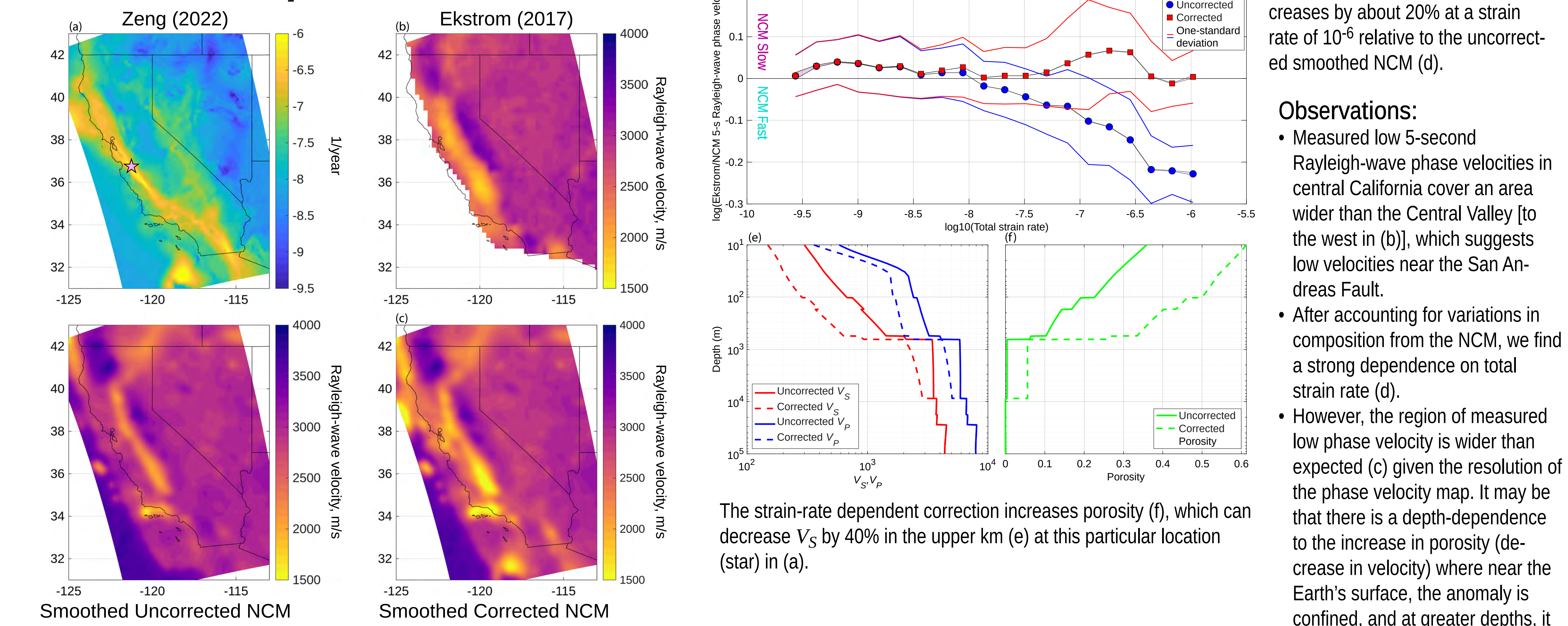


Overview

The U.S. Geological Survey (USGS) National Crustal Model (NCM) for seismic hazard studies is underpinned by a three-dimensional (3D) geologic framework model composed of continuous vertical profiles defined on a 1-km lateral grid. The NCM uses geology-based rules to convert geology to geophysical parameters, similar to the USGS San Francisco Bay region 3D community seismic velocity model (SFCVM). However, this basic characterization does not account for multiple sources of 3D wave speed variability, for example, as occurs across fault damage zones. In this study, we identify several sources of variability not presently accounted for in the NCM and devise methods to implement them. Rayleigh-wave phase velocities across the western United States, after accounting for NCM compositional variability, are found to correlate with total strain rate, and crustal and mantle temperatures. Sources considered that may explain this correlation include higher porosity (and lower wave speed) within a smooth representation of fault damage zones, velocity dispersion due to a thermally activated attenuation mechanism within the crust (the NCM can be considered anharmonic in the mid-to-lower crust and mantle), and the presence of melt in the upper mantle. We also compare the gravity signal from the NCM to observed Bouguer gravity anomalies to further characterize compositional sources of variability and non-isostatic anomalies.

