Text S1. For each horizontal GNSS time series, we model the data with the following linear equation:

$$d = asin(2\pi t) + bcos(2\pi t) + csin(4\pi t) + dcos(4\pi t) + et + f \quad (1)$$

where *d* is the data, *a* and *b* are the coefficients for the annual seasonal components, *c* and *d* are the coefficients for the biannual seasonal components, *e* is the long-term slope, and *f* is the offset term. We solve for *a-f* using a linear least-squares inversion, and then remove the scaled seasonal and slope terms from the GNSS time series data.

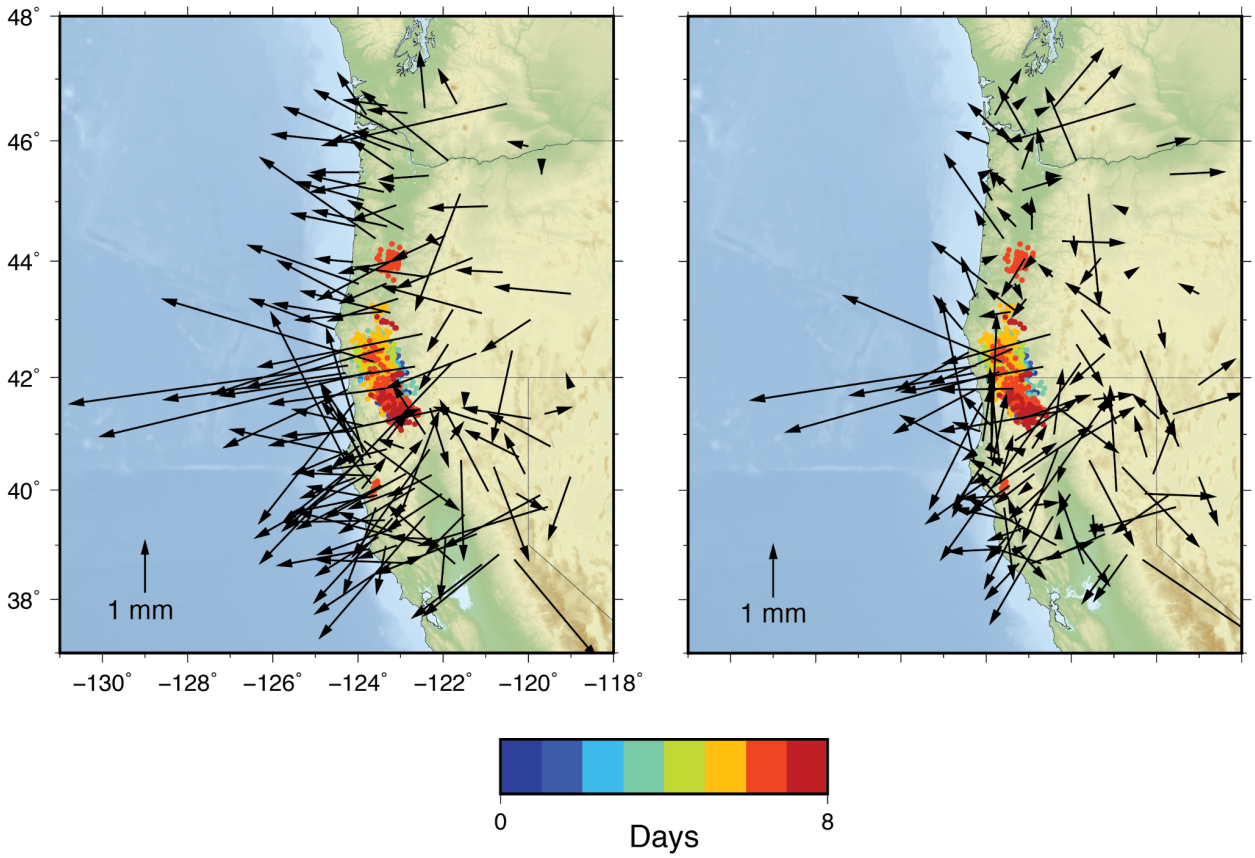

Figure S1. Map of displacements for ETS Event 9 (November 2018) before (left) and after (right) the removal of the common mode signal.

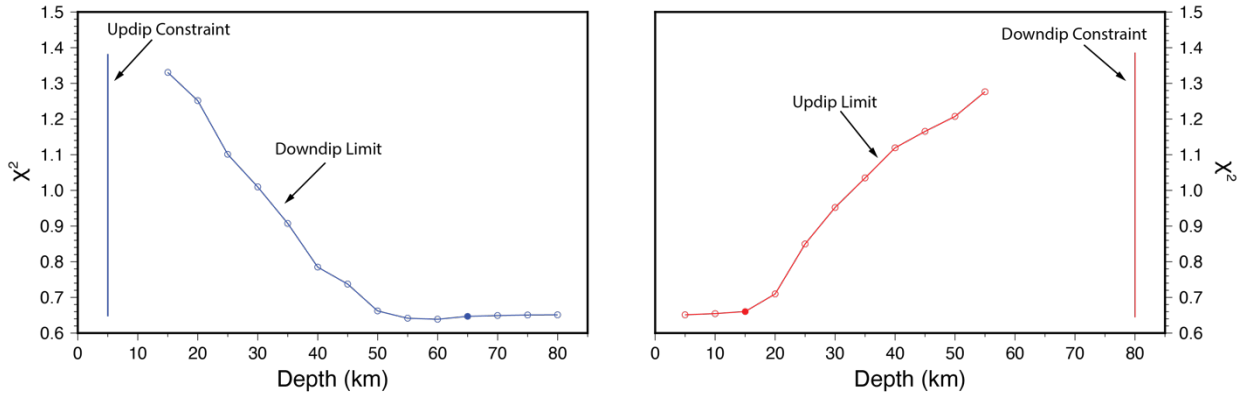

Figure S2. Results from our megathrust depth analysis. **Left** Results for the downdip limit of the megathrust fault. The vertical bar indicates the updip depth constraint and each empty circle represents an inversion run with a different downdip depth limit. The filled circle indicates the downdip depth that we use for the final inversion. **Right** Results for the updip limit of the megathrust fault. The vertical bar indicates the downdip depth constraint and each empty circle represents an inversion run with a different updip depth limit. The filled circle indicates the updip depth that we use for the final inversion.

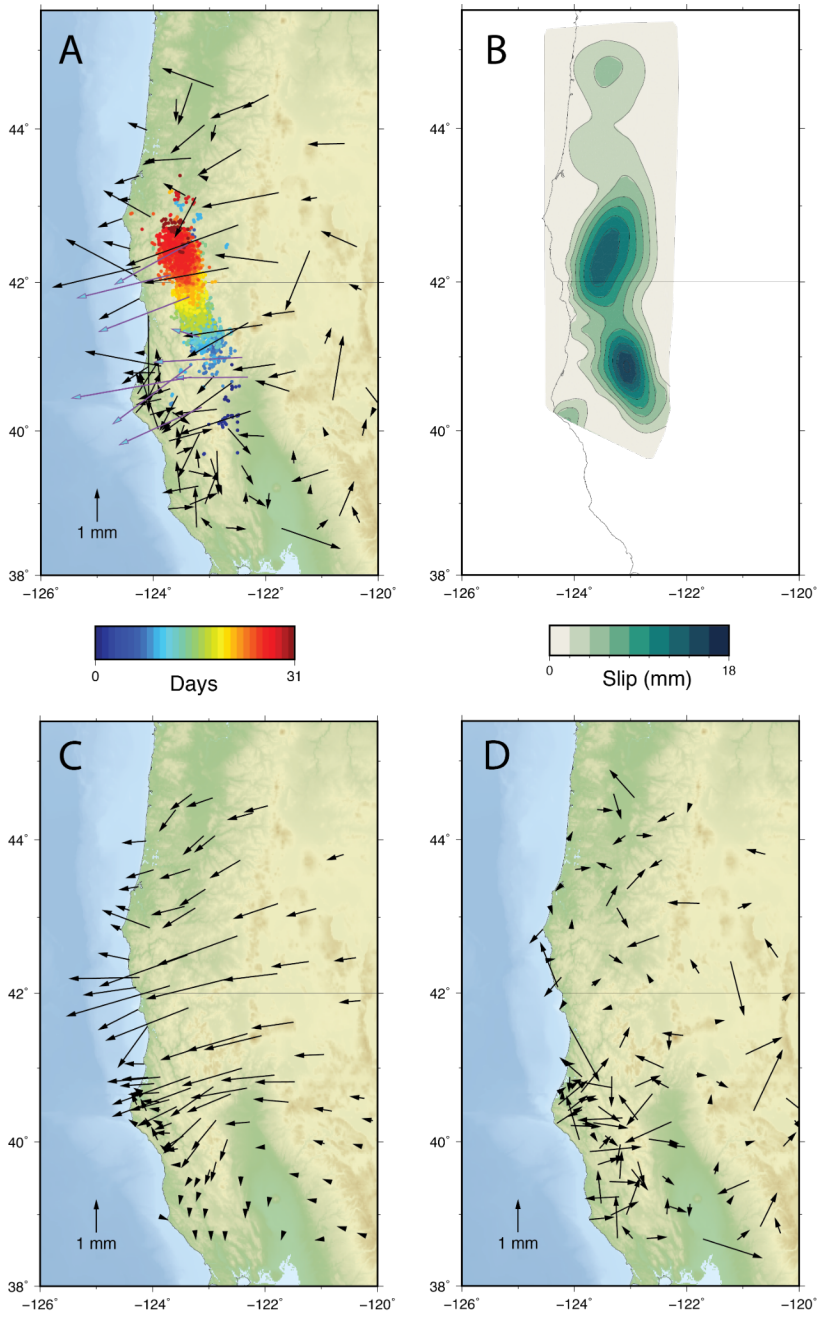

Figure S3. Model results for ETS Event 1 (August 2016). **A** Vector map showing horizontal surface displacements for ETS Event 15. Purple vectors with cyan filling show displacements at index stations. Circles show the location of tremor during the event and are colored by the number of days that passed since the first instance of tremor. **B** Distributed slip model from our inversion with the contours (black lines with green shading) outlining every 2 mm of fault slip. **C** Vector map showing the predicted surface displacements resulting from the slip model in panel B. **D** Vector map showing the misfit between the observed and predicted surface displacements.

