As is**	**Lumped at each sub-province center**	**Mean vulnerability curves**	**Median V_{S30}**
Case 1	As is	Lumped at each sub-province center	Mean vulnerability curves	Distributed V_{S30}
Case 2	As is	Lumped at each sub-province center	Distributed vulnerability models	Median V_{S30}
Case 3	As is	Distributed over 0.025-degree grids	Mean vulnerability curves	Median V_{S30}
Case 4	Disregard building height variation	Lumped at each sub-province center	Mean vulnerability curves	Median V_{S30}
Case 5	Disregard year built	Lumped at each sub-province center	Mean vulnerability curves	Median V_{S30}
Case 6	Disregard both building height and year built	Lumped at each sub-province center	Mean vulnerability curves	Median V_{S30}

Uncertainties/Variabilities considered

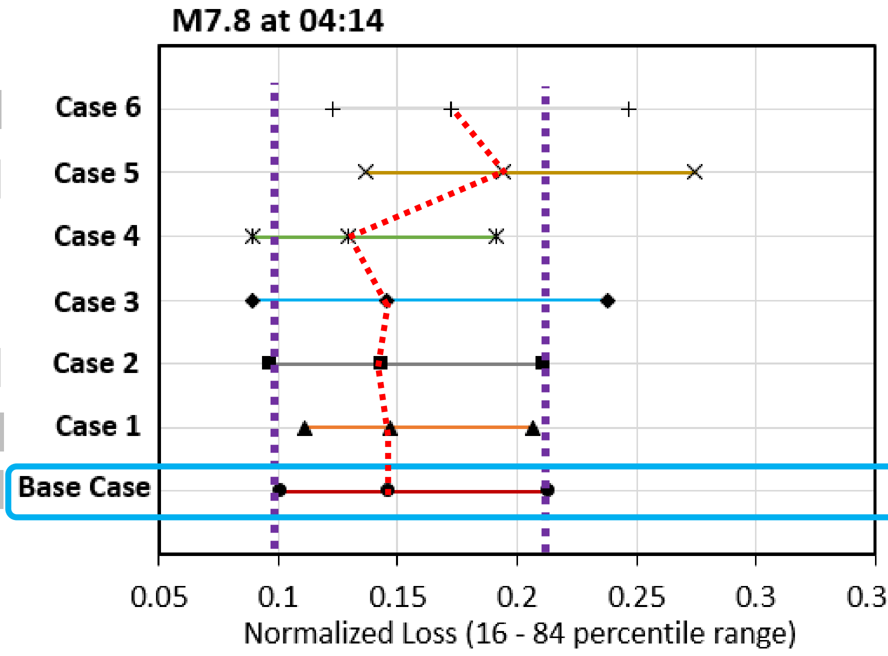


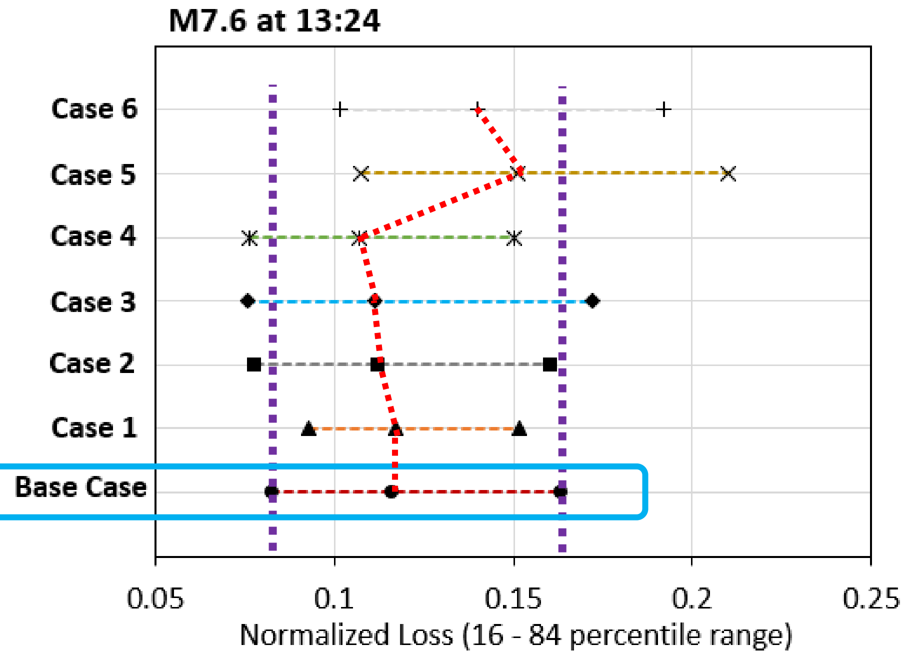
03 | Observations *(Influence of V_{S30}, vulnerability modeling, spatial distribution of portfolio and portfolio granularity on estimated loss)*

