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Revised probabilistic hazard map of Turkey and its implications on seismic design

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Outline

- *Revision of Turkish Seismic Hazard Map Project (T-SHM): Brief overview*
  - Motivation
  - Major studies
  - Main deliverables
- *Implications on design codes*
  - Turkish design spectrum
  - Long-period spectral corner period (T_L)
  - Damping scaling factors
  - Vertical design spectrum

Acknowledgements

- *Disaster and Emergency Management Authority (AFAD) and Turkish Catastrophe Insurance Pool (TCIP)*
- *Project group*
- *Dr. Özkan Kale*

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ELABORATION OF MAPS FOR CLIMATIC AND SEISMIC ACTIONS FOR STRUCTURAL DESIGN IN THE BALKAN REGION

27-28 October 2015, Zagreb

Revision of Turkish seismic hazard map project

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A multi-institutional project funded by the Disaster and Emergency Management Authority (AFAD) and Turkish Catastrophe Insurance Pool (TCIP)

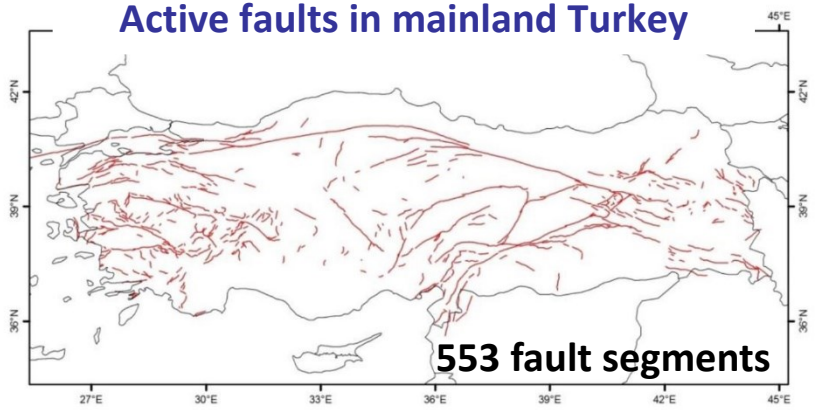
- Revise seismic hazard maps at the national level based on the recent state-of-the-art developments and findings in this field (Turkey and worldwide)
- Provide spectral ordinates (PGA, SA at T = 0.2s and 1.0s) for return periods of 43 years (69%/50 years), 72 years (50%/50 years), 475 years (10%/50 years) and 2475 years (2%/50 years) for their use in the definition of updated code spectra and insurance premiums

Earthquake Catalog

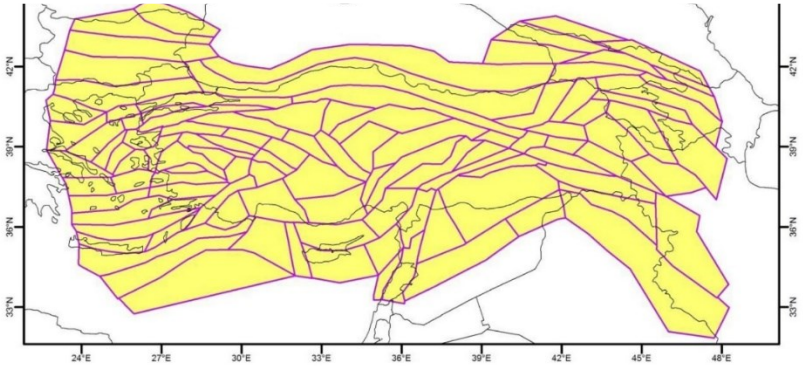
- *Compilation of instrumental catalog (12674 earthquakes) is based on national / international catalogs*
- *Historical catalog (512 earthquakes) is compiled from the recently finished GEM-Historical Catalog, SHARE and EMME projects*
- *Minimum magnitude bound is 4*
- *Homogenized magnitudes (M_w) through empirical conversion equations developed from the compiled catalog*
- *Declustering and completness analyses*

Seismic Sources

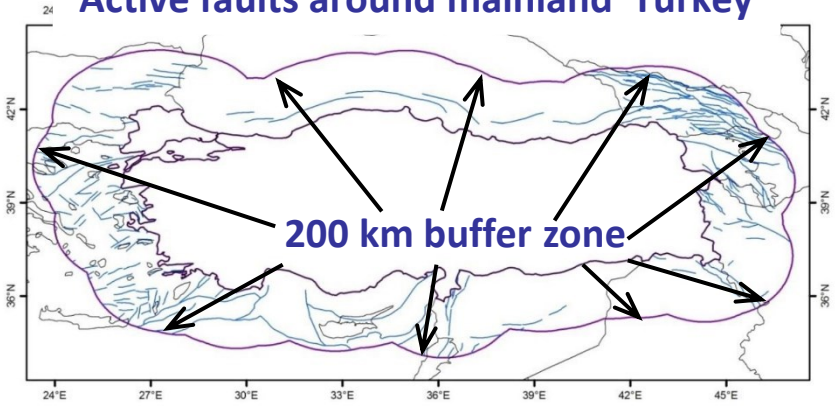
Active faults in mainland Turkey



Area sources in and around mainland Turkey



Active faults around mainland Turkey



Literature review, already finished national and international projects, earthquake catalogs, GIS maps to determine active fault segments, area sources, maximum magnitudes, slip rates, geometries, style-of-faulting, depth distribution etc.