Figures presented below are Preliminary Information-Subject to Revision. Not for Citation or Distribution.

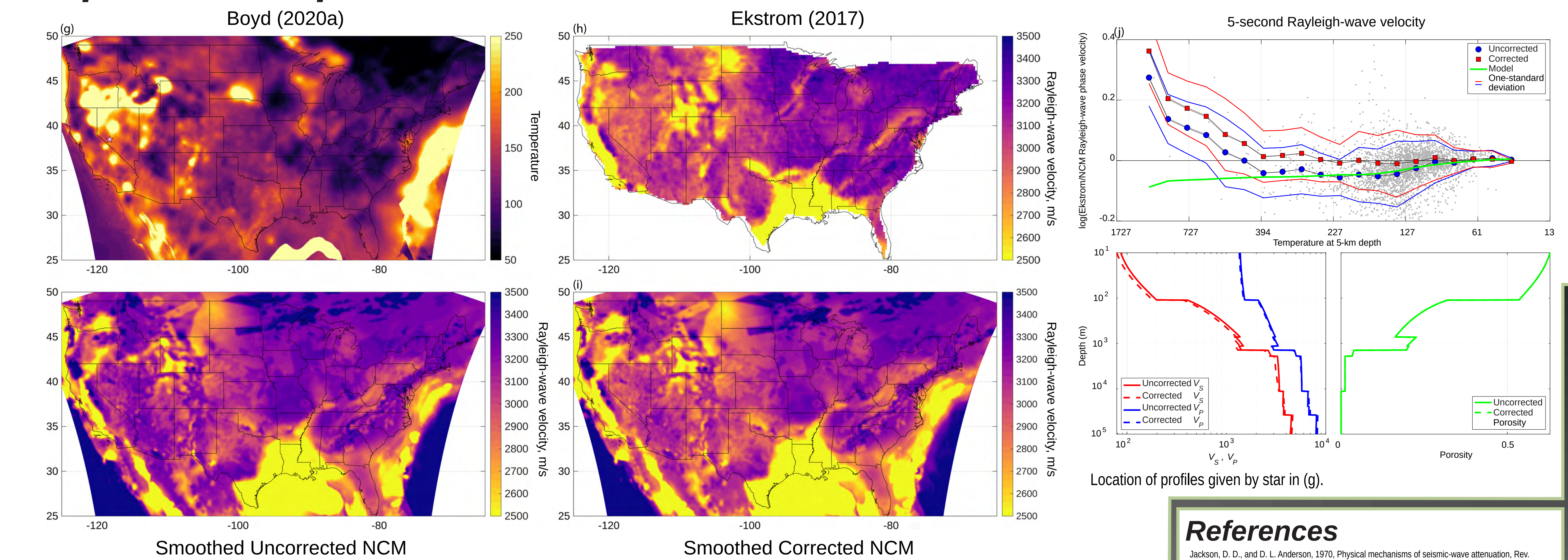
Strain-Rate Dependence



Surficial total strain rate and 5-second Rayleigh-wave phase velocity

For strain-rate dependence (e.g., fault damage zones), we assume a relationship between increasing porosity and increasing total strain rate using a strain-rate map derived from the Global Positioning Satellite velocity field published by Zeng (2022). Application of this strain rate field will average out a signal that may be up to a few kilometers wide across the highest displacement faults. Additional smoothing of 5-second Rayleigh-wave phase velocities derived from the revised velocity model is implemented for a more proper comparison with measured values from Ekstrom (2017).

