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# Seismic Hazard Maps with the Effect of Local Geology for Washington, DC

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## INTRODUCTION

We have improved the preliminary seismic hazard maps of Cramer et al., 2016 for the Washington, DC area. Ground motion prediction equations, source models, and logic tree alternatives are taken from the 2014 U.S. Geological Survey national seismic hazard model of Peterson et al., 2014. We have added an improved 3D geological model based on the over-burden thickness map of Froelich, 1975. As in our 2016 preliminary effort, we use three shear-wave velocity profiles for the Piedmont, Fall Line, and Coastal Plain regions from Olgun et al., 2015 and develop three reference profiles extended to hard rock for the hazard calculations. Site amplification distributions relative to hard rock conditions for a grid of points are developed from the local geology model to modify the hard rock hazard curves to local geology specific hazard curves using the approach of Cramer, 2011. Seismic hazard maps are first generated on a 0.005 degree grid, and then extended to a 0.001 degree grid by modeling ground motion as a function of overall sediment depth.

## 3D GEOLOGICAL MODEL

We have digitized and used the sediment thickness map of Froelich, 1975 (Figure 1). Based on Olgun et al., 2015, we developed three reference profiles, one for thin to no soil (< 3m), one for Quaternary alluvium up to 20 m deep, and one for 20 m of alluvium over Cretaceus Potomic Formation sediments up to 600 m deep (Figure 2).

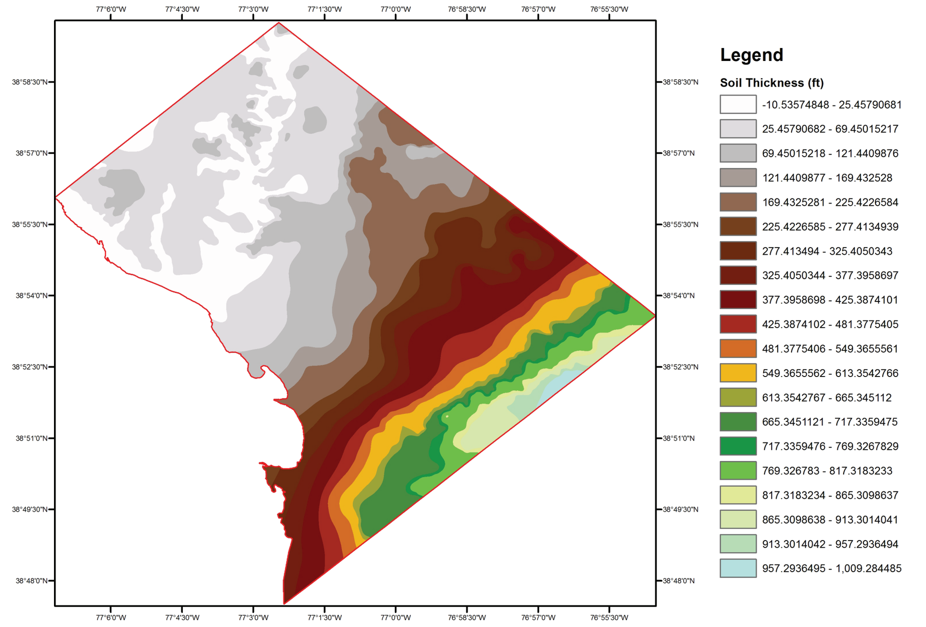


Figure 1: Digitized Froelich, 1975, sediment thickness map (in feet).