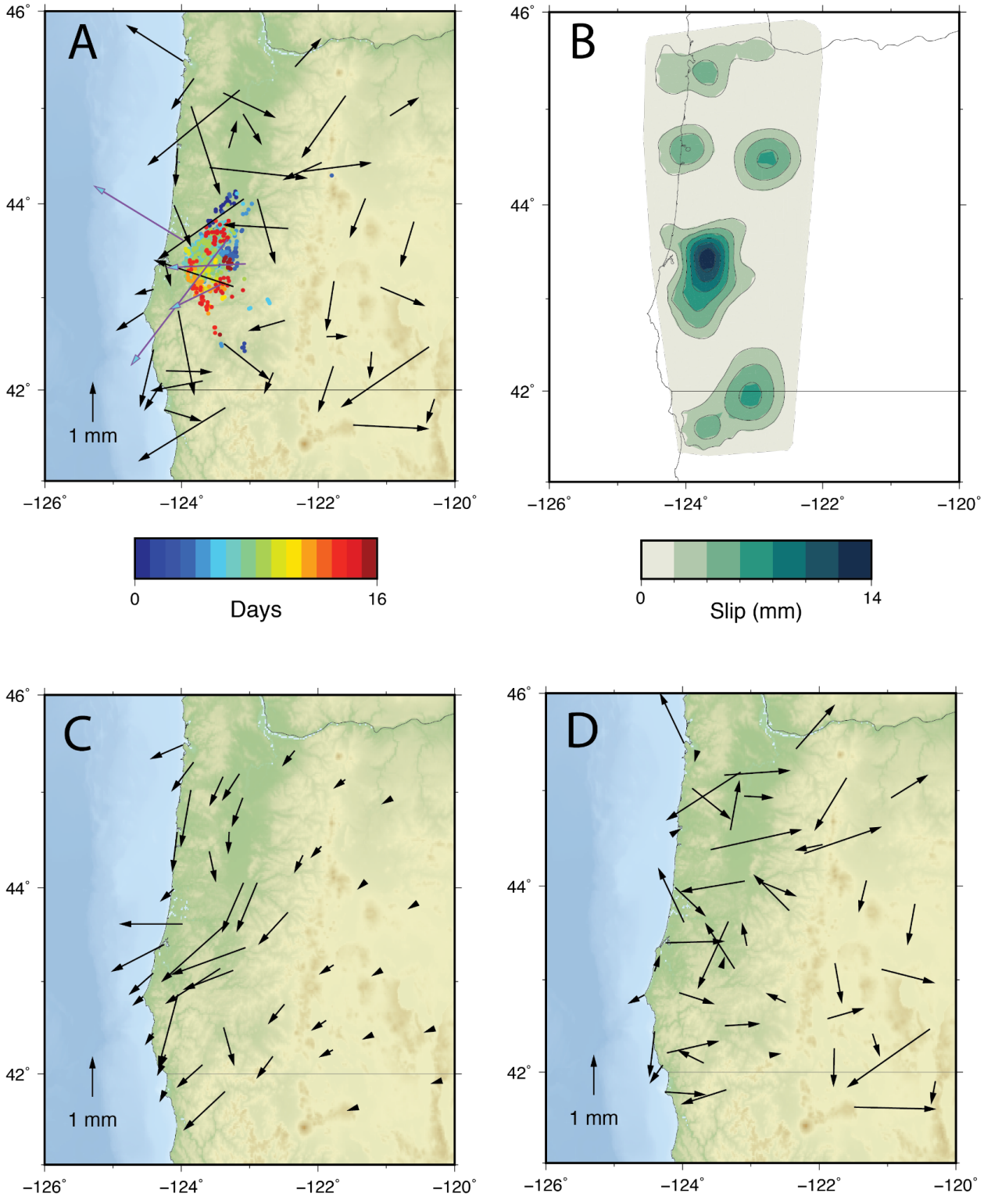

Figure S4. Model results for ETS Event 2 (September 2016). Panels are the same as Figure S3.

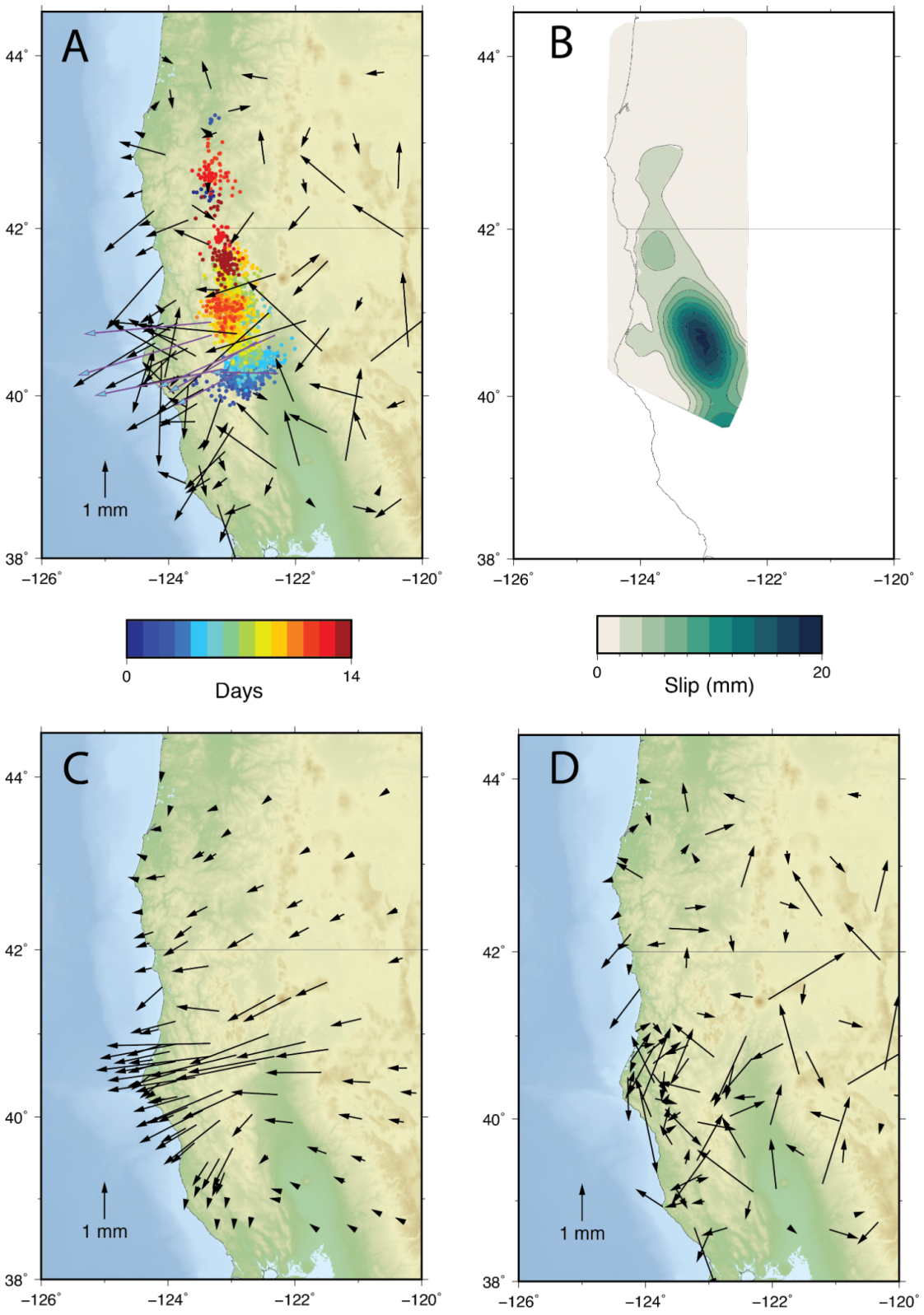

Figure S5. Model results for ETS Event 3 (April 2017). Panels are the same as Figure S3.