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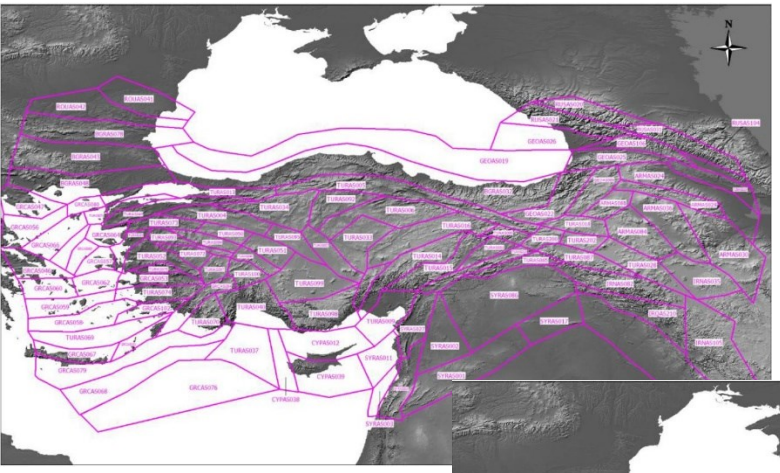
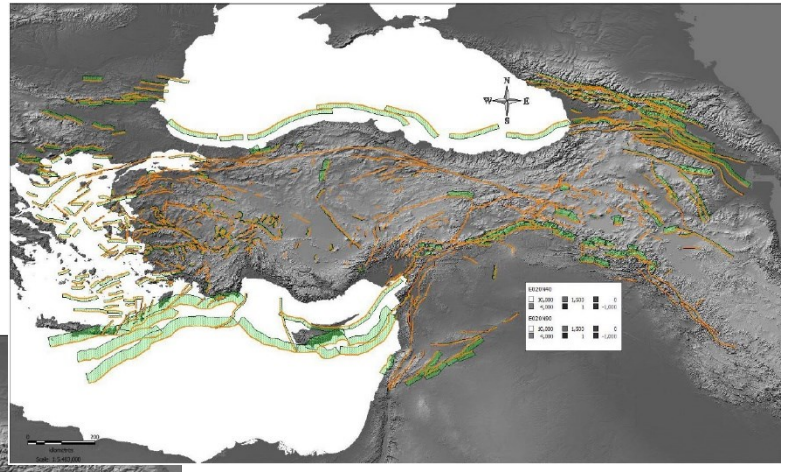
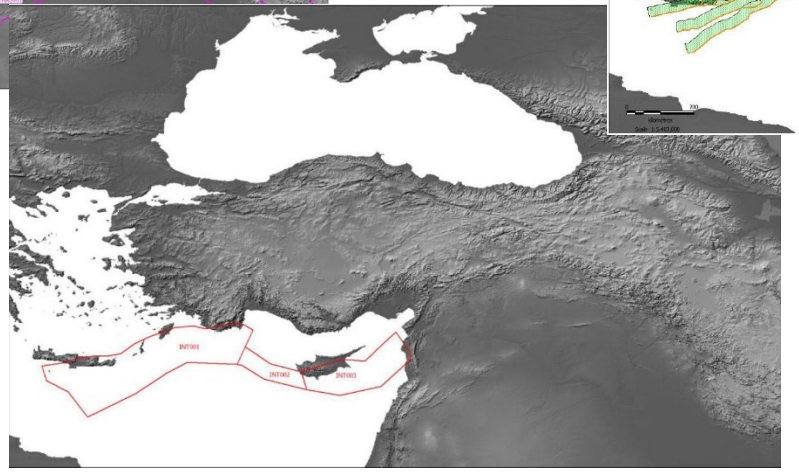
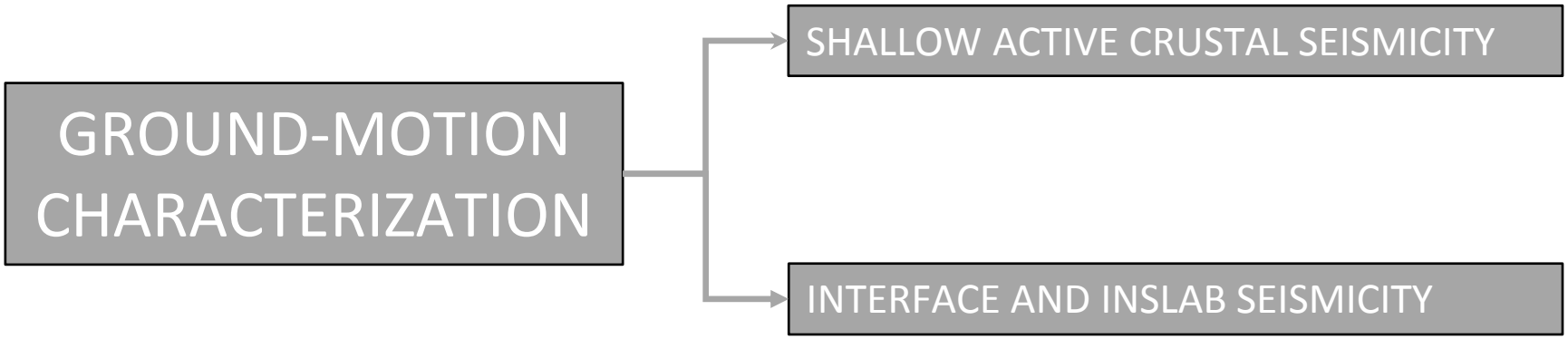
SOURCE CHARACTERIZATION

- AREA SOURCE (AS)
- FAULT + BACKGROUND (FS)







