Continuous Maps of $z_{1.0}$ and $z_{2.5}$ for California from Integrated Data Sources to Support Site Response Modeling

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1. Community Velocity Models (CVMs)

Community velocity models (CVMs) are 3-D representations of subsurface seismic velocity strcuture. Although originally developed to support simulation models, CVMs are commonly used in ground motion model development to estimate isosurface depths (z_x) which represent the depth where a specific velocity horizon is encountered within a 1D vertical profile.

CVMs have limitations when applied to assign $z_{1.0}$ and $z_{2.5}$. Specifically, their derivation is often focused on representing deeper, subsurface structures, however shallower features are also important for modeling site response. Near-surface features are relatively poorly constrained in CVMs, which often omit shallow stratigraphy and localized geologic variability that is observed in nature. To overcome this, some CVMs incorporate geotechnical layers to enhance the accuracy of near-surface velocities in smaller, detailed domains.

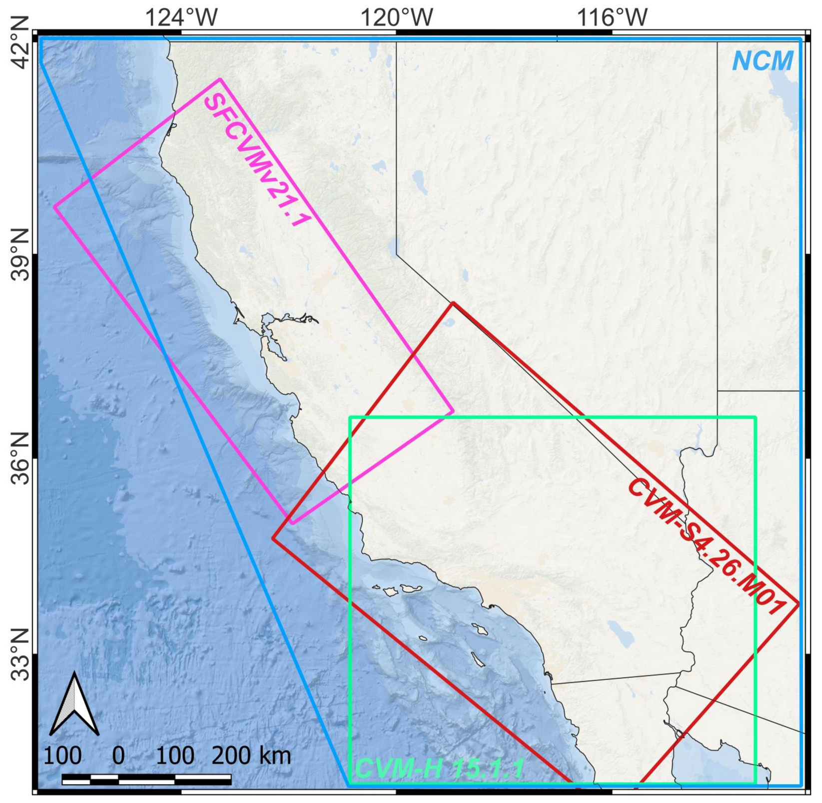

Figure 1: Map showing the coverage area of four CVMs used in this study.

Broad-Scale Model

1. USGS National Crustal Model (NCM) (Boyd 2022)

Regional-Scale Models

1. CVM-Hv15.1.1 (Shaw et al. 2015) – Southern California
2. CVM-S4.26.M01 (Lee et al. 2014) – Southern California
3. SFCVMv21.1 (Hirakawa and Aagaard 2022) – Northern California

2. Detailed vs Regional Domains

Regional-scale models encompass high-resolution velocity data in areas we refer to as *detailed domains* and low-resolution velocity data elsewhere (i.e., *regional domain*). Generally, z_x values for relatively low values of x (e.g., 1.0 km/s) are non-zero within detailed domains and zero elsewhere (which is geologically inconsistent). SFCVMv21.1 defines a specific high-resolution domain, CVM-S4.26.M01 defines irregular regions with embedded rule-based models for near-surface, lower-velocity materials, and CVM-Hv15.1.1 defines rectangular regions with embedded basin models (these include both sites with $z_x = 0$ and $z_x > 0$).