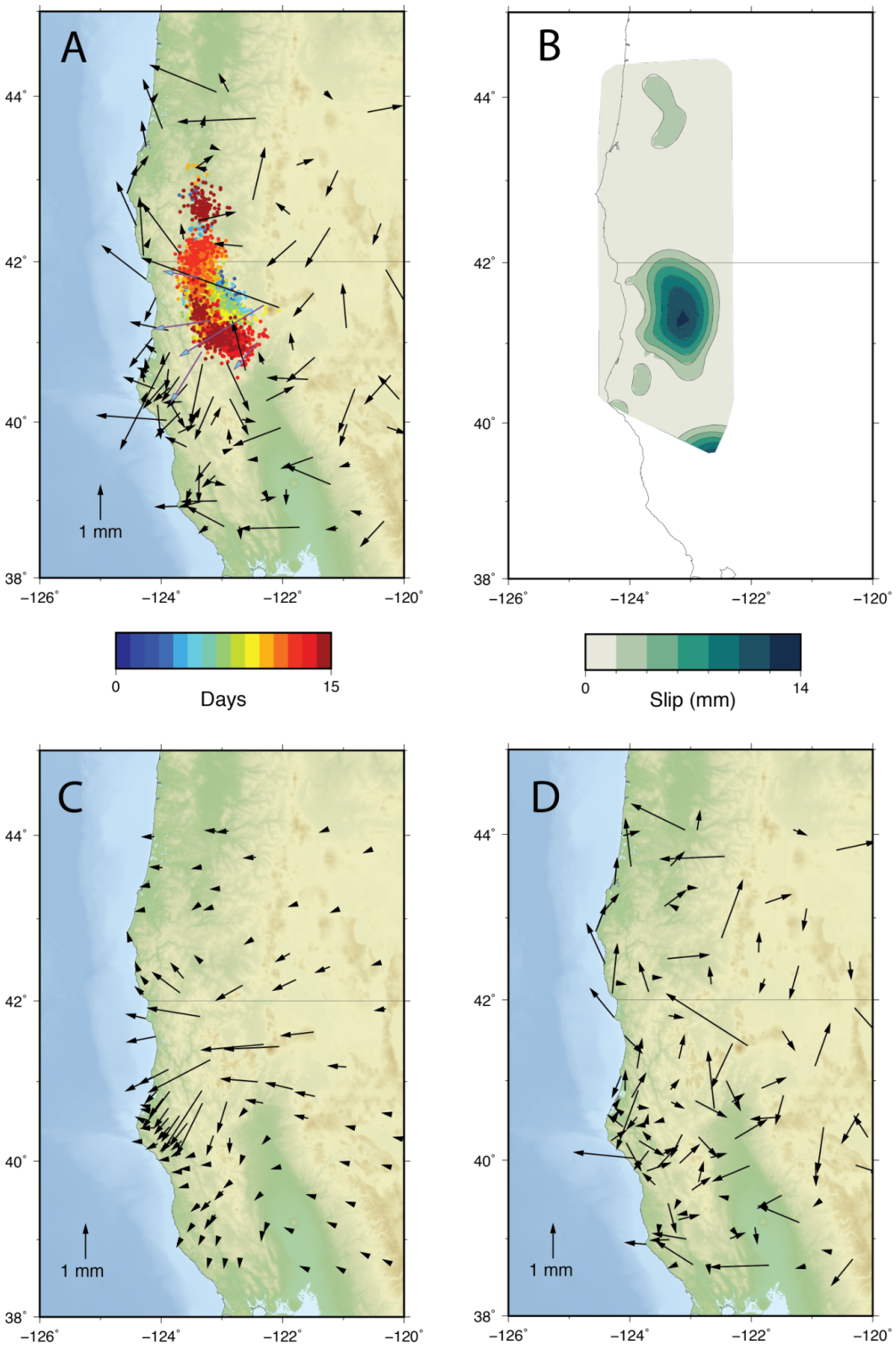

Figure S6. Model results for ETS Event 4 (July 2017). Panels are the same as Figure S3.

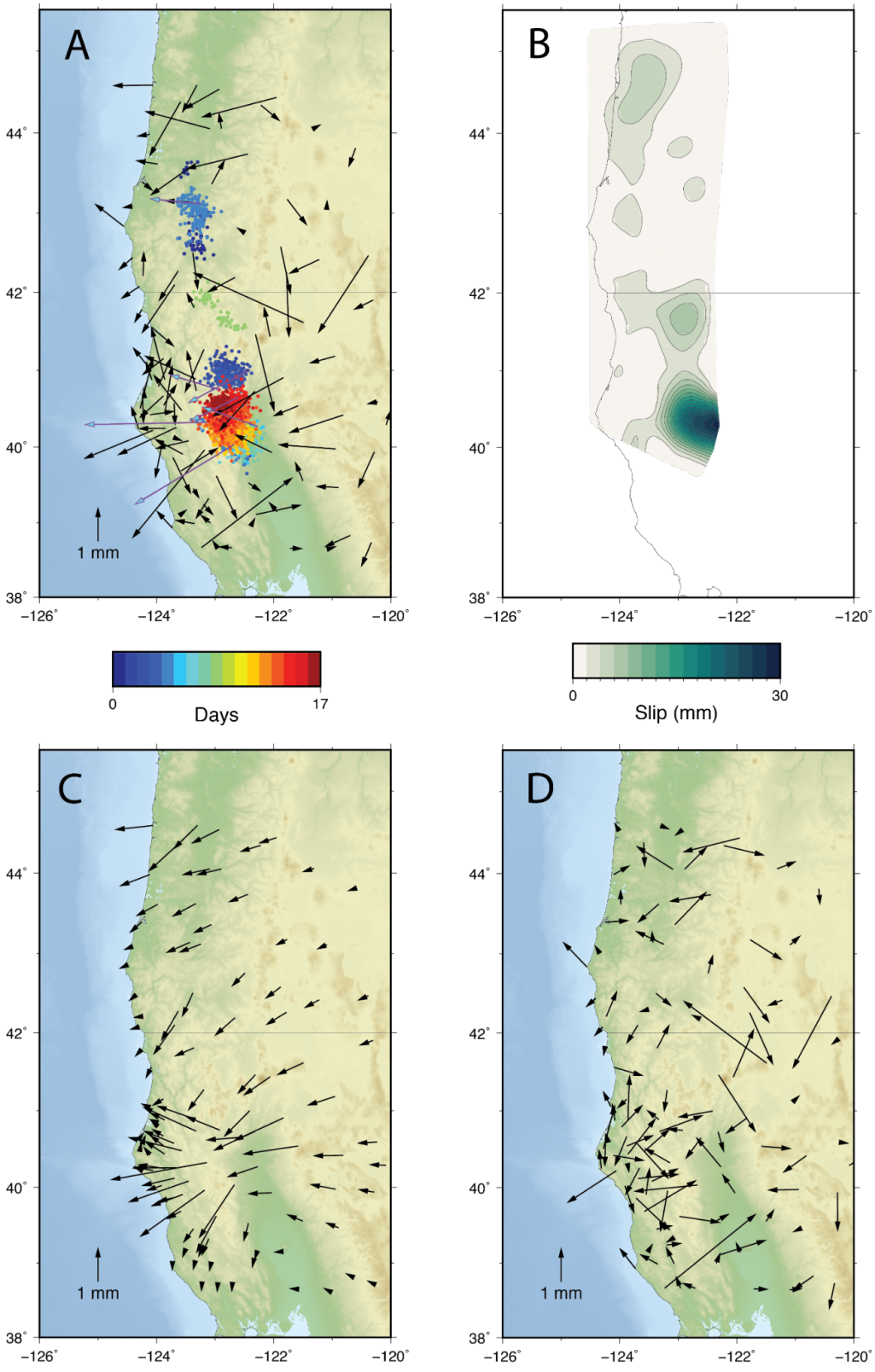

Figure S7. Model results for ETS Event 5 (October 2017). Panels are the same as Figure S3.

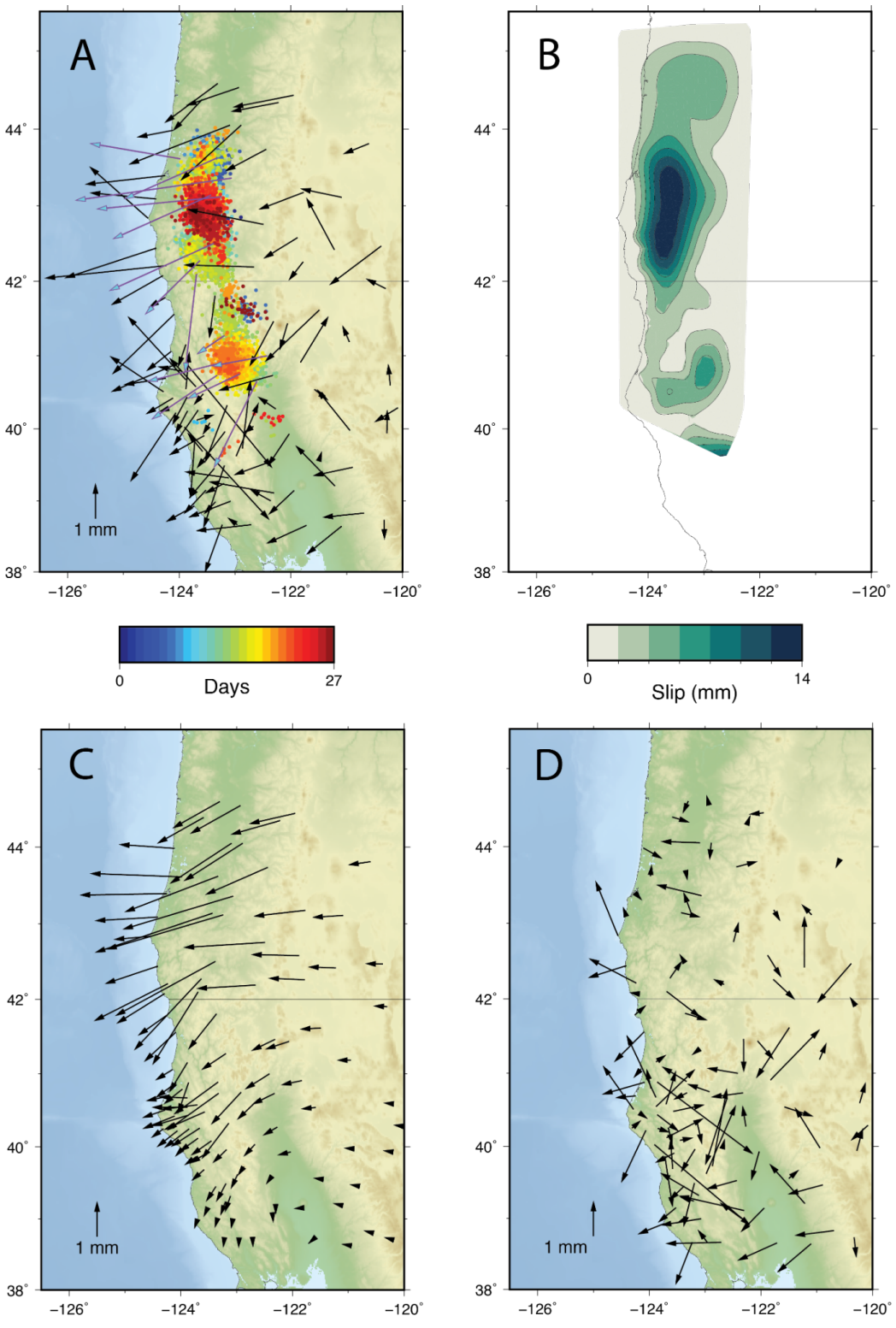

Figure S8. Model results for ETS Event 6 (December 2017). Panels are the same as Figure S3.