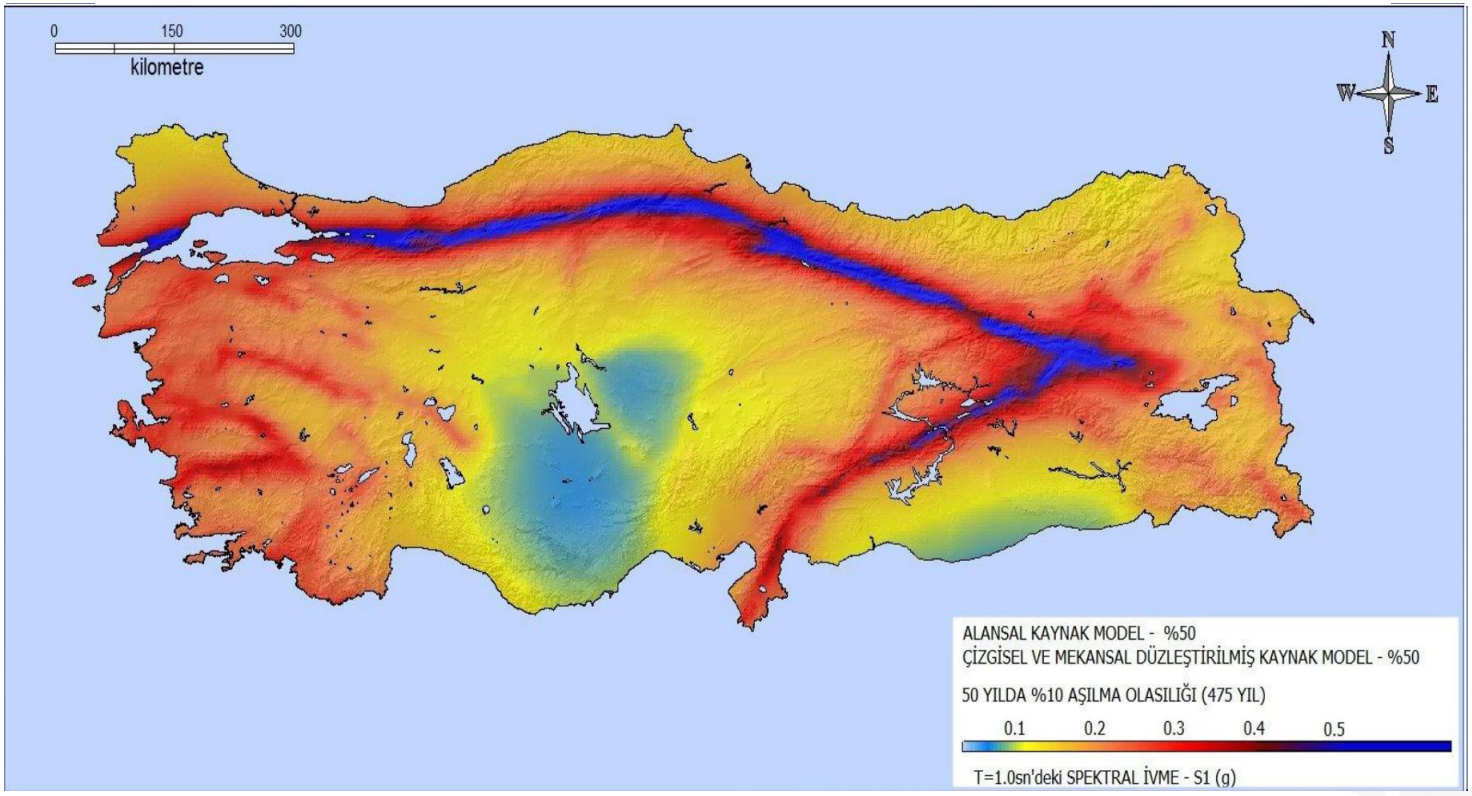


Akkar et al. (2014) – 0.3
Akkar and Çağnan (2014) – 0.3
Chiou and Youngs (2008) – 0.3
Zhao et al. (2006) – 0.1

Zhao et al. (2006) – 0.4
Lin and Lee (2008) – 0.2
Atkinson and Boore (2003) – 0.2
Youngs et al. (2006) – 0.2

- Compute hazard for each seismic source model considering the GMPEs and seismic source logic-trees.
- Combine the results with alternative source model weights

SA at 1.0s – 475 yrs (10% in 50 yrs)



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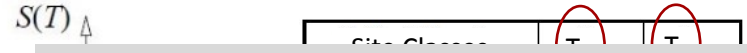
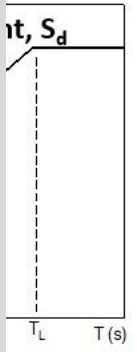
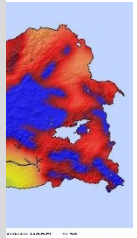
Implications to seismic design

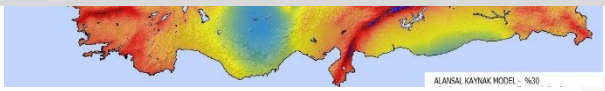
Current Turkish design spectrum

Proposed Turkish design spectrum









In Turkish code:

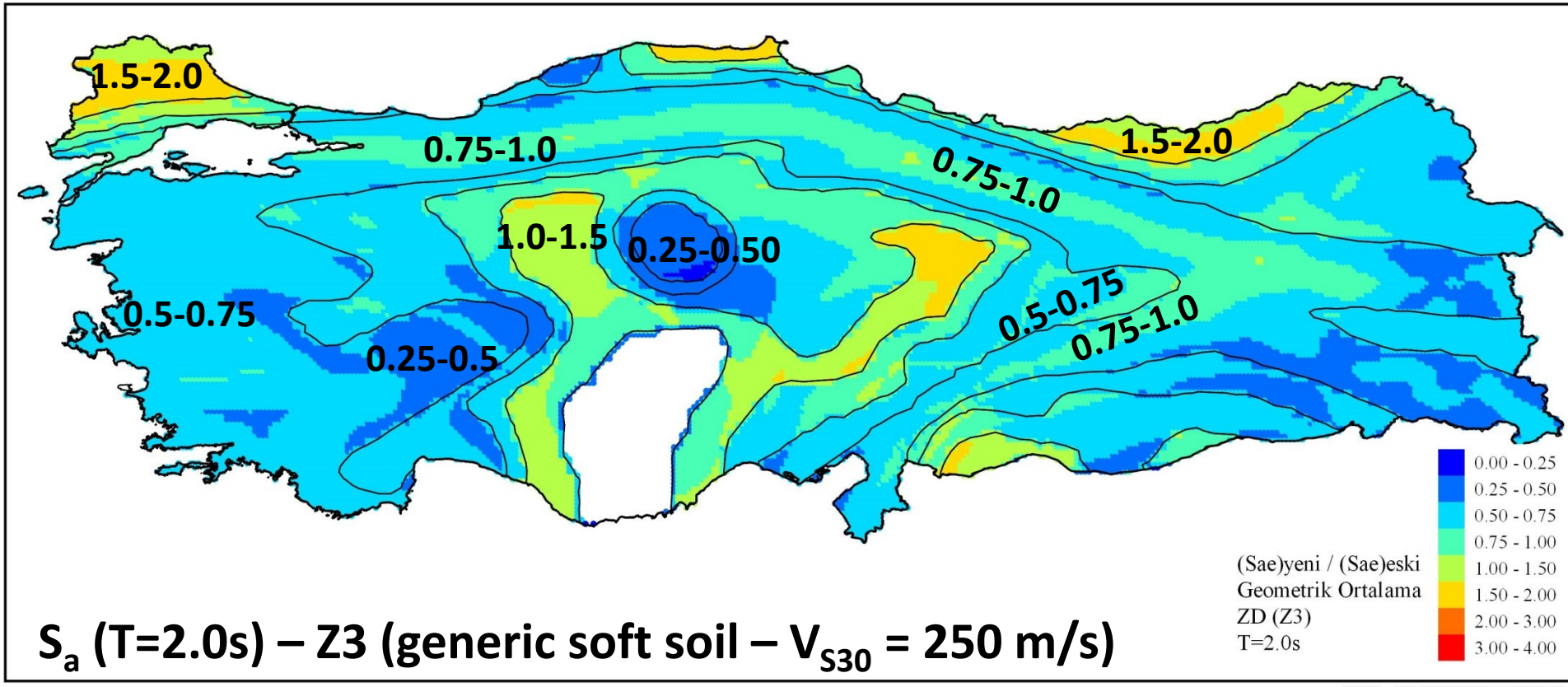
Design: 10% probability of exceedance in 50 years (T_R = 475 yrs)