We assessed each regional-scale CVM to identify detailed domains where the z_x estimates can be considered reliable for x = 1.0 and 2.5 km/s (i.e., $z_{1.0}$ and $z_{2.5}$). The $z_{1.0}$ and $z_{2.5}$ detailed domains are allowed to be different because these parameters exhibit different sensitivities depending on how the model was develop (e.g., tomographic methods are often ineffective for resolving $z_{1.0}$, whereas they can more reliably resolve $z_{2.5}$). We define detailed domains as those which are:

1. Geologically consistent (i.e., $z_x \neq 0$ everywhere; no unexpected discontinuities)
2. Describe the totality of a geologic structure (i.e., provide velocities across the entire domain spanned by a sedimentary basin).

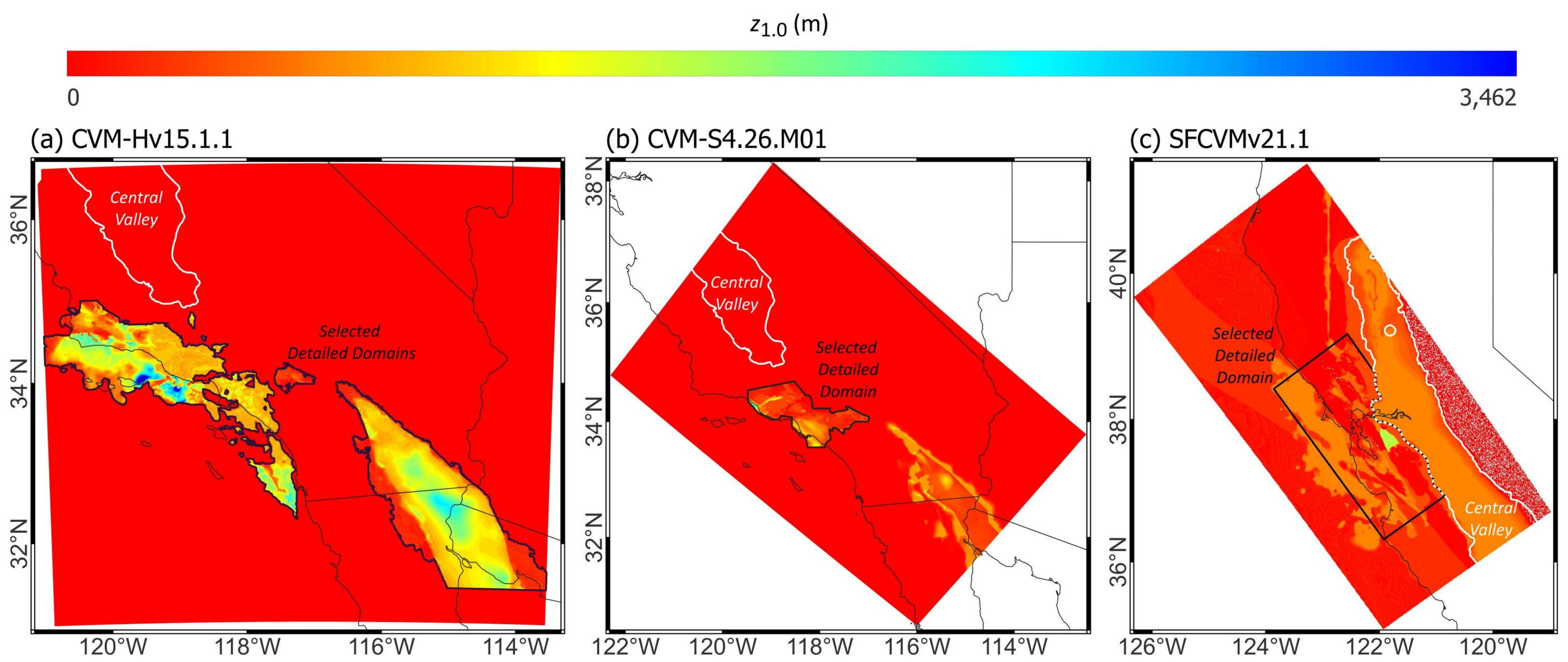

Figure 2: Outlines of California regional CVMs selected detailed domains for $z_{1.0}$: (a) CVM-Hv15.1.1; (b) CVM-S4.26.M01; and (c) SFCVMv21.1.