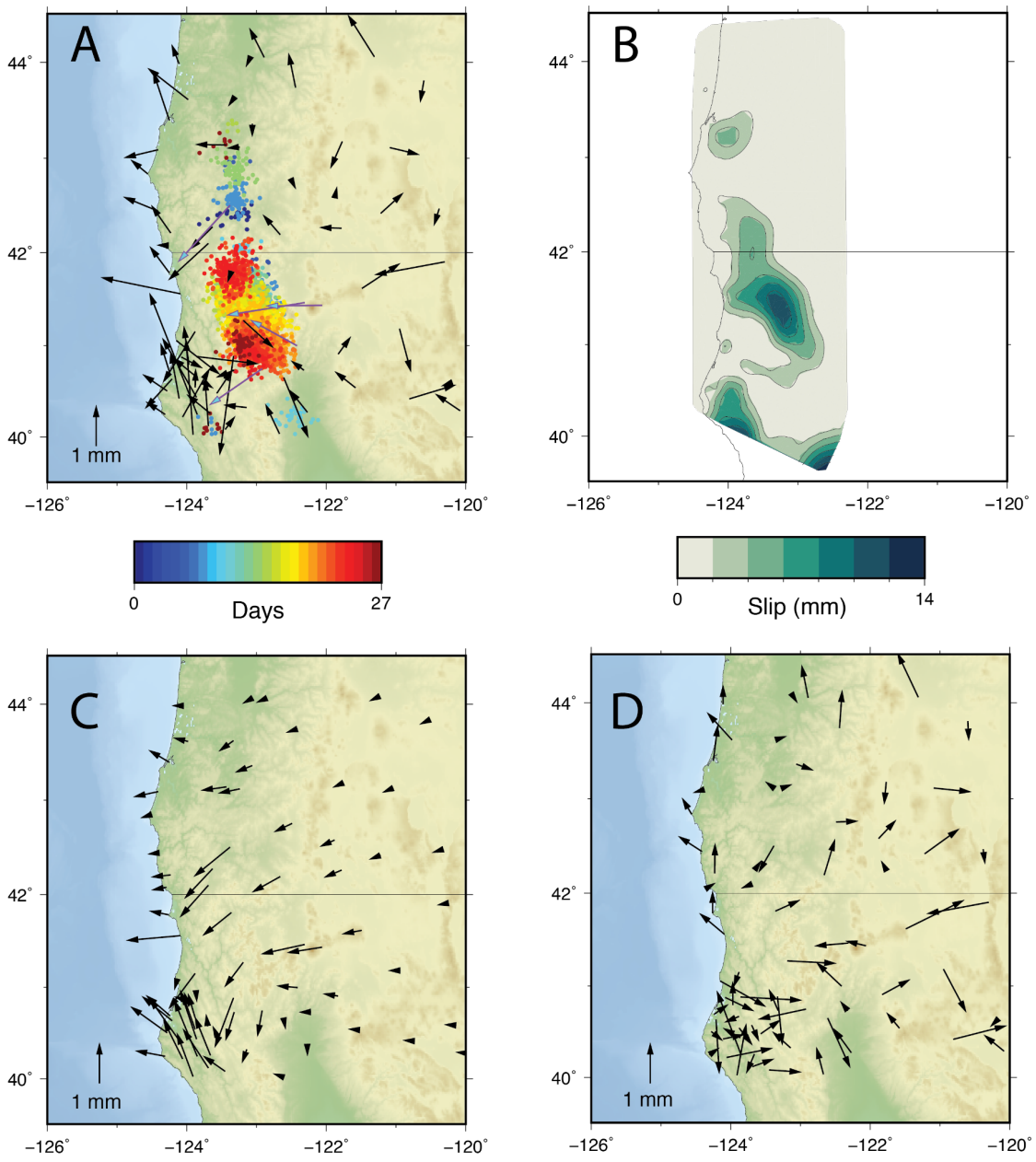

Figure S9. Model results for ETS Event 7 (May 2018). Panels are the same as Figure S3.

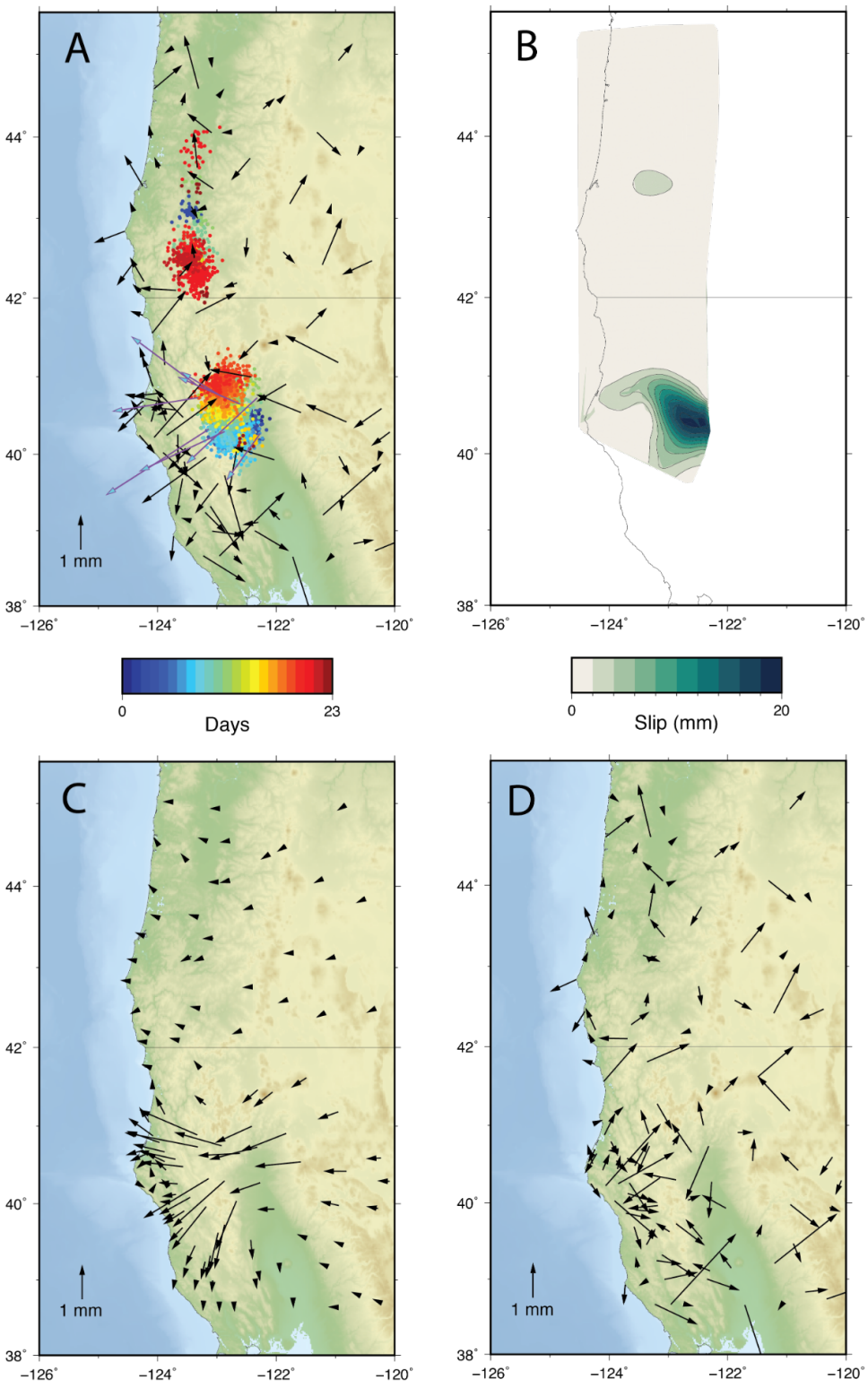

Figure S10. Model results for ETS Event 8 (June 2018). Panels are the same as Figure S3.