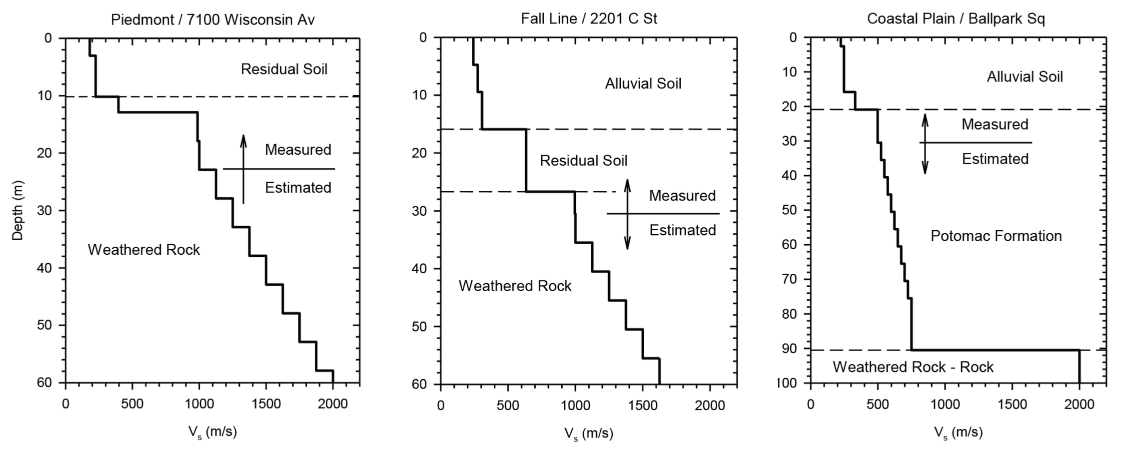


Figure 2: Vs profiles for three representative sites from Olgun et al., 2015.

## SITE RESPONSE

Observed soil response varying with soil depth from Pratt et al., 2017, are shown in Figure 3. Note decrease in fundemental peak resonance with increasing sediment thickness.