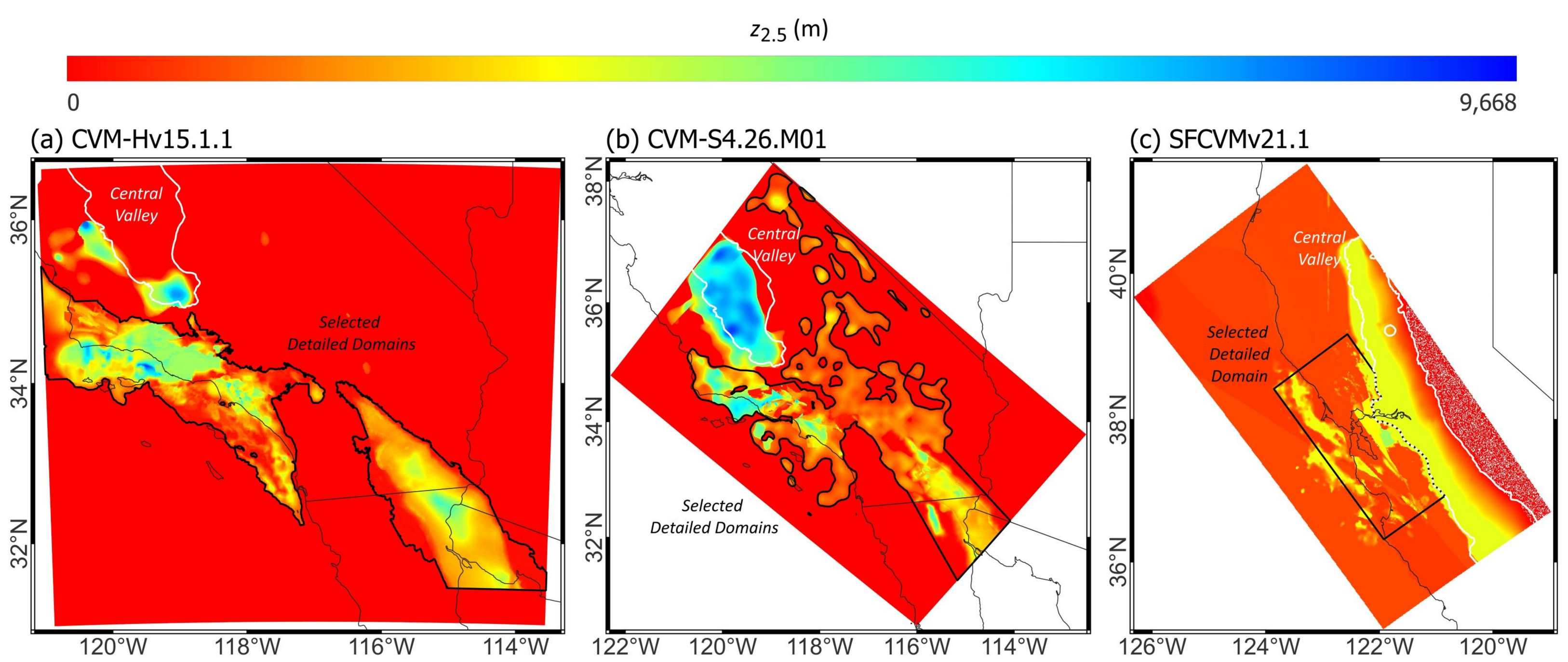

Figure 3: Outlines of California regional CVMs selected detailed domains for $z_{2.5}$: (a) CVM-Hv15.1.1; (b) CVM-S4.26.M01; and (c) SFCVMv21.1.