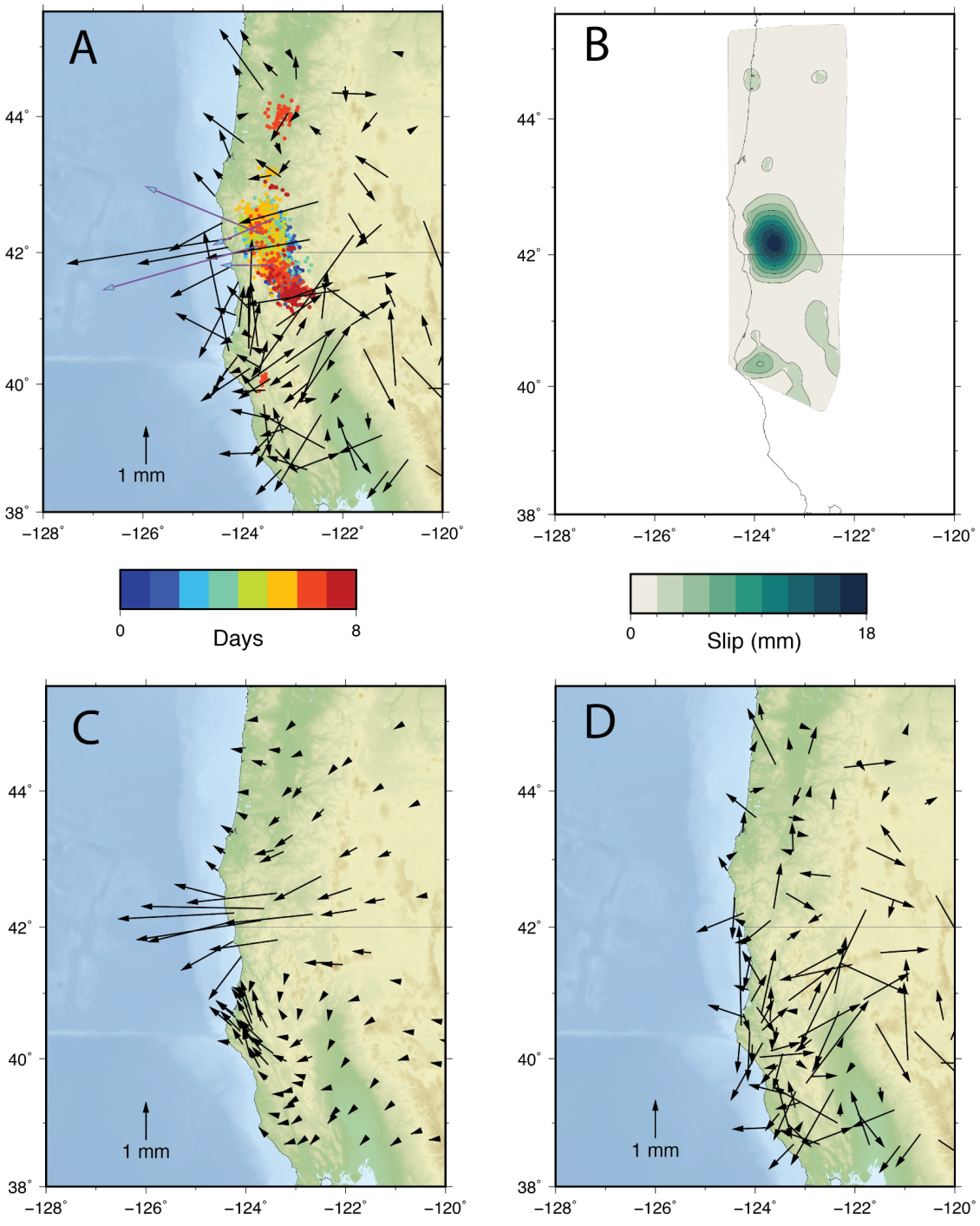

Figure S11. Model results for ETS Event 9 (November 2018). Panels are the same as Figure S3.

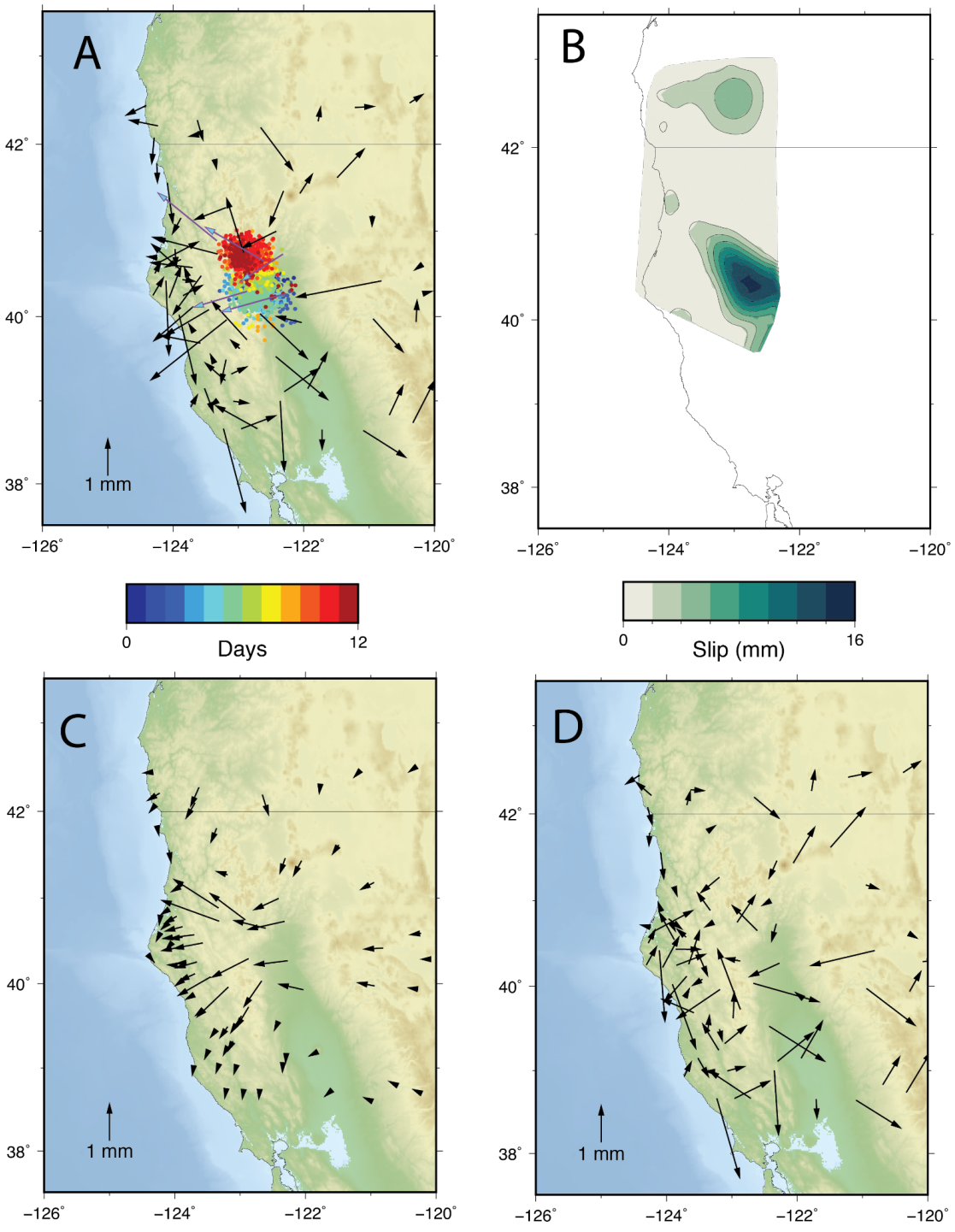

Figure S12. Model results for ETS Event 10 (February 2019). Panels are the same as Figure S3.

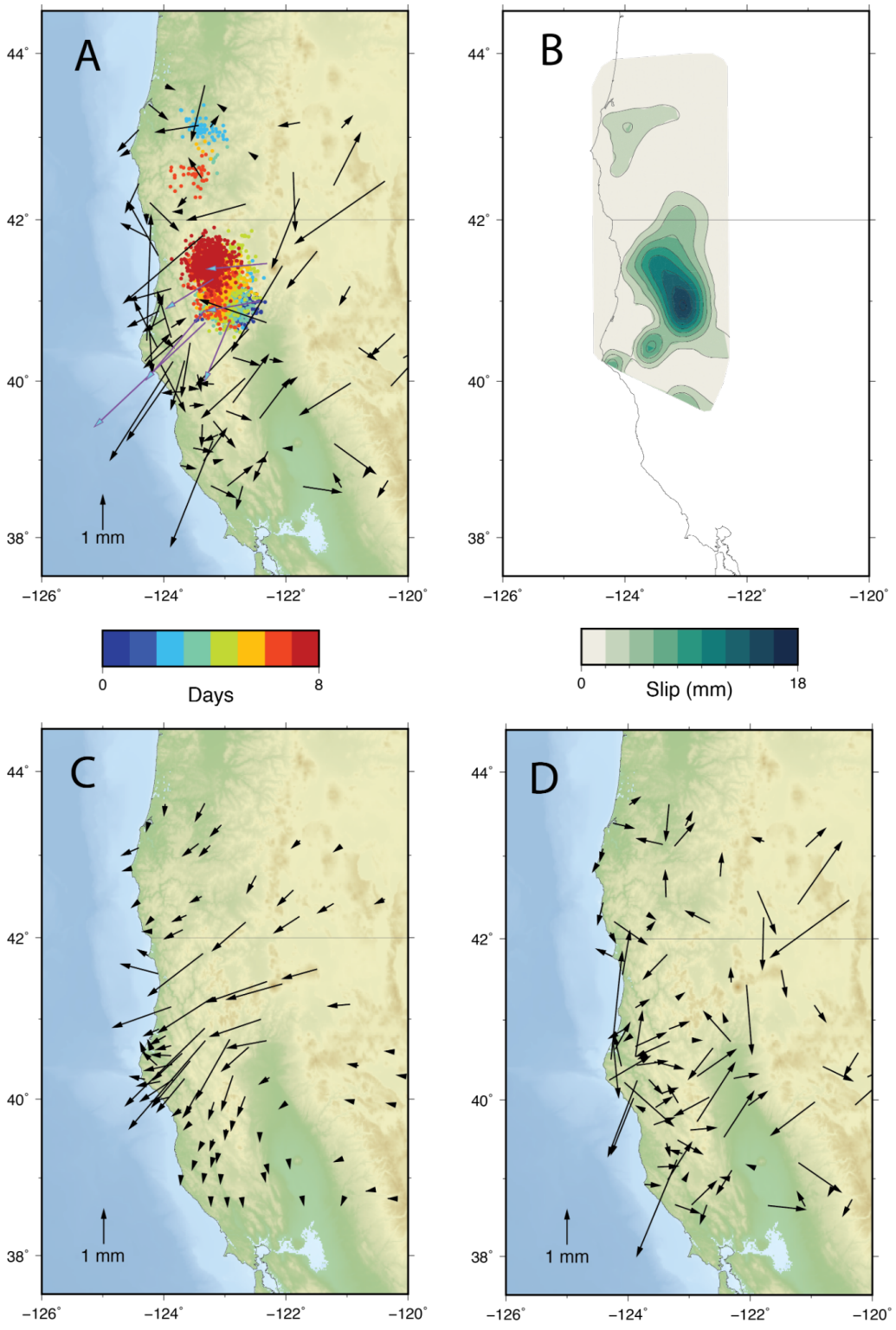

Figure S13. Model results for ETS Event 11 (March 2019). Panels are the same as Figure S3.