Immediate Occupancy, Life Safety and Collapse Prevention performances: 50% to 2% probability of exceedance in 50 years

Current code: Zonation map represents T_R = 475 years. Increase it by 50% for T_R = 2475 years and reduce it by 50% for T_R = 72 years (50%/50)

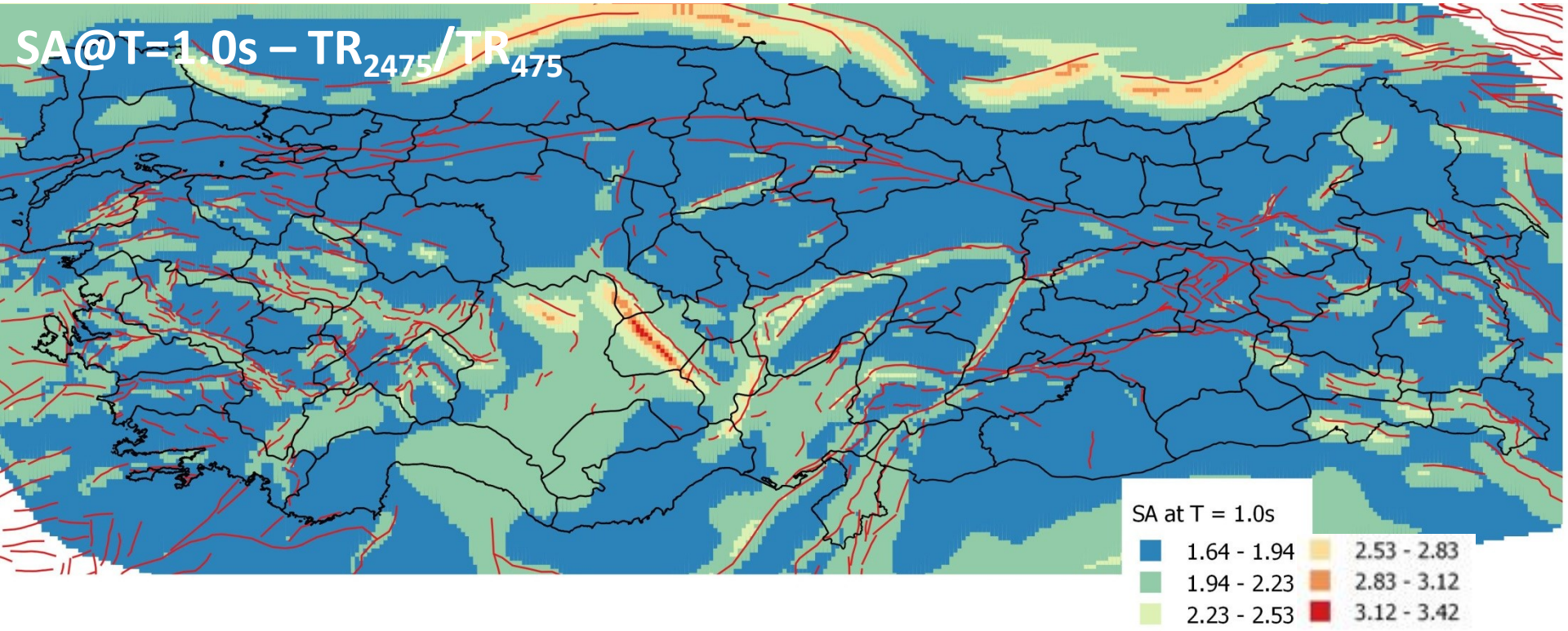
Revised code: Separate maps of SA at T = 0.2s and T = 1.0s for each T_R

(New code & New map / Current code & Current map)