Case	Portfolio granularity	Portfolio spatial distribution	Vulnerability	V_{S30}
Base Case	**As is**	**Distributed over 0.025-degree grids**	**Distributed vulnerability models**	**Distributed V_{S30}**
Case 1	As is	Distributed over 0.025-degree grids	Distributed vulnerability models	Median V_{S30}
Case 2	As is	Distributed over 0.025-degree grids	Mean vulnerability curves	Distributed V_{S30}
Case 3	As is	Lumped at each sub-province center	Distributed vulnerability models	Distributed V_{S30}
Case 4	Disregard building height variation	Distributed over 0.025 degrees	Distributed vulnerability models	Distributed V_{S30}
Case 5	Disregard year built	Distributed over 0.025 degrees	Distributed vulnerability models	Distributed V_{S30}
Case 6	Disregard both building height and year built	Distributed over 0.025 degrees	Distributed vulnerability models	Distributed V_{S30}

Uncertainties/variabilities considered

- Case 6: PGV, vulnerability, V_{S30}
- Case 5: PGV, bldg. height , vulnerability, V_{S30}
- Case 4: PGV, year built , vulnerability, V_{S30}
- Case 3: PGV, portfolio, vulnerability, V_{S30}
- Case 2: PGV, portfolio, spatial distribution, V_{S30}
- Case 1: PGV, portfolio, spatial distribution, vulnerability
- Base Case: PGV, portfolio, spatial distribution, vulnerability, V_{S30}





03| Observations *(Overall remarks from previous two slides)*

1) A well-defined portfolio → Leads to → Insignificant variations in median losses originating from the uncertainties in V_{S30}/vulnerability, as well as the spatial distribution of portfolio

2) Dispersion about median losses are sensitive to the uncertainties in V_{S30}, vulnerability and the spatial distribution of portfolio → But → if portfolio granularity is well-defined, betterment in portfolio's spatial distribution results in a decrease in the dispersion about median loss

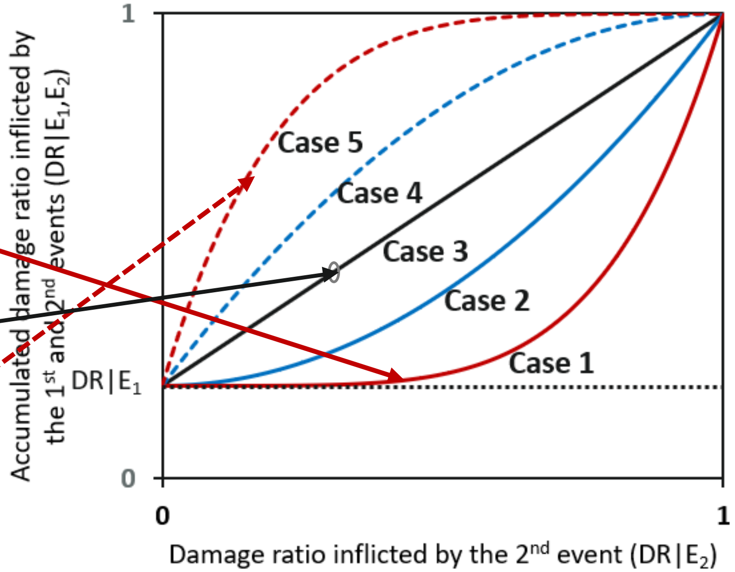
3) There is an intricate interaction between loss and V_{S30}/vulnerability uncertainty → This is because → V_{S30} uncertainty affects the ground-motion distributions, which eventually affects the loss distribution due to inflated/deflated vulnerability uncertainty