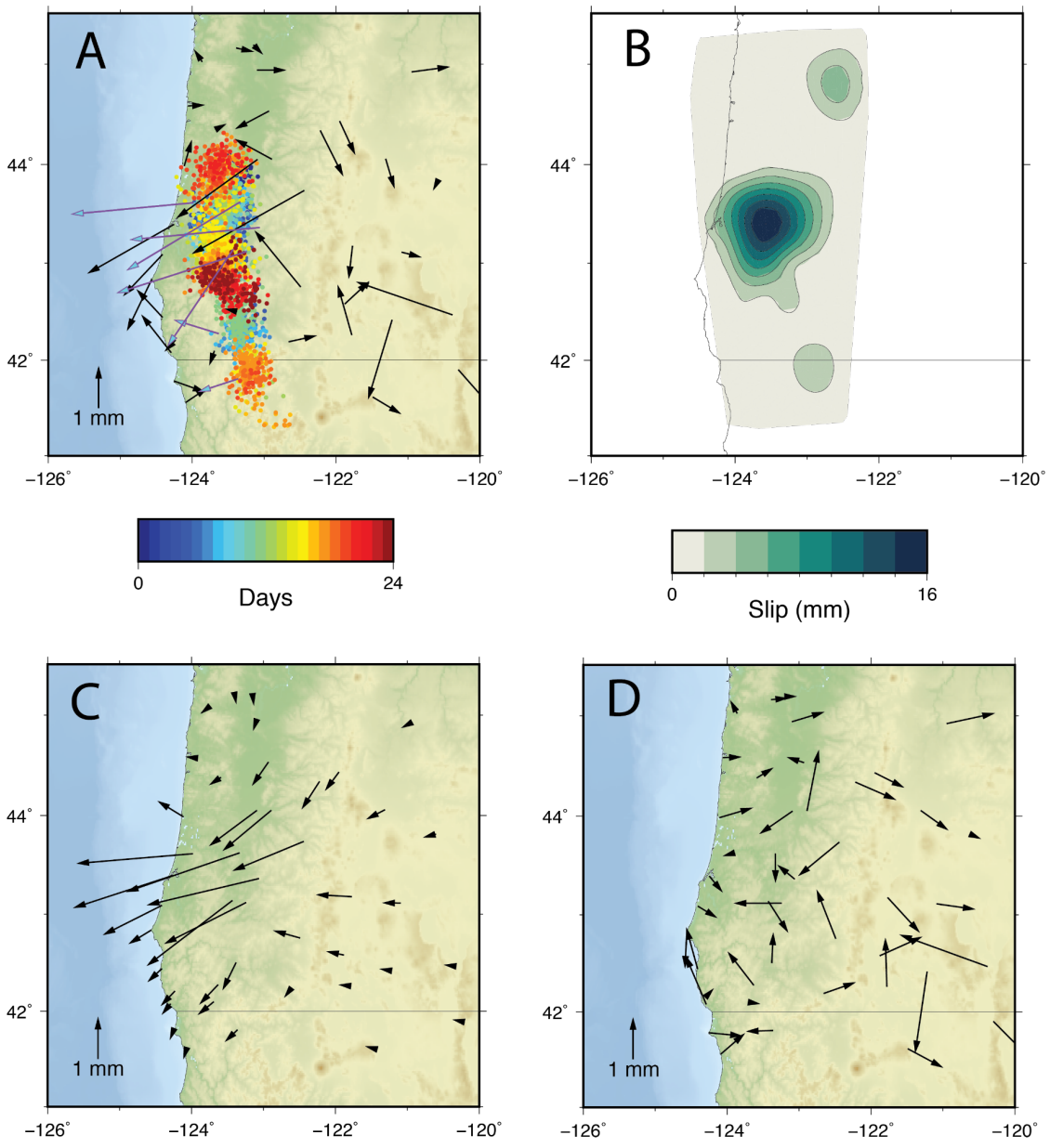

Figure S14. Model results for ETS Event 12 (July 2019). Panels are the same as Figure S3.

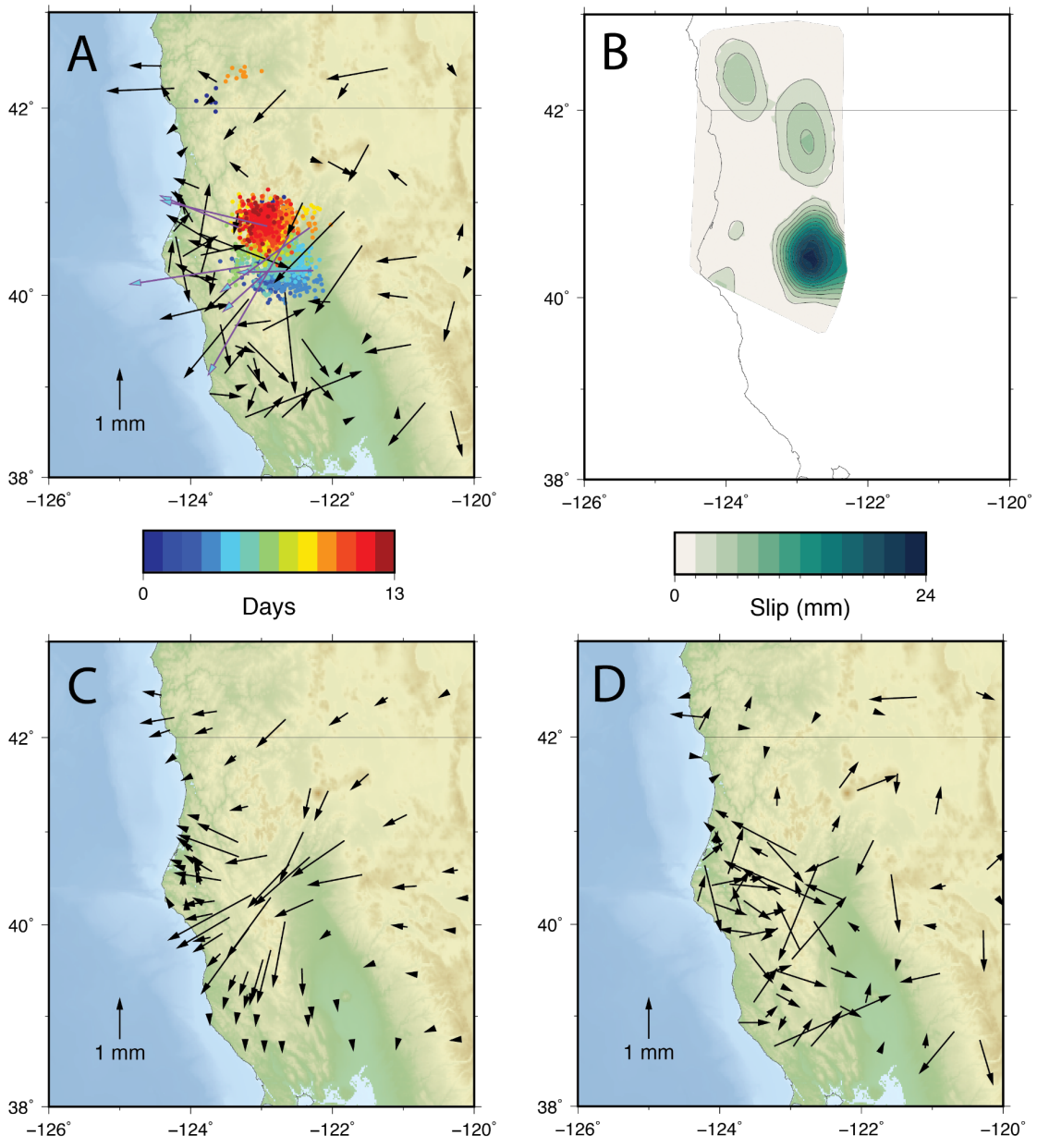

Figure S15. Model results for ETS Event 13 (November 2019). Panels are the same as Figure S3.