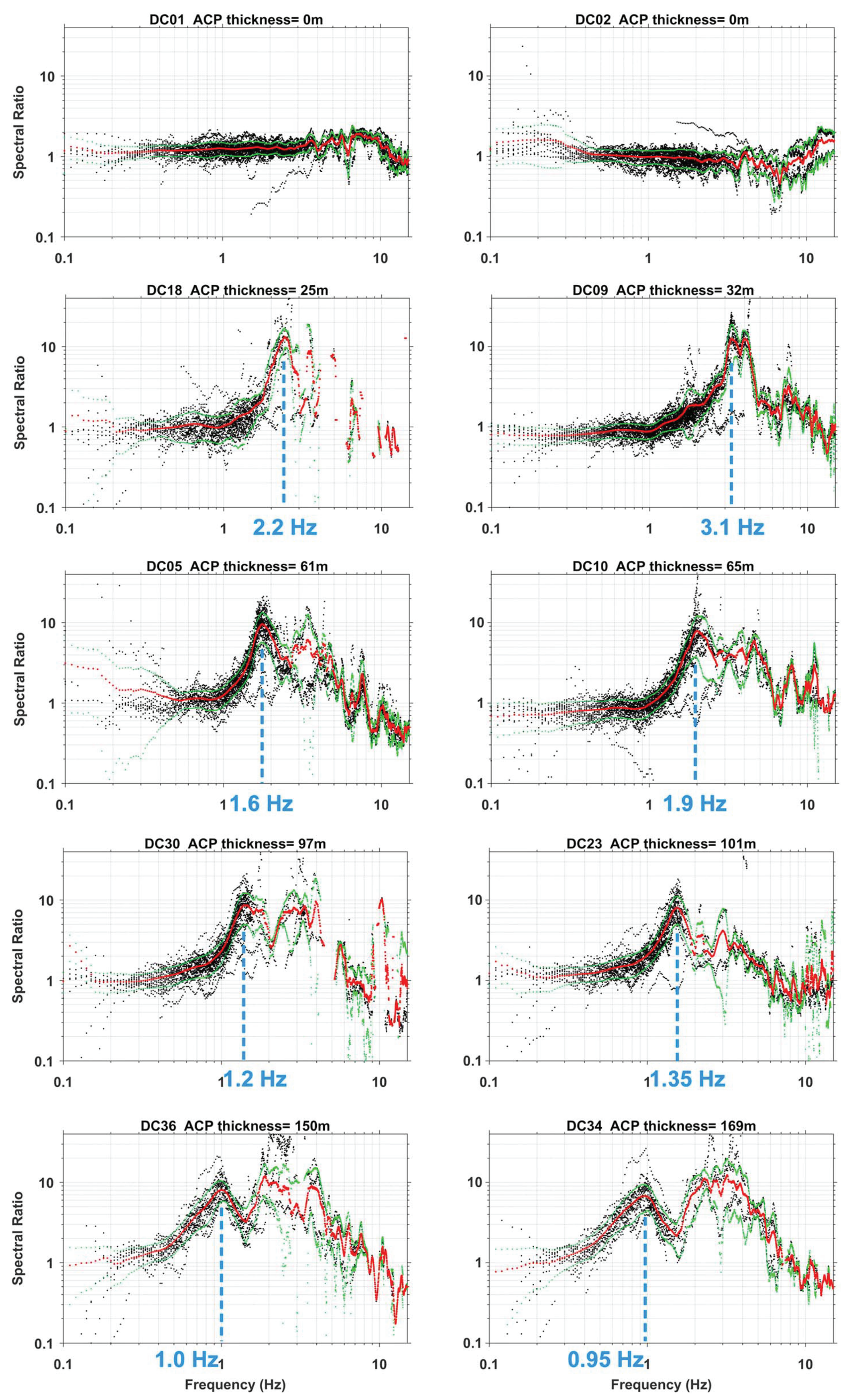


**Figure 3.** Spectral ratios at sites with well-defined resonance peaks, arranged by increasing thickness of ACP strata and unconsolidated deposits (i.e., depth to bedrock). The site number and depth to bedrock are listed above each graph. Each black dot represents the spectral ratio of a single frequency during a single earthquake, the red dots are the geometric mean of the data points at each frequency component, and the green dots show one standard deviation from the mean. Strong resonance peaks occur at nearly all sites on ACP strata, and the frequency of the primary resonance peak decreases with increasing ACP thickness as expected from equation (1).

## GROUND MOTION VS. DEPTH OF SEDIMENT

We use ground motion vs. sediment depth values from 0.005 degree grid maps to model ground motion estimates as a function of depth in 1 m bins (Figure 4). Note small uncertainty in hazard values at any given depth although hazard can change rapidly with depth.

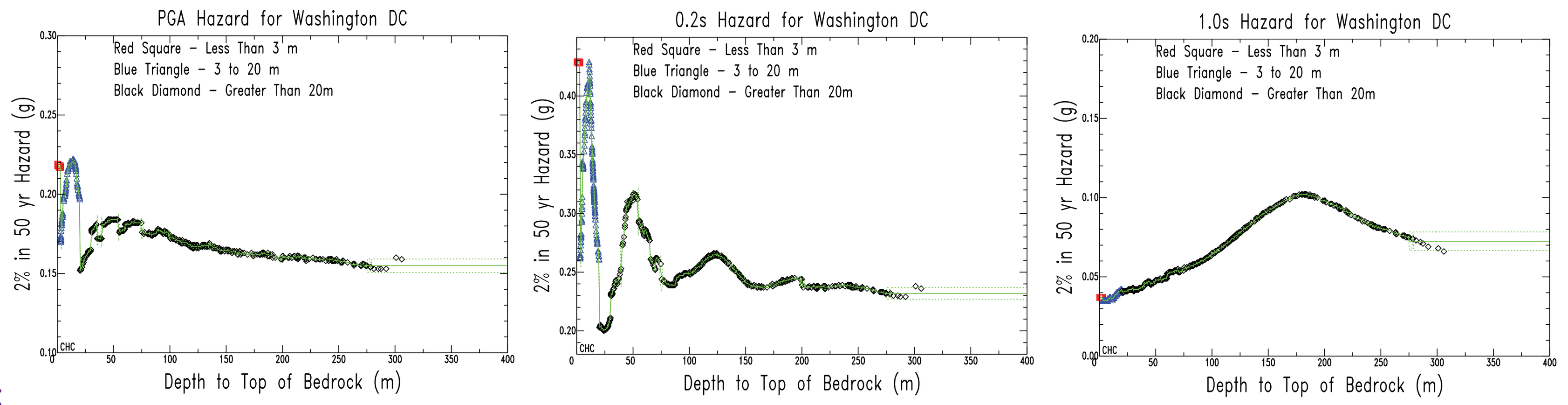


Figure 4: Ground motion hazard vs. depth-to-bedrock for PGA, 0.2s, and 1.0s (left to right). Three depth catagories correspond to each of the three reference profiles used in study.

## 0.005 vs. 0.001 DEGREE GRID HAZARD MAPS

A comparison of seismic hazard maps for 0.005 and 0.001 degree grids. The 0.001 degree grid map is generated using the ground motion vs. sediment depth relation in the center of Figure 4. Note the effects of increased resolution on the hazard map.