Temperature Dependence

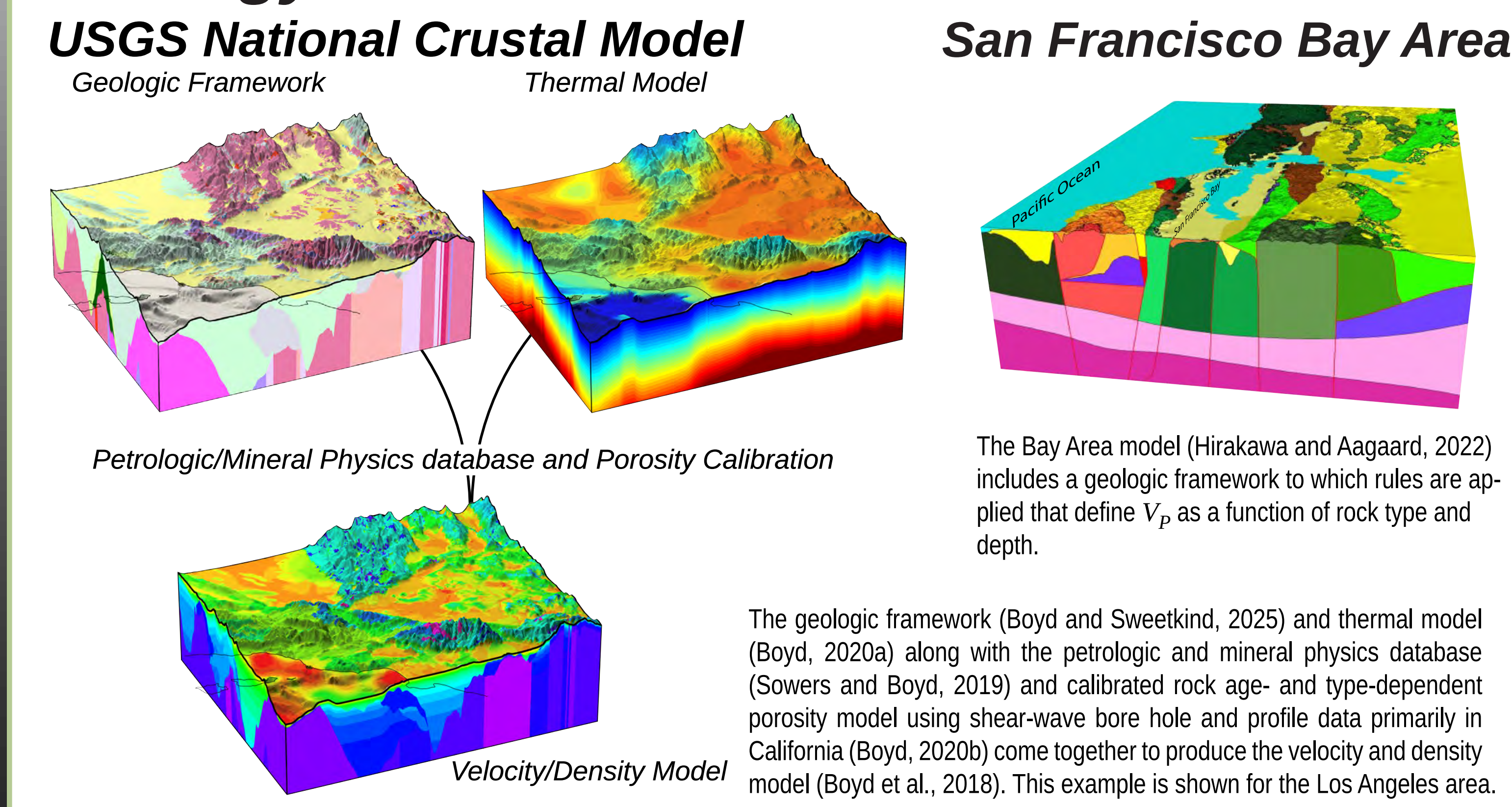


Temperature (T) at 5-km depth and 5-second Rayleigh-wave phase velocity

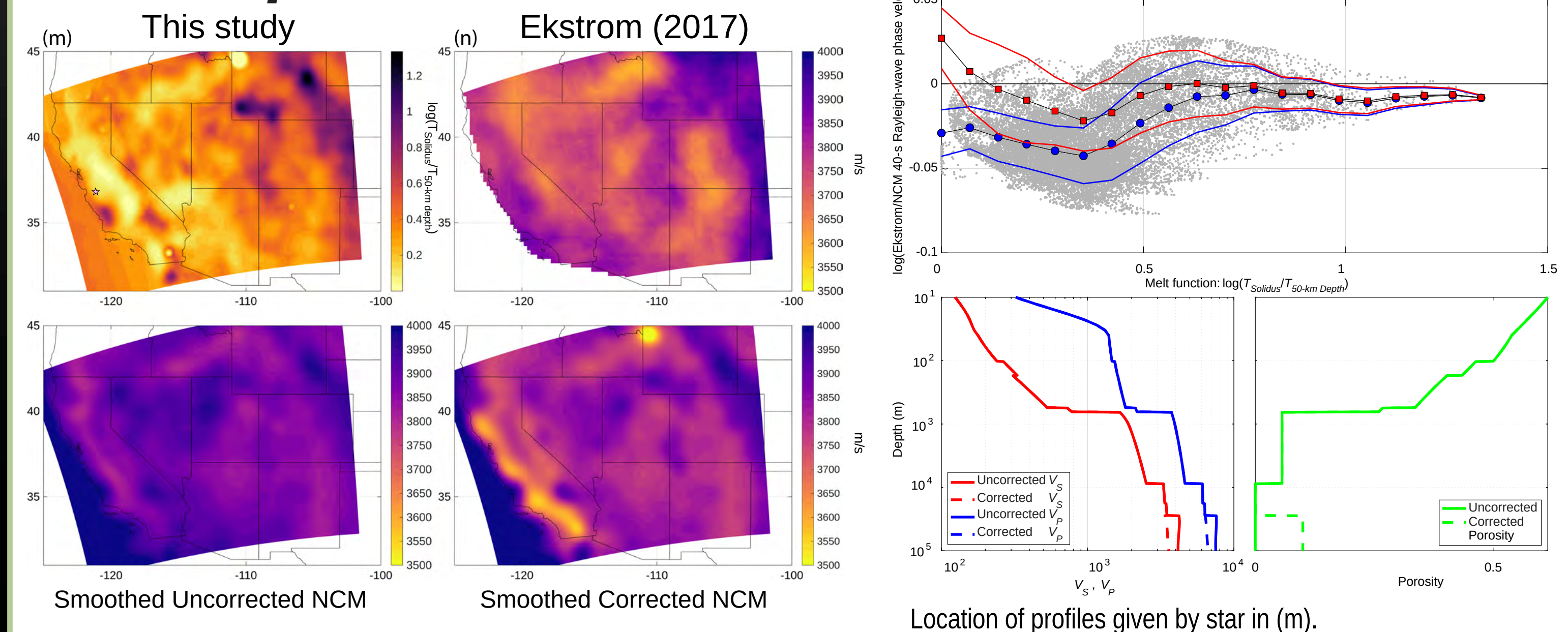
Velocity dispersion (Spencer, 1981) is modeled with relaxation times defined by a temperature-dependent attenuation mechanism (Jackson and Anderson, 1970). Temperature is taken from the NCM (Boyd, 2020a), and the coefficients for the attenuation mechanism, e.g. activation energy and modulus reduction, are chosen in order to match the measured Rayleigh-wave dispersion from Ekstrom (2017) at 5- and 10-second periods.

- Observations:**
- Higher crustal temperatures in the western U.S. (g) accompany measured 5-second Rayleigh-wave phase velocities (h) that are slow relative to the NCM (e; Temperature < 400°C), even when the NCM accounts for a strain rate dependence (i).
 - At 5- and 10-second periods (j, k), the temperature dependence of the velocity dispersion—constant velocity at low temperature transitioning to a constant lower velocity at higher temperature with the transition moving to higher temperature at lower frequency (as predicted by the model, green curves)—is consistent with anelasticity where activation energy increases from 22 to 33 kJ/mol and modulus reduction decreases from 17% to 13% going from 5- to 10-km depth. However, the dispersion seen at 20 seconds (l) cannot be modeled as well and may indicate different activation energies and mechanisms.
 - At relatively high temperatures, the NCM is far too slow, which likely indicates other issues or mechanisms playing a role.