3. Combining Multiple CVM z_x Estimates

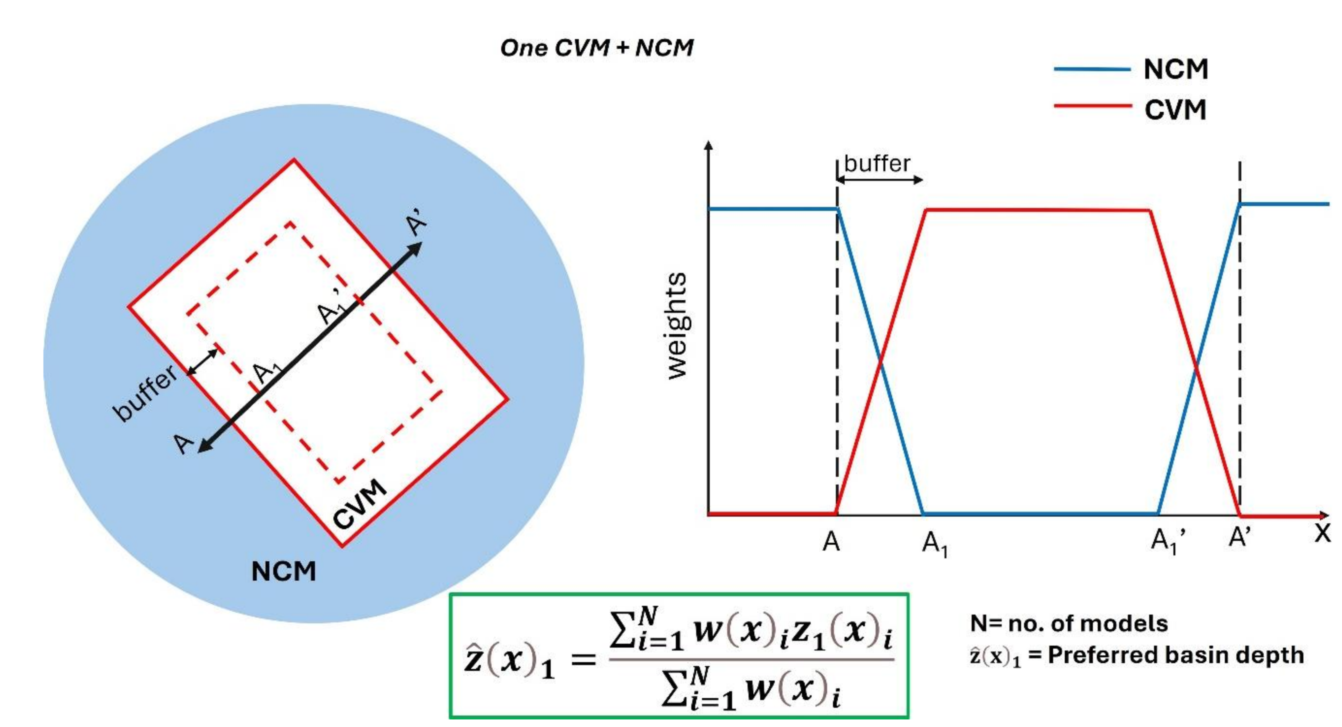

Figure 4: Schematic representation of the preferred basin model using one regional-scale CVM and the NCM. The left panel shows the spatial relationship between the regional-scale CVM (red) and the NCM (blue), with buffer zones defining smooth transition regions. The right panel illustrates the corresponding weight functions applied to each model along a transect A–A′. Within the buffer zones, weights transition linearly to blend the two models. The combined basin depth at any location is computed using a weighted average of available model values as shown in the equation.