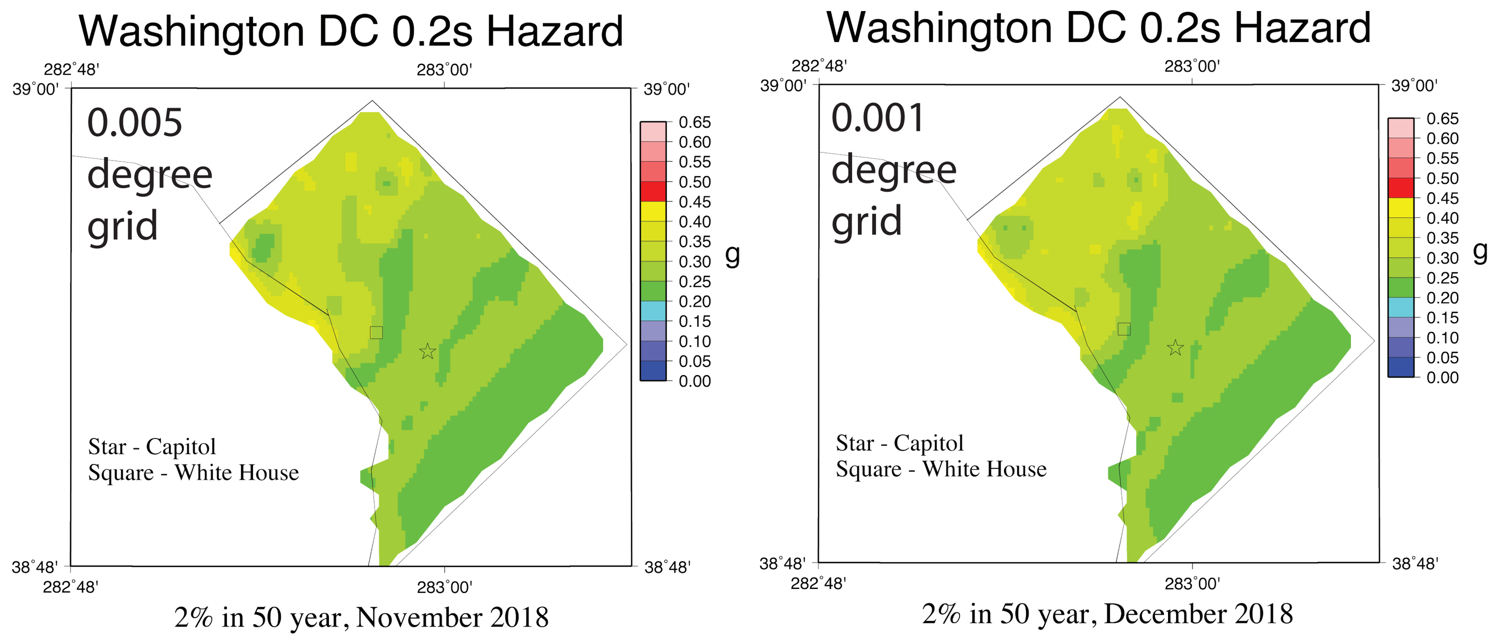


Figure 5: 0.2s hazard maps with local site effects (0.005 degree grid on left and 0.001 degree grid on right).

## PROBABILISTIC HAZARD MAPS

Probabilistic hazard maps with the effect of local geology are plotted over the USGS national seismic hazard map for B/C boundary conditions (Figure 6). Maps are for 2%-in-50-year hazard.