Geology-Based Crustal Models



Melt Dependence

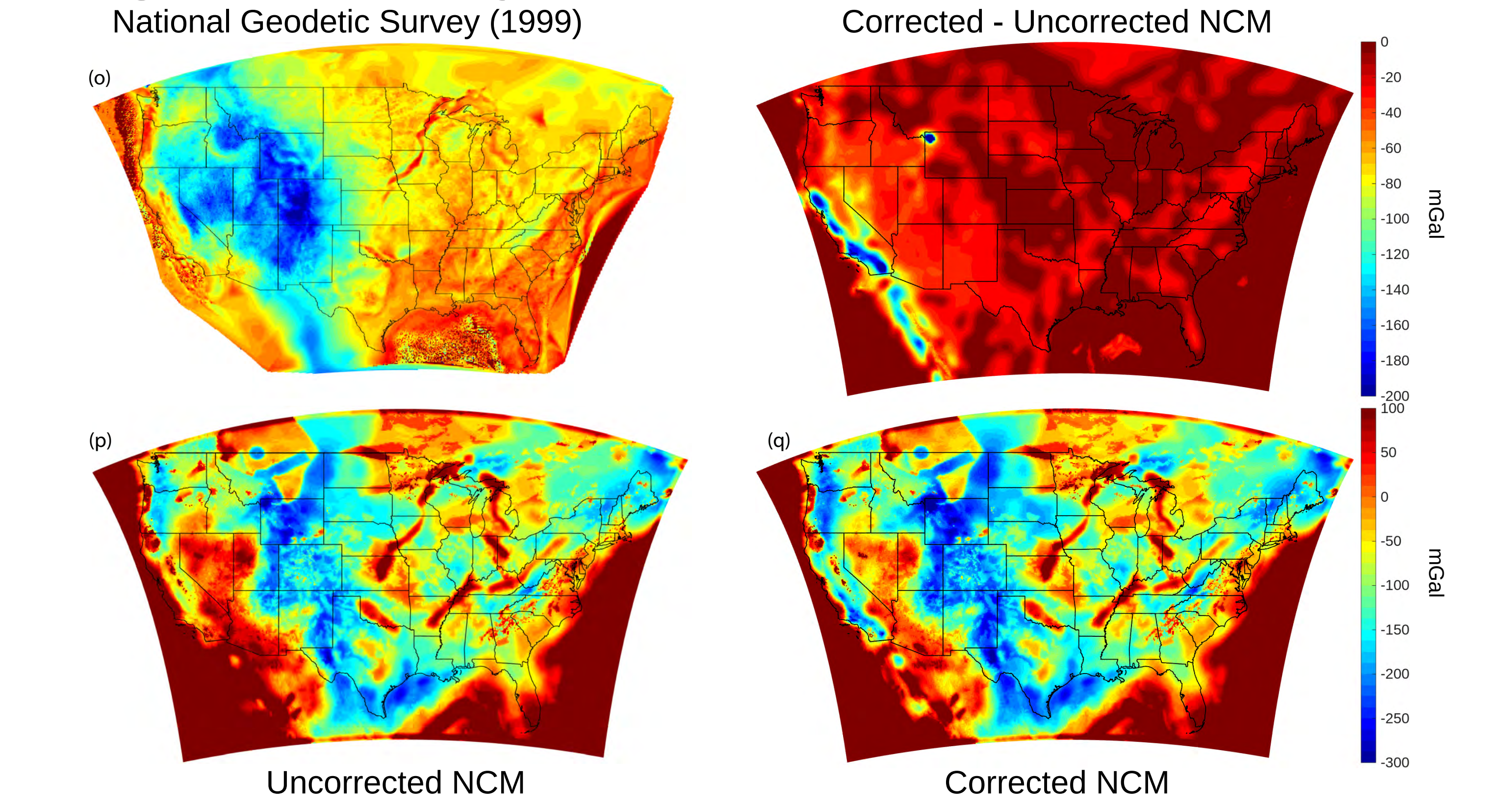


Melt function ($\log(T_{Solidus}/T)$) at 50-km depth and 40-second Rayleigh-wave phase velocity

Melt (increased pososity; reduced shear-modulus) is modeled to develop as temperatures approach the solidus. Temperature is taken from the NCM (Boyd, 2020a), and the solidus for basalt is assumed (Turcotte and Schubert, 1982).

- Observations:**
- Significant amounts of melt are predicted in Yellowstone and parts of California (m) but do not appear reflected in measured Rayleigh-wave phase velocities (n). This could indicate problems with measured V_p velocities, which drive NCM temperature estimates at this depth, compositional variations, variations in the solidus temperature, or other unmodeled phenomena.

Bouguer Gravity Anomalies



- Observations:**
- Comparisons of measured Bouguer gravity anomalies (o) to that predicted from the NCM (p, q) suggest additional factors at play. These include dynamic topography—uplift in the basin and range and subsidence(?) in the central and eastern United States, and regional variations in lithospheric composition.

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