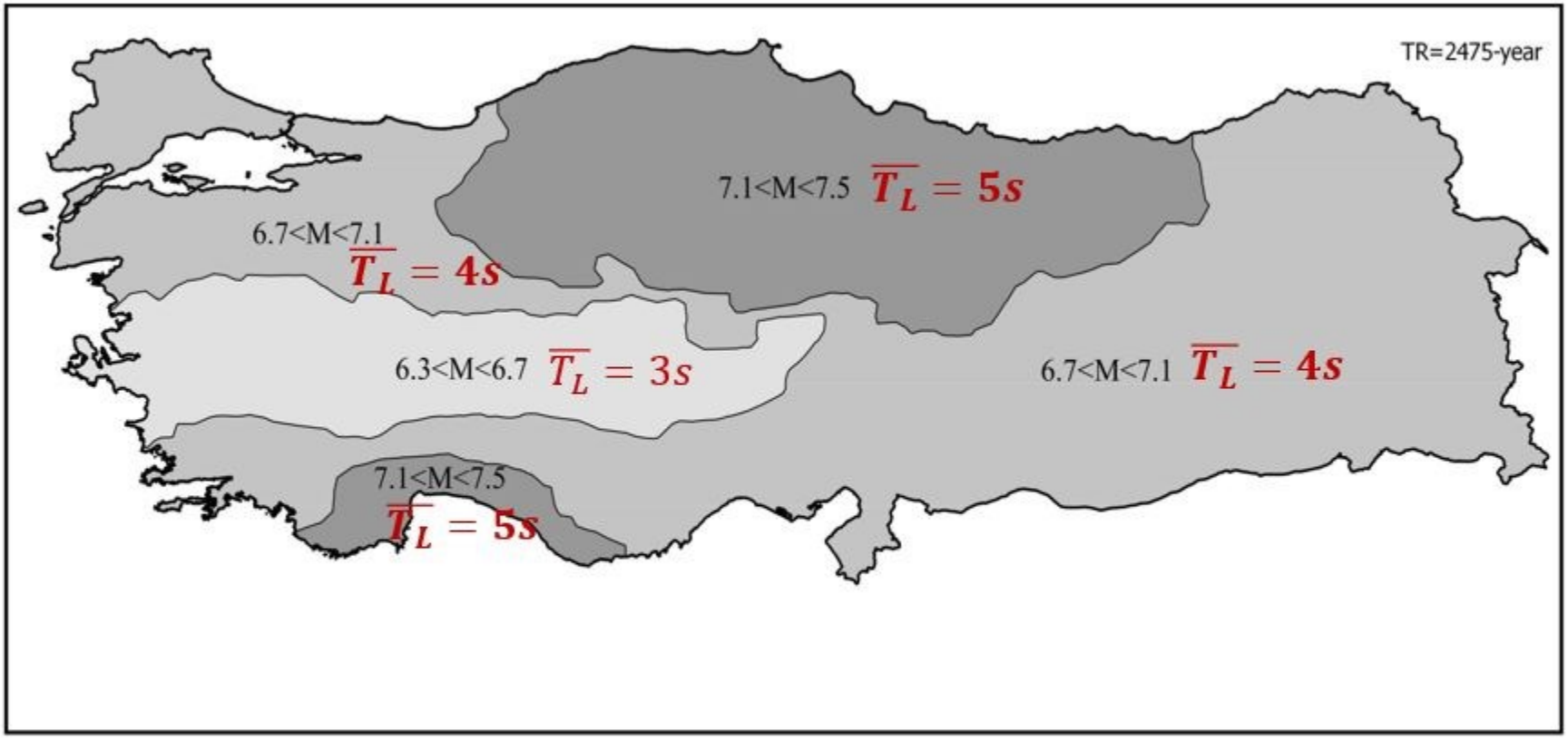
S_a (T=2.0s) – Z3 (generic soft soil – V_{S30} = 250 m/s)

Spectral ratio distribution between 2475-year and 475-year spectral ordinates



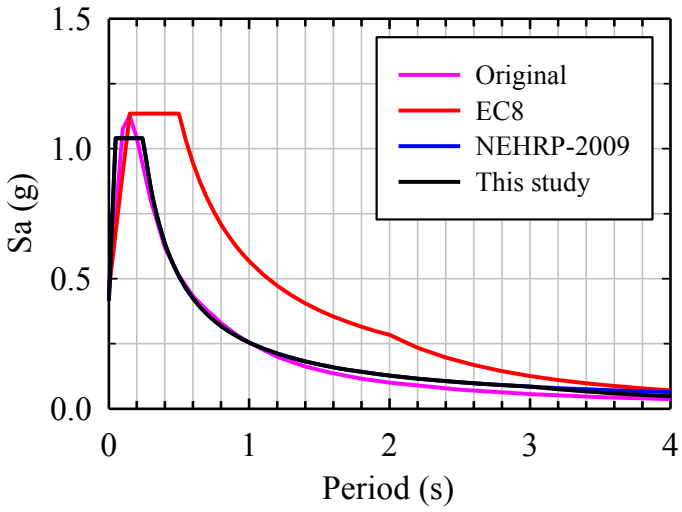
Spectral ratio between 2475-year and 475-year spectral ordinates varies between 1.6 and 3.5. It increases towards seismically less active regions

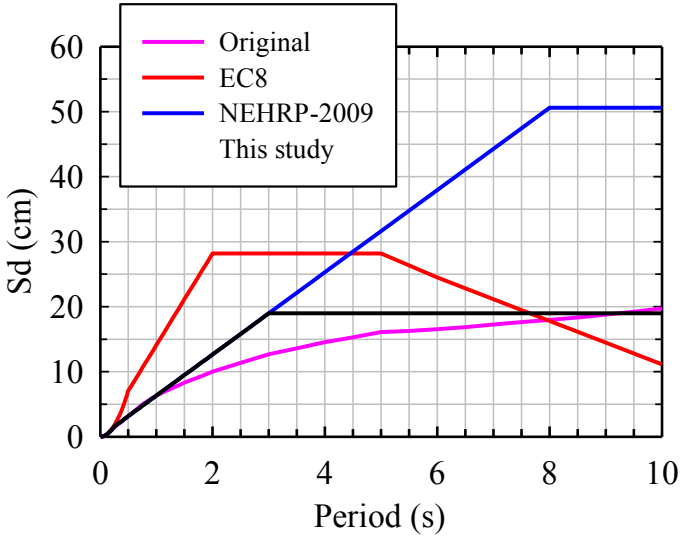
Long-period spectral corner period



Comparisons between various codes (T_L)