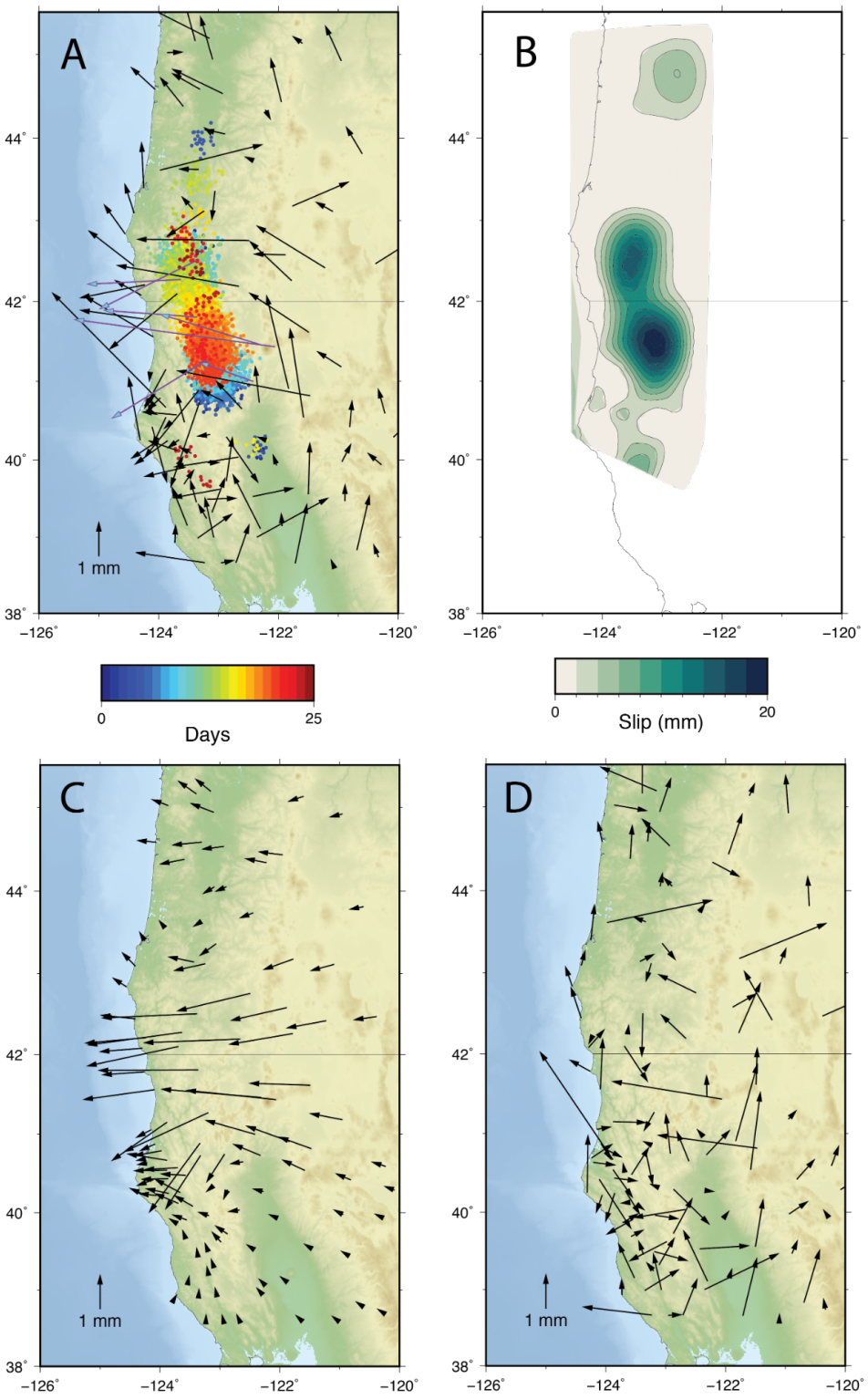

Figure S16. Model results for ETS Event 14 (December 2019). Panels are the same as Figure S3.

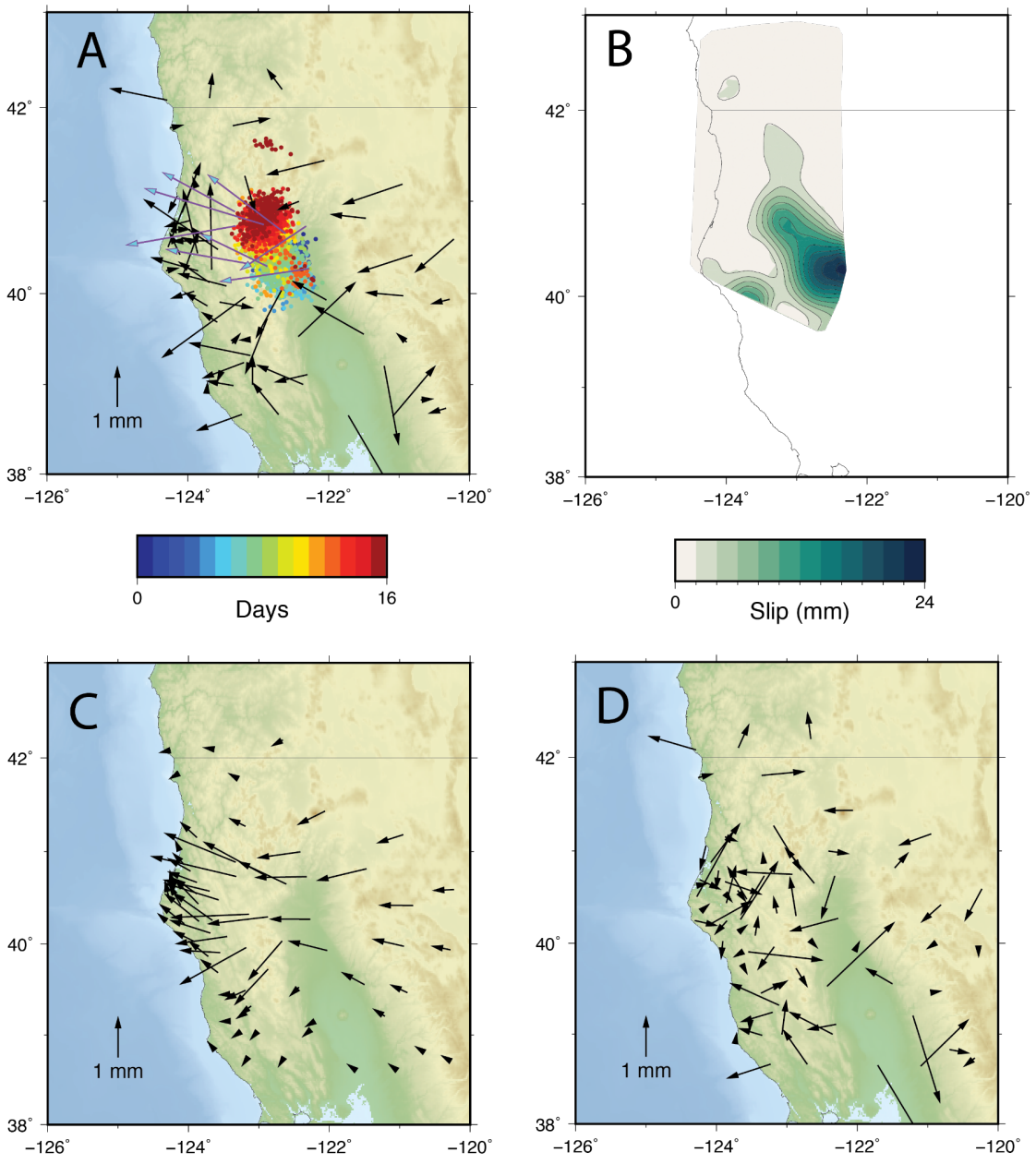

Figure S17. Model results for ETS Event 15 (June 2020). Panels are the same as Figure S3.