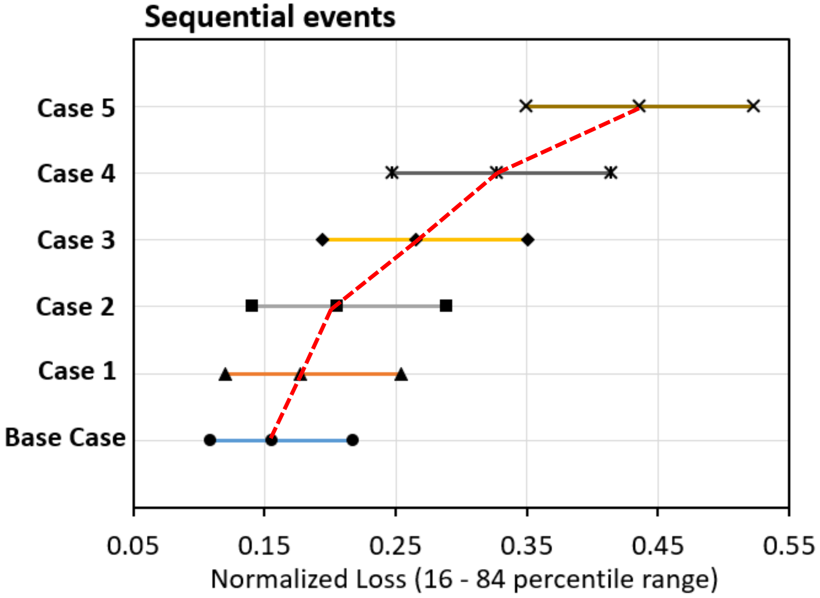
4) Underreported portfolio granularity (height variation/year built) shifts the loss distribution → This is because → The damage modalities of the portfolio are affected in a biased manner due to deficient physical properties of buildings in the portfolio

03| Observations *(Modeling of sequential earthquakes)*

- ***Portfolio is lumped at the sub-province centers/V_{S30} as distribution/Vulnerability as distribution***

Case	Assumption
Base Case	**Maximum loss of the 1st and 2nd earthquakes**
Case 1	Portfolio exhibits very slow deterioration after the 1st earthquake
Case 2	Portfolio exhibits slow deterioration after the 1st earthquake
Case 3	Portfolio exhibits moderate deterioration after the 1st earthquake
Case 4	Portfolio quickly deteriorates after the 1st earthquake
Case 5	Portfolio severely deteriorates after the 1st earthquake





Variations in modifying models change the loss distributions as each time the portfolio damage modality changes

03| Observations *(Modeling of sequential earthquakes)*

Step #1 Collect damage states of building portfolio from public-open databases and compute a "reference damage index" to select a "fairly suitable" modifying model among the alternatives that are tailored to estimate portfolio loss subjected to sequential earthquakes.

Step #2 Perform loss analyses with the alternative modifying models. The resolution of the observed damage data is the guidance on the level of complexity in loss calculations.

Step #3 Compare loss estimations of alternative modifying models with reference damage indices by error analysis.