Site: 38.45N-30.45E
M_{mean}=6.54
$\overline{T_L}$= 3s





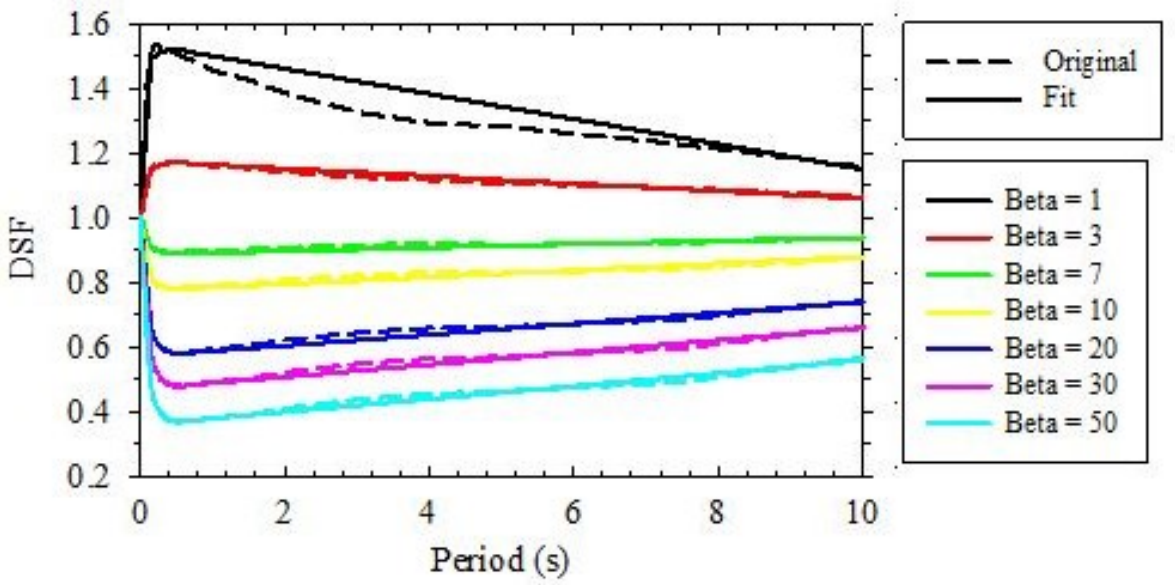
Damping Scaling Factor (DSF)

$$DSF = \frac{SA(\xi \neq 5\%)}{SA(\xi = 5\%)}$$

currently expressed as predictive models in terms of magnitude, source-to-site distance, site conditions, faulting style etc.)

$$\ln(DSF) = f(M, R, V_{S30}, Sof) + \varepsilon\sigma$$

Requires simplifications for their effective use in the codes

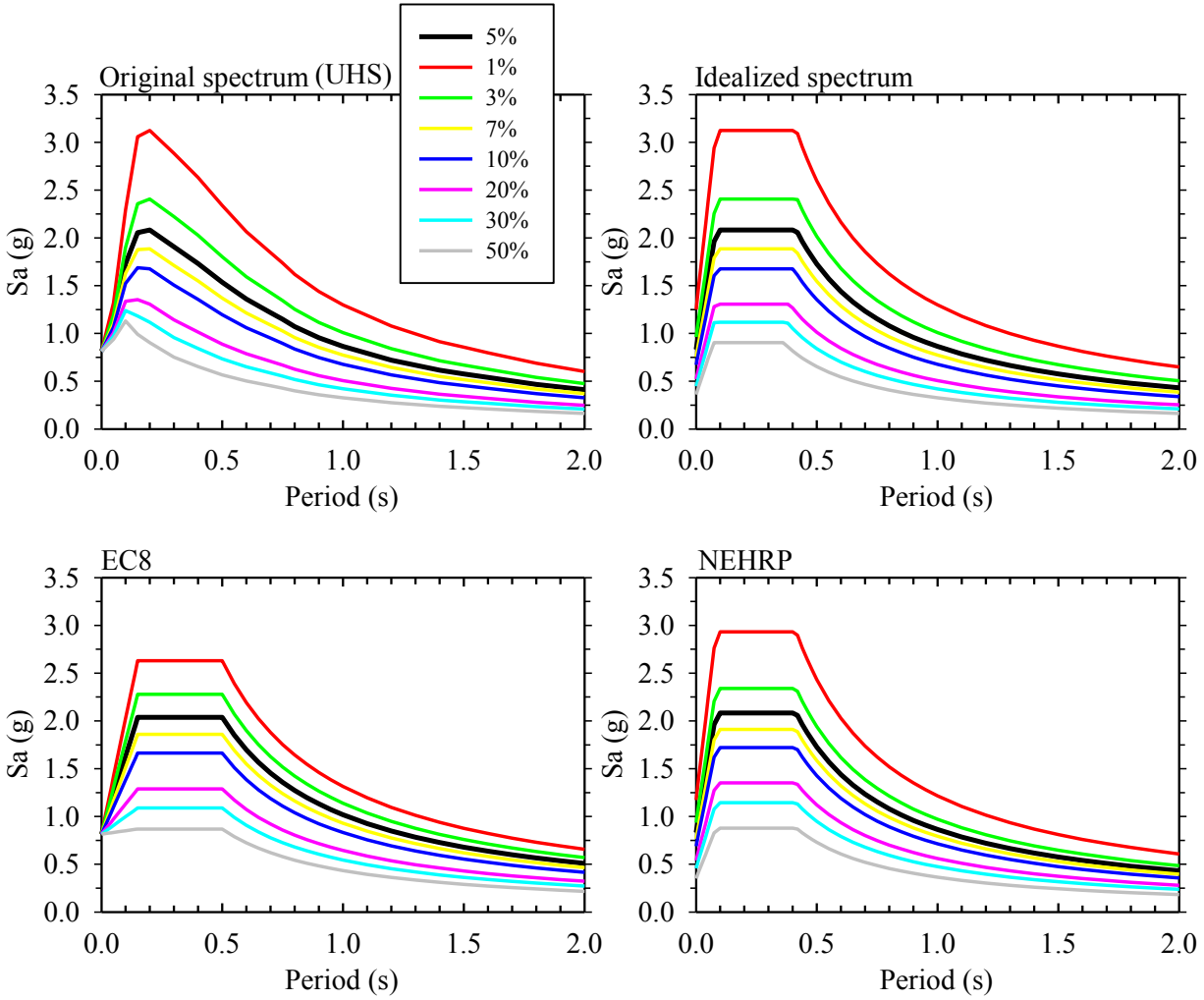


$$0.0s < T < 0.15s \qquad DSF = 1.0 + \frac{(DSF_{T=0.15s} - 1.0) * T}{0.15}$$

$$0.15s \leq T \leq 0.5s \qquad DSF = \frac{a * T}{(b + T)}$$

$$0.5s < T \leq 10s \qquad DSF = DSF_{T=0.5s} + \frac{(DSF_{T=10s} - DSF_{T=0.5s})(T - 0.5)}{9.5}$$