4. CVM-Based Results

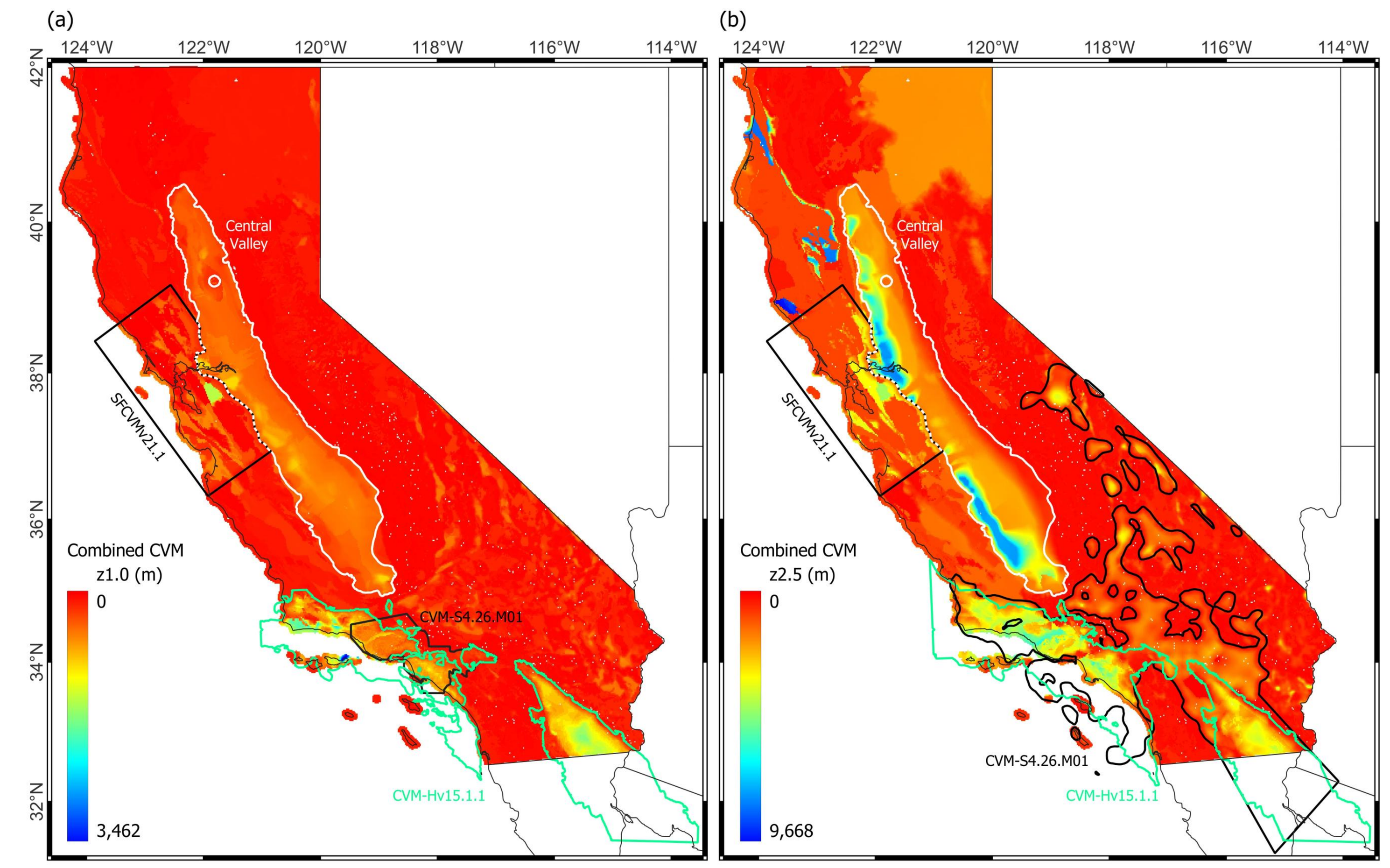

Figure 5: Maps of the combined CVM-based (a) $z_{1.0}$ and (b) $z_{2.5}$ isosurfaces in California. Polygons are shown to identify the detailed domains of the regional CVMs (shown in black and green) and the extent of the Central Valley (shown in white).

5. Integrating Geology-Based $z_{1.0}$ Estimates

To address the issue of unreliable CVM-based z_x estimates at non-basin (i.e., pre-Quaternary) sites, we incorporate the geology-based $z_{1.0}$ proxy values provided by Shams et al. (2025). The final $z_{1.0}$ isosurface for California uses the combined CVM-based $z_{1.0}$ values at Quaternary sites and some unique conditions (e.g., Livermore basin in Northern Califorina, which maps as Tertiary, but is modeled as having deep $z_{1.0}$) and the geology-based $z_{1.0}$ estimates elsewhere.