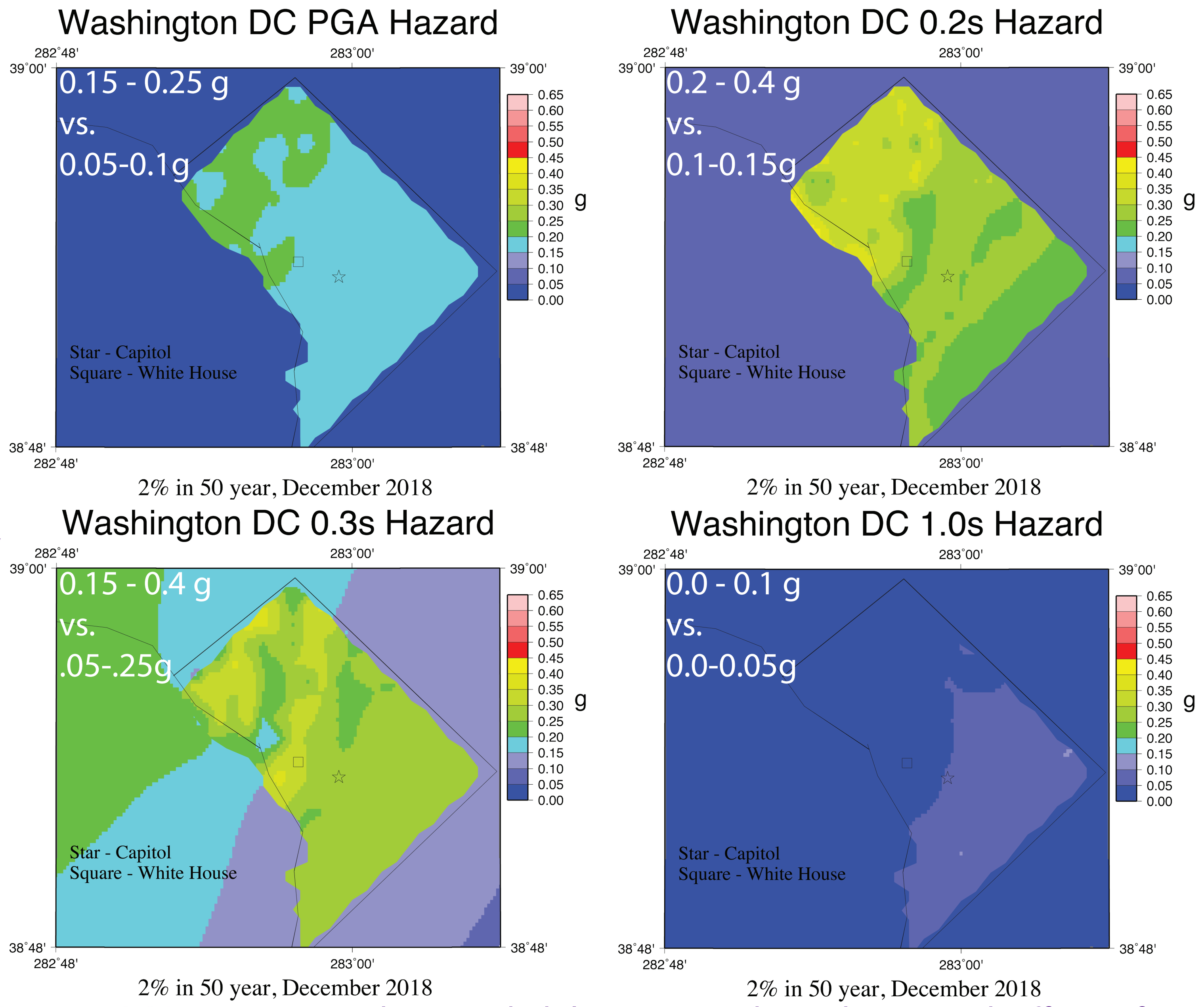


Figure 6: PGA, 0.2s, 0.3s, and 1.0s probabilistic seismic hazard maps with effects of local geology inset into USGS national seismic hazard maps.

## SCENARIO HAZARD MAPS

Scenario hazard maps with the effect of local geology for an M6.0 Mineral Virginia earthquake about 100 km from Washington DC (Figure 7).