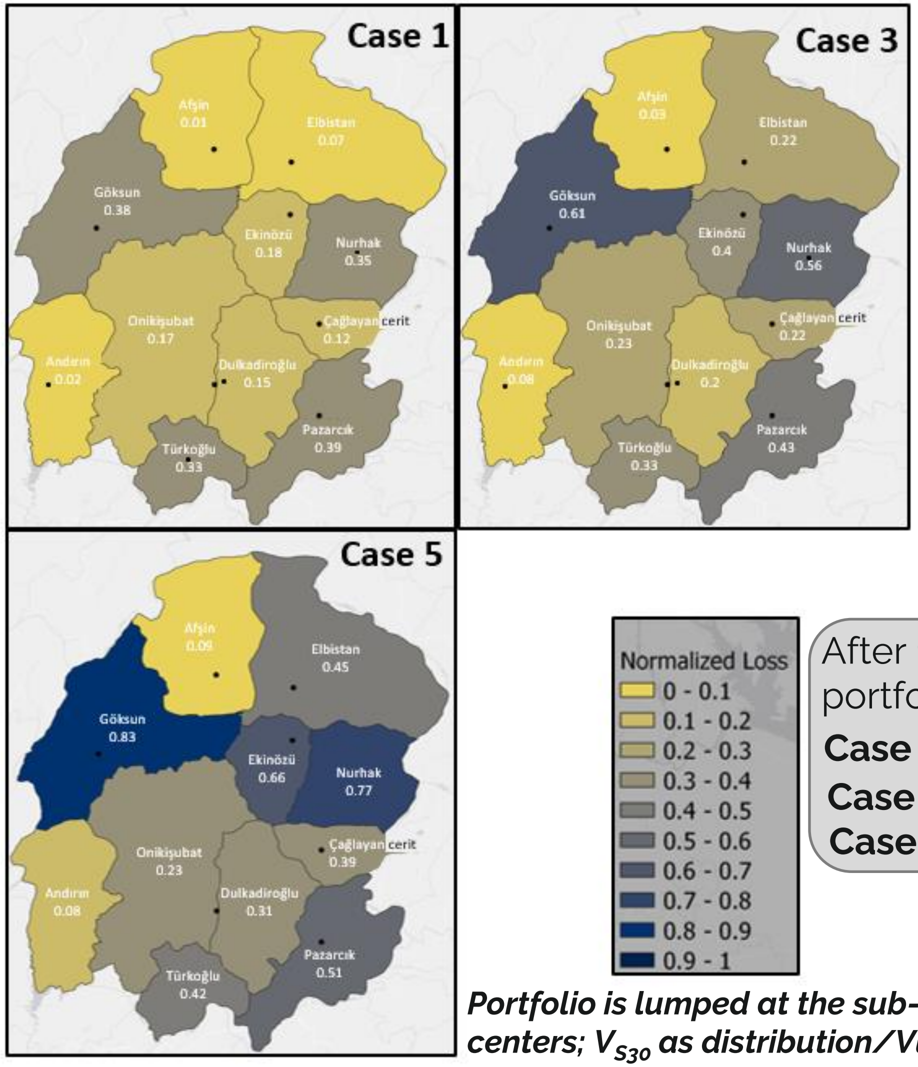
03| Observations *(Modeling of sequential earthquakes)*

Step #1 *Public open data (Ministry of EUC as of 27/02/2023)*

Compound loss determined from local fragility studies

Sub-province	No Damage	Light	Moderate	Severe	Collapse	Reference Index
Afşin	49.0%	28.2%	1.2%	17.5%	4.0%	0.25
Andırın	68.0%	22.7%	2.1%	6.2%	1.0%	0.10
Çağlayancerit	42.4%	32.6%	4.3%	16.8%	3.8%	0.25
Dulkadiroğlu	45.0%	30.1%	2.1%	16.4%	6.3%	0.26
Ekinözü	27.9%	22.3%	6.9%	37.0%	6.0%	0.47
Elbistan	61.9%	23.3%	0.7%	7.9%	6.3%	0.17
Göksun	33.4%	29.2%	3.3%	26.4%	7.7%	0.38
Nurhak	15.3%	29.4%	3.5%	37.5%	14.3%	0.56
Onikişubat	46.4%	37.2%	3.1%	10.7%	2.6%	0.18
Pazarcık	33.8%	31.9%	1.7%	22.6%	10.0%	0.36
Türkoğlu	37.5%	31.5%	2.1%	17.7%	11.2%	0.33

Step #2 *Normalized median losses of each sub-province by the corresponding TIV with alternative modifying models*



