Amplification of ground motions by Cook Inlet basin, Alaska, from intermediate-depth earthquakes

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Outline

• Earthquake ground motion database
• Ground motion residuals
• Source and site analyses of intermediate-depth (intraslab) earthquakes in Cook Inlet region
• Amplification by Cook Inlet basin
• Analysis of three earthquake clusters
• Summary with implications for update of Alaska seismic hazard model
• 44 intermediate-depth (intraslab) earthquakes within 300 km Anchorage (Jan. 1, 2008–March 1, 2019) (strec, SLAB 2.0 for seismotectonics)

• Mw 4.9–7.1, depths 35–144 km, distances to 350 km

• Waveforms from regional broadband and strong-motion instruments (IRIS, CESMD)—important contributions from temporary networks (e.g., SALMON, USGS aftershocks)
Strong-motion processing

[Images of Strong-motion graphs]

Parsing and processing ground motion data: https://usgs.github.io/ground-motion-processing/

[GitHub repository interface with commit history and license information]
• Underlying data—~3000 records (RotD50)
• PGA, PGV, PSA (0.01–10 s)
• Analysis: T=0.1, 0.3, 1.0, 3.0, 5.0 s
• Ground motion model, Abrahamson et al. (2016) “BCHydro”: developed from global database.
  - No basin terms
  - Source depth-scaling: increasing short-period \( \ln(\text{SA}) \); saturates \( z=120 \) km
  - Likely supplanted NGA-Sub

• McNamara et al. identified GMM is providing good overall fit to data.

• Compute residuals from intraslab variant, using \( V_{s30} \) from topo-based proxies

\[
R_{es} = \ln (S_{Aes}) - \ln (S_{Aes}^{GMM})
\]
Analysis of ground motion residuals

- Separate total ground motion residuals into bias, between-event, and within-event terms through linear mixed-effects regression

\[ R_{es} = \delta B_e + \delta W_{es} + c \]

- Formulation shares similarities with seismological decomposition of ground motions for source and site spectral properties (e.g., Hartzell, 1992)

\[ S_i(f) \cdot R_j(f) \cdot P_{ij}(f) = U_{ij}(f), \]
Bias and between-event terms

(a) 

(b) \( T = 0.3 \) s

(c) \( T = 3.0 \) s
Bias and between-event terms

(a) All depths
(b) $T = 0.3$ s
(c) $T = 3.0$ s

$\delta B_e$
Within-event terms, trends with distance

- Within-event terms show no correlations with distance, indicating average agreement with path attenuation from BCH (Wooddell and Abrahamson, 2018, SSA)

- Following analyses use the site terms (1 observation from each site, from each earthquake)

- Examining spatial trends and trends within Cook Inlet basin
**Spatial trends, within-event terms**

- Mean site terms at each location
- High short-period terms within basin, Kenai Peninsula, northeast of basin
- High long-period terms within basin and northwest of Anchorage
- Some correspondence between spatial patterns of short- and long-period terms
• Basin depths from Shellenbaum et al. (2010): Top Mesozoic unconformity depth map of the Cook Inlet Basin, Alaska—assume proxy for \( Z_{2.5} \) (depth to \( V_s = 2.5 \) km/s)

• Short and long-period sites are amplified with the basin

• Long-period amplifications correlate with basin depth and follow NGA-West-2 empirical predictions (\( V_{s30} = 260 \) and 500 m/s)

• Amplifications (deep to shallow sites) \( >2 \) for periods 0.5–5 s
Earthquake cluster analysis

$$A F_{s,cl} = \langle \delta W_e \rangle_{e \in cl} - \langle \delta W_e \rangle_e$$
Earthquake cluster analysis

\[ AF_{s,cl} = \langle \delta W_{es} \rangle_{e \in cl} - \langle \delta W_{es} \rangle_e \]
Earthquake cluster analysis

T = 0.3 s

T = 3.0 s
Earthquake cluster analysis, amplification factors
Source- and path-dependent amplification

(Frankel et al., 2009) and path-dependent amplification

(Bowden and Tsai, 2017)

(Denolle et al., 2014)

(Wirth et al., 2019)
Summary and seismic hazard implications

- Intermediate-depth (intraslab) earthquakes and permanent/temporary networks provide good ground motion database for examining amplification of Cook Inlet region

- Good distance scaling from Abrahamson et al., (2016): (1) overpredicts short-period ground motions; (2) need further work on event term (e.g., depths, Mw)

- Short- and long-period effects on ground motions from Cook Inlet basin
  - Short-period amplifications nearly invariant to basin depth—need site response studies
  - Long-period scaling with basin depth

- Analysis from three earthquake clusters shows spatial patterns (apparent amplification on far side of basin) at all periods and variations in the scaling of long-period ground motions with basin depth.
Questions
Between-event terms, magnitude