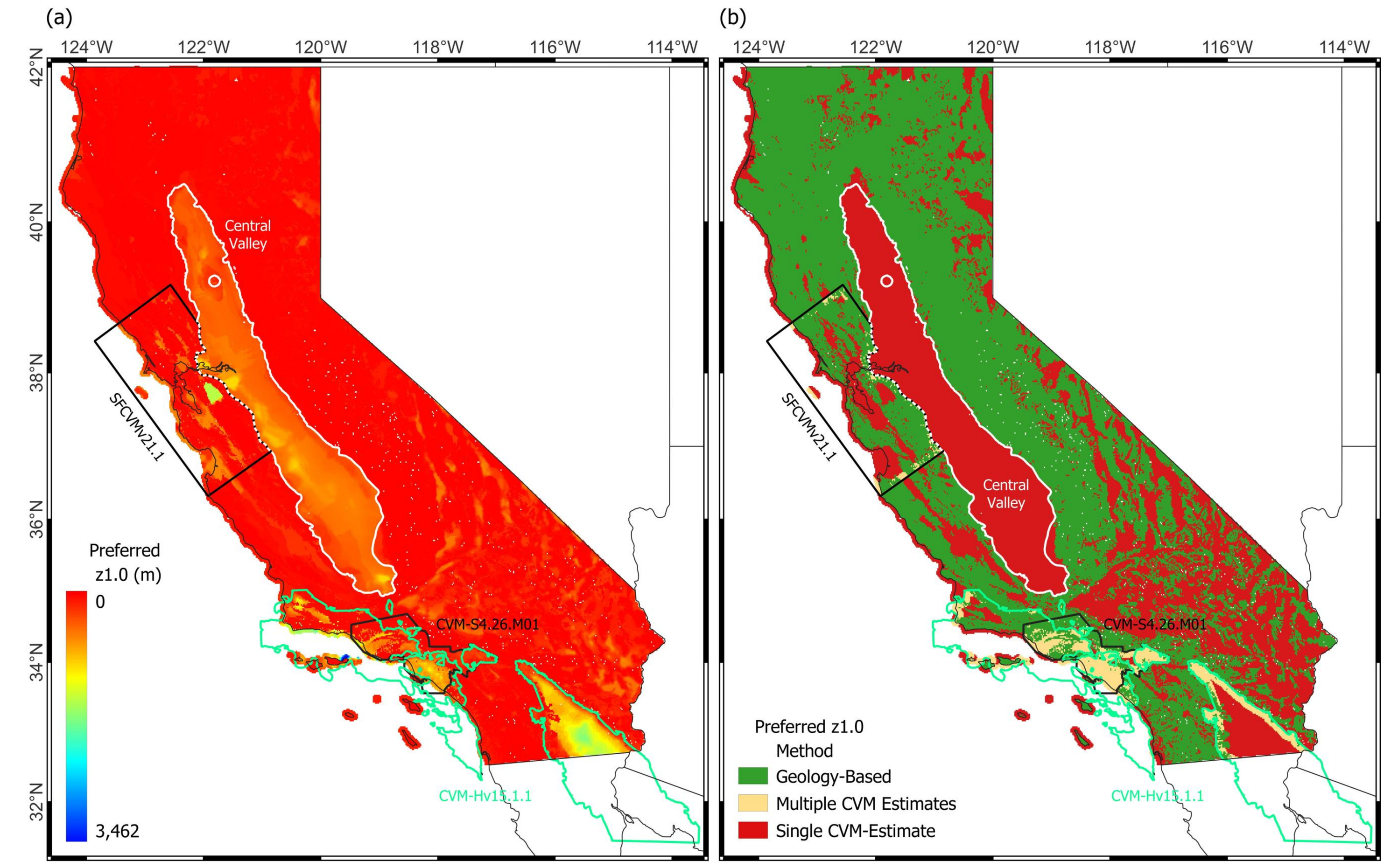

Figure 6: Maps of the preferred (a) $z_{1.0}$ value and (b) assignment method. Polygons are shown to identify the detailed domains of the regional CVMs (shown in black and green) and the extent of the Central Valley (shown in white).

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