After 1[st] event, portfolio deteriorates

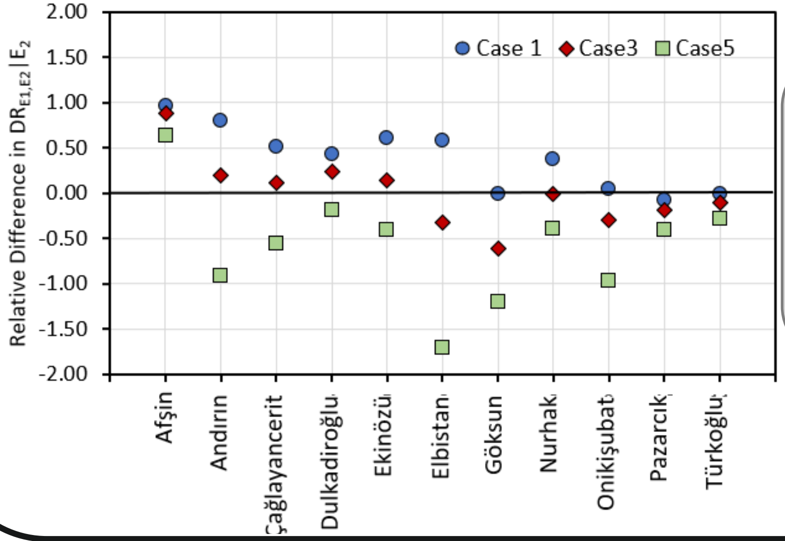
Case 1: very slowly

Case 3: moderately

Case 5: severely

Portfolio is lumped at the sub-province centers; V_{S30} as distribution/Vulnerability as distribution

Step #3 *Relative differences of each model wrt Reference Index*



Averages of relative differences for each model:

Case 1: 0.38

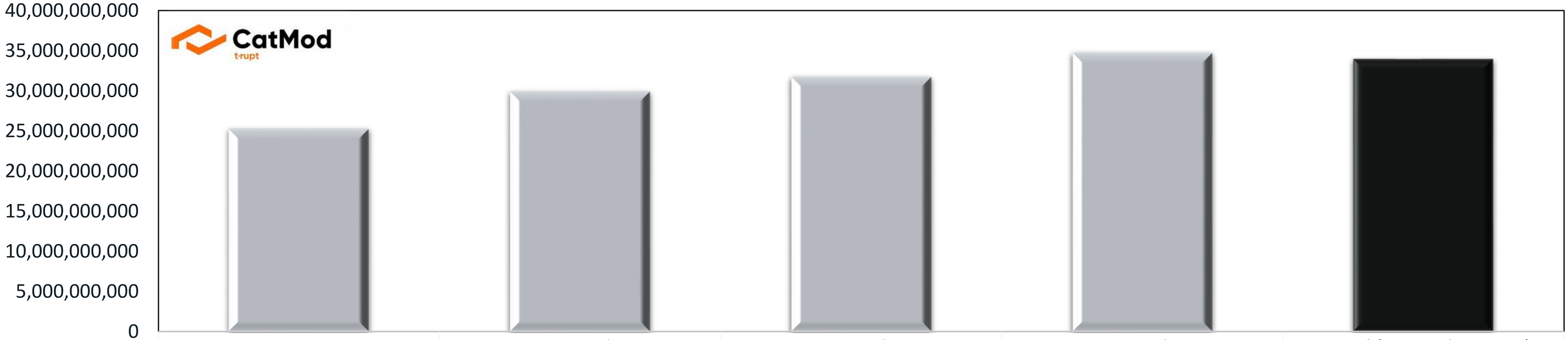
Case 3: 0.01

Case 5: -0.58

03| Observations *(Modeling of sequential earthquakes – Estimated losses and comparisons with TCIP payouts)*

Using Model 3 to account for the sequential M_w7.8 and M_w7.6 earthquakes – Portfolio as is; lumped at sub-province centers; uncertainty in site conditions and vulnerabilities

Ground up (Total) Loss (₺)



	Mean	10% Exceedance	5% Exceedance	1% Exceedance	Actual (September 2023)
Ground Up Loss	25,306,720,442	29,945,427,948	31,782,583,121	34,772,301,077	34,000,000,000

The re/insurance industry need “event response” reports to secure their cash flow after a catastrophic event (~430k first notification of losses by the end of March in the Kahramanmaraş earthquakes)

The natural catastrophe modeling must respond such inquiries in a reasonable period after the catastrophic event has occurred by developing physically justifiable models. This presentation outlines such a methodology and its application

There is a handful variable that affects the computed loss distribution

Of those which are discussed in this presentation the portfolio granularity and its spatial distribution can significantly affect the median loss variation. Disregarding/considering the uncertainty in the vulnerability models and soil conditions affect the tails of the loss distribution

To understand the specific contribution of each variable on the loss distribution further analysis (such as variance analysis) is required

Thank you