Implementation of DSFs to design as well as UHS



- Proposed DSFs are applicable to both UHS and design spectrum
- Comparable differences in the short period range with respect to EC8. But consistent results with NEHRP
- EC8 yields smaller amplifications for lightly damped systems. This is not the case for the proposed DSF expression

Horizontal-to-vertical spectrum

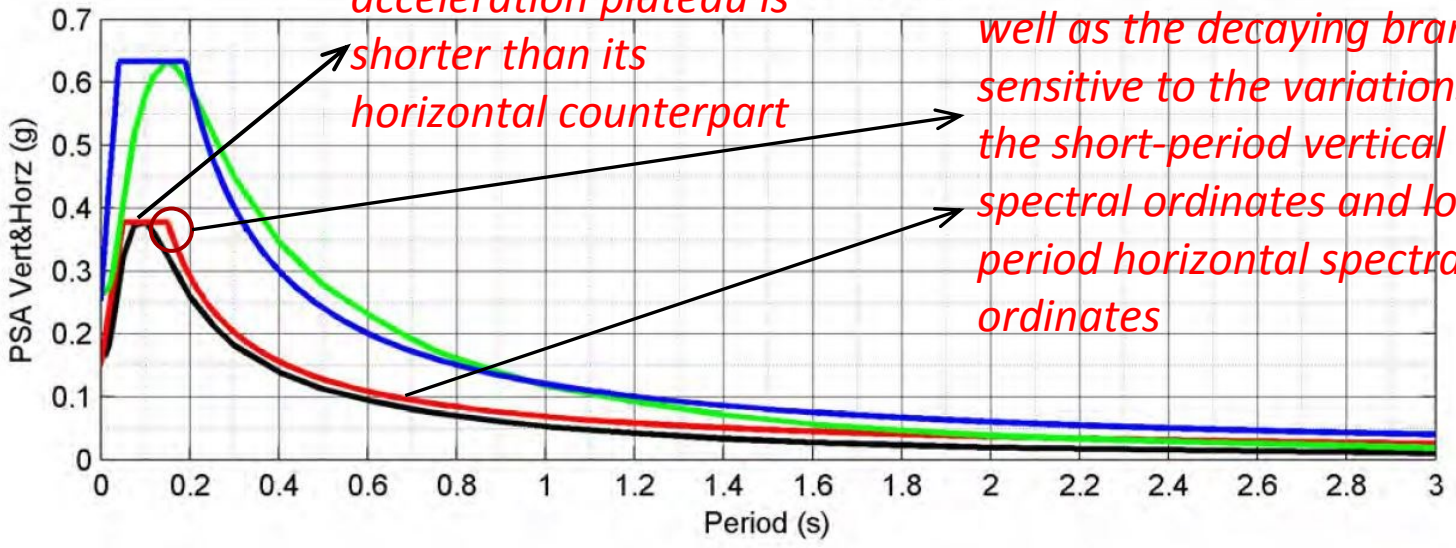
Vertical spectrum should be consistent with the horizontal spectrum

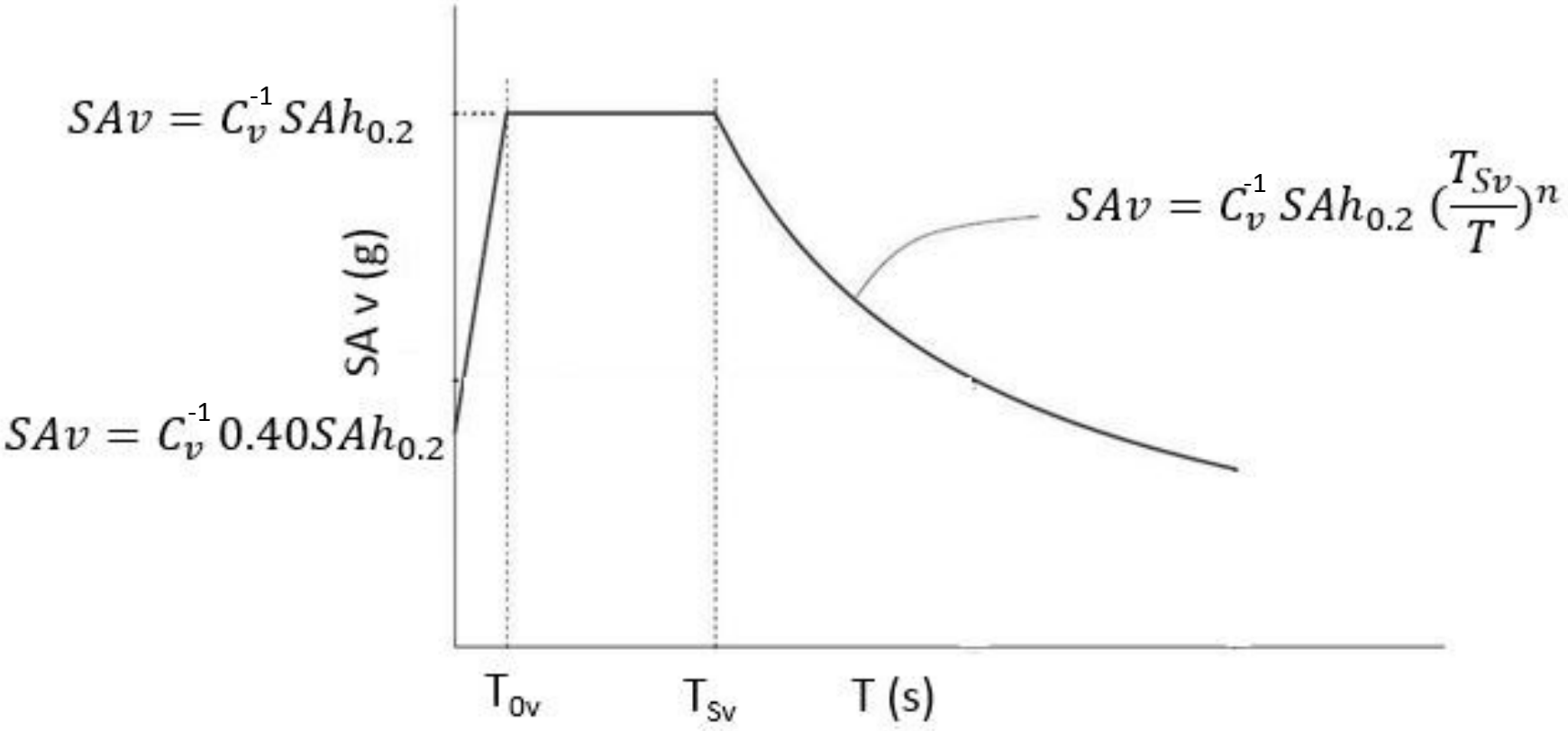
Develop the vertical spectrum from the already defined horizontal spectrum