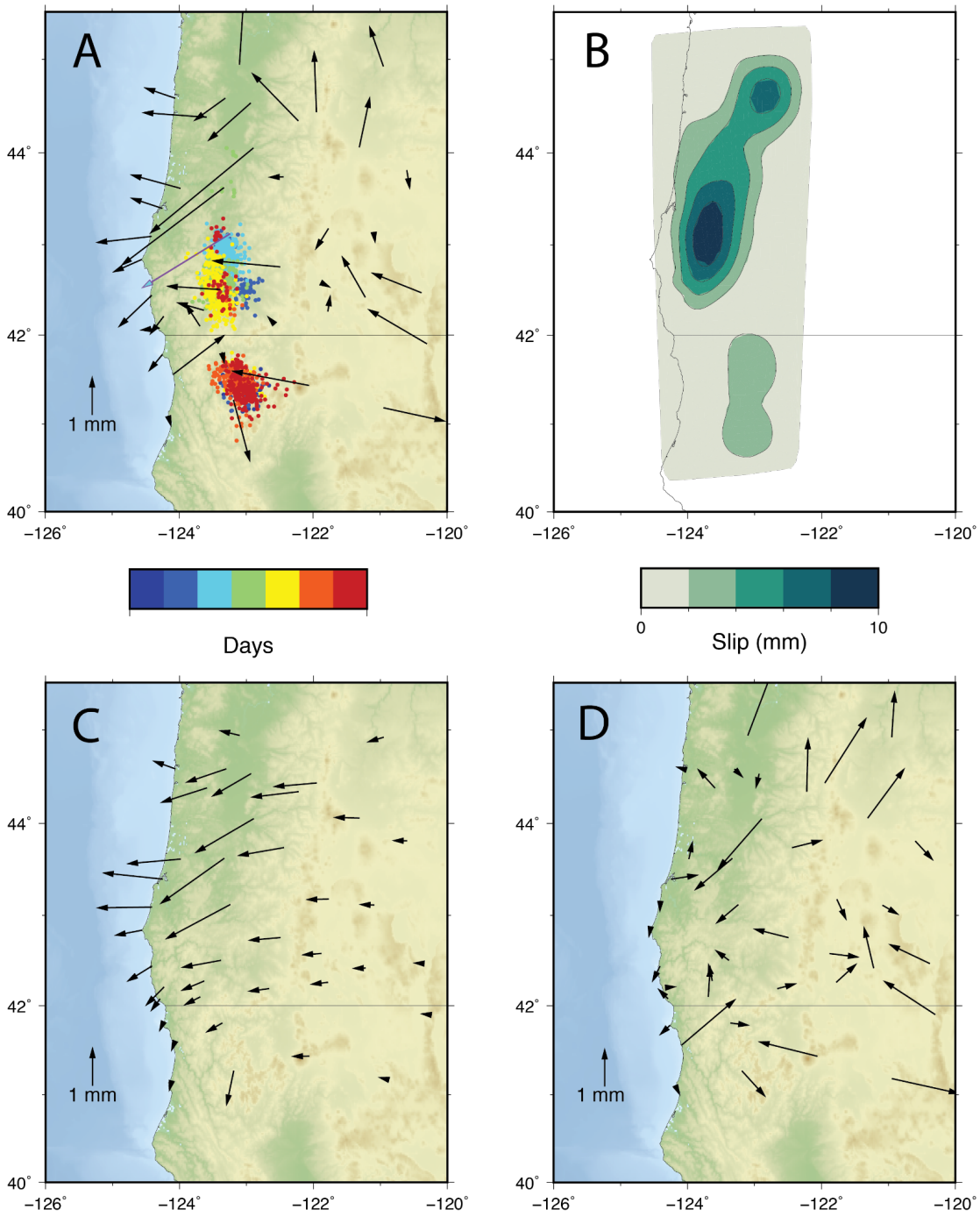

Figure S18. Model results for ETS Event 16 (September 2020). Panels are the same as Figure S3.

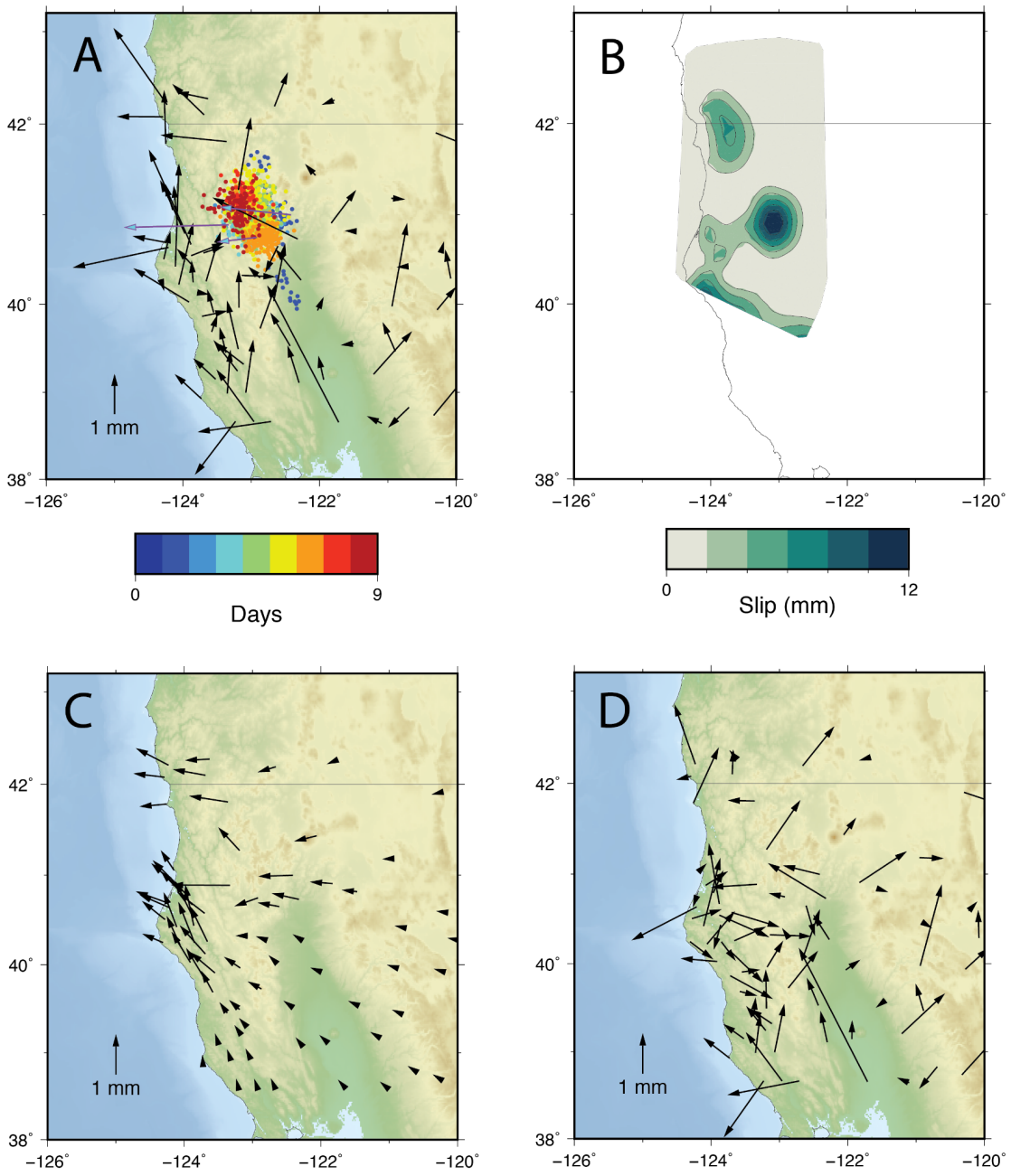

Figure S19. Model results for ETS Event 17 (November 2020). Panels are the same as Figure S3.

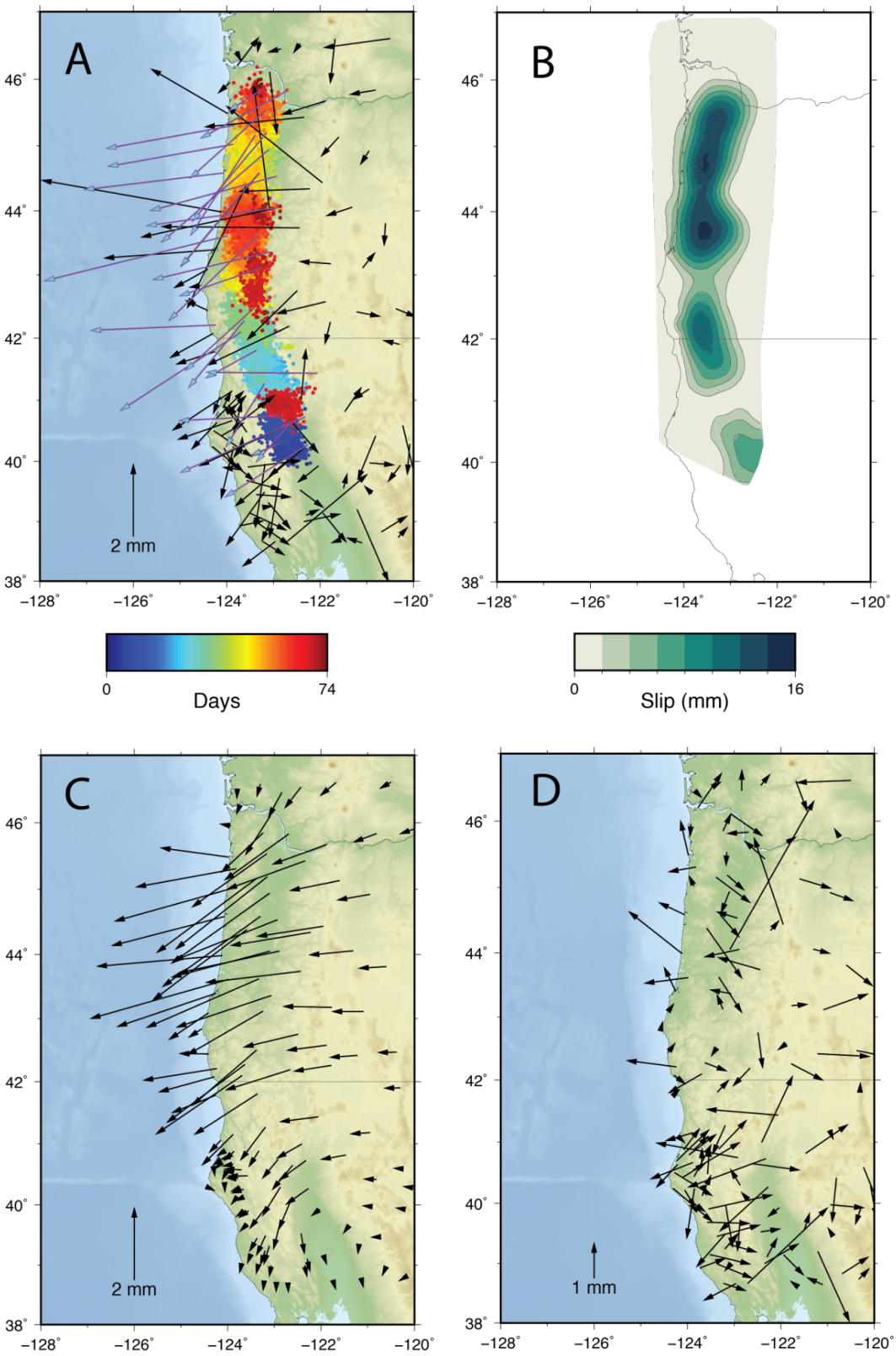

Figure S20. Model results for ETS Event 18 (March 2021). Panels are the same as Figure S3.