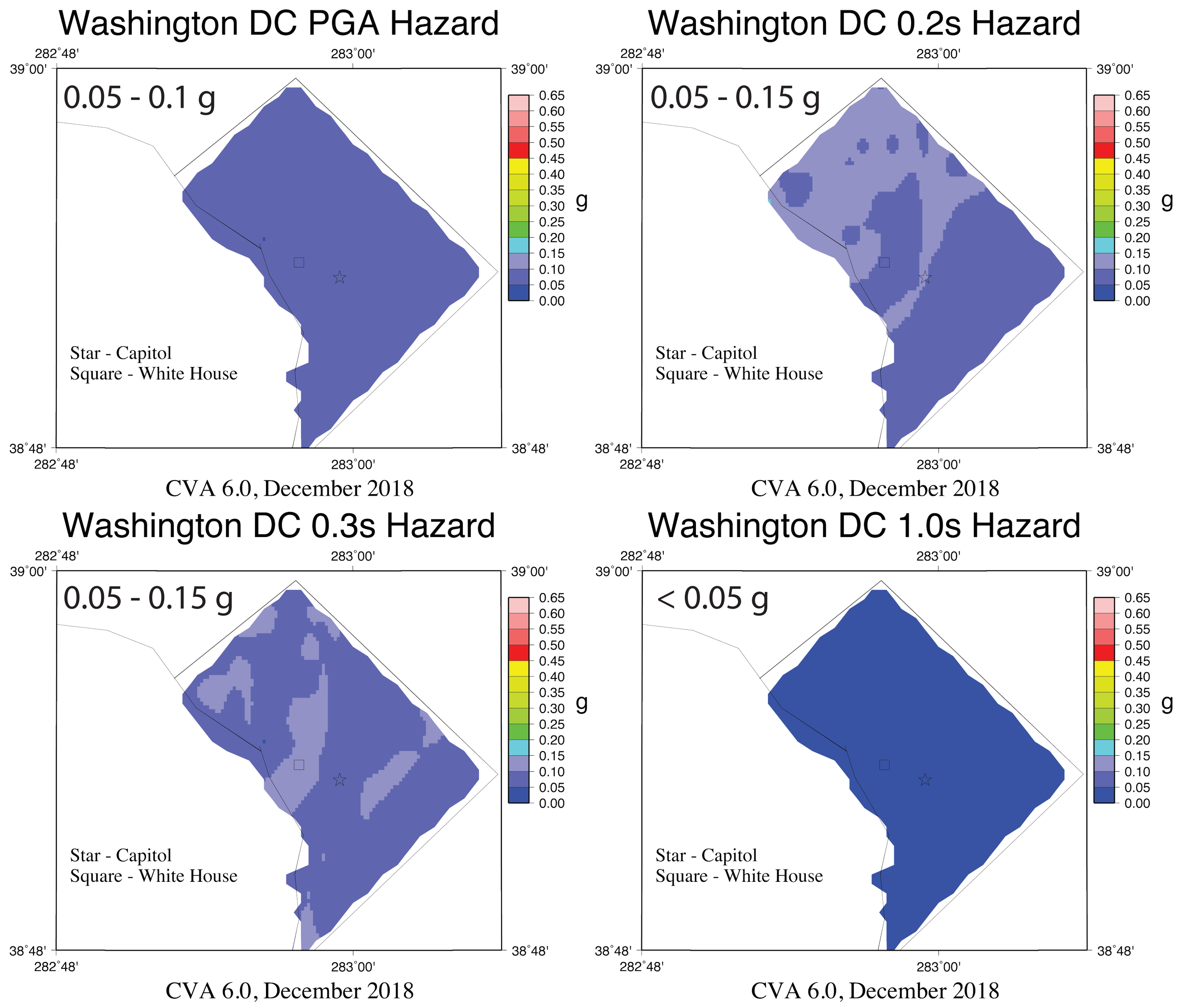


Figure 9: PGA, 0.2s, 0.3s, and 1.0s scenario seismic hazard maps with the effect of local geology for a M6.0 Mineral, VA earthquake.

## SUMMARY

We have updated the preliminary urban seismic hazard maps for Washington, DC using the sediment thickness map of Froelich, 1975.

Local geology in the Washington DC area strongly amplifies higher frequency ground motions (PGA, 0.2 s) in keeping with the results of Olgun et al., 2015 and Pratt et al., 2017.

This soil response is driven by the 10 -20 m thick low shear-wave velocity (200-300 m/s) top layers of the soil model (residual soil or alluvium).

The thicker Cretaceous Potomac Formation sediments (up to 300 m in the SE edge of the study area) have their greatest effect on seismic hazard at longer periods (1.0 s) from the 200+ m thick sediments near the SE edge of Washington DC.

References:
Cramer (2011), FTR to USGS, grant G09AP00008; Cramer et al. (2016), SRL 88, 246
Froelich (1975), USGS OFR75-538; Olgun et al. (2015), FTR to USGS, grant G13AP00076
Petersen et al. (2014), USGS OFR2014-1091; Pratt et al. (2017), GRL 44, 12,150-12,1660