Behavior of vertical spectrum is different than the horizontal spectrum:

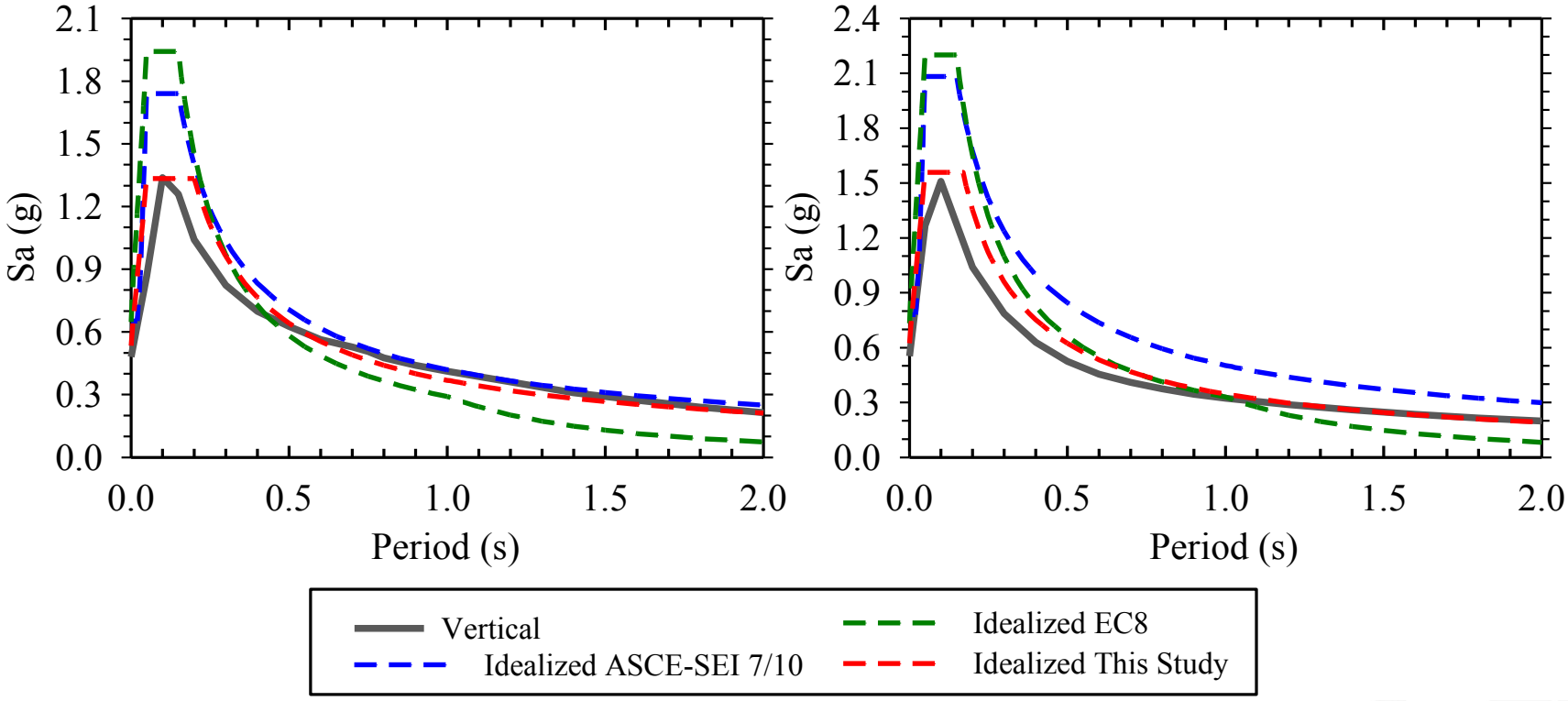
The vertical constant acceleration plateau is shorter than its horizontal counterpart

Short-period corner period as well as the decaying branch is sensitive to the variations in the short-period vertical spectral ordinates and long-period horizontal spectral ordinates




$SAv = C_v^{-1} SAh_{0.2}$
$SAv = C_v^{-1} SAh_{0.2} (\frac{T_{Sv}}{T})^n$
SA v (g)
$SAv = C_v^{-1} 0.40SAh_{0.2}$
T_{0v}
T_{Sv}
T (s)

Case studies for vertical spectrum



Conclusions

- *Earthquake zone approach will not be used any more in Turkish earthquake code after the implementation of probability-based hazard maps*
- *The probabilistic hazard maps study provided a good opportunity to revisit damping scaling factor, vertical spectrum and long-period corner period definitions that might be of use in the design codes*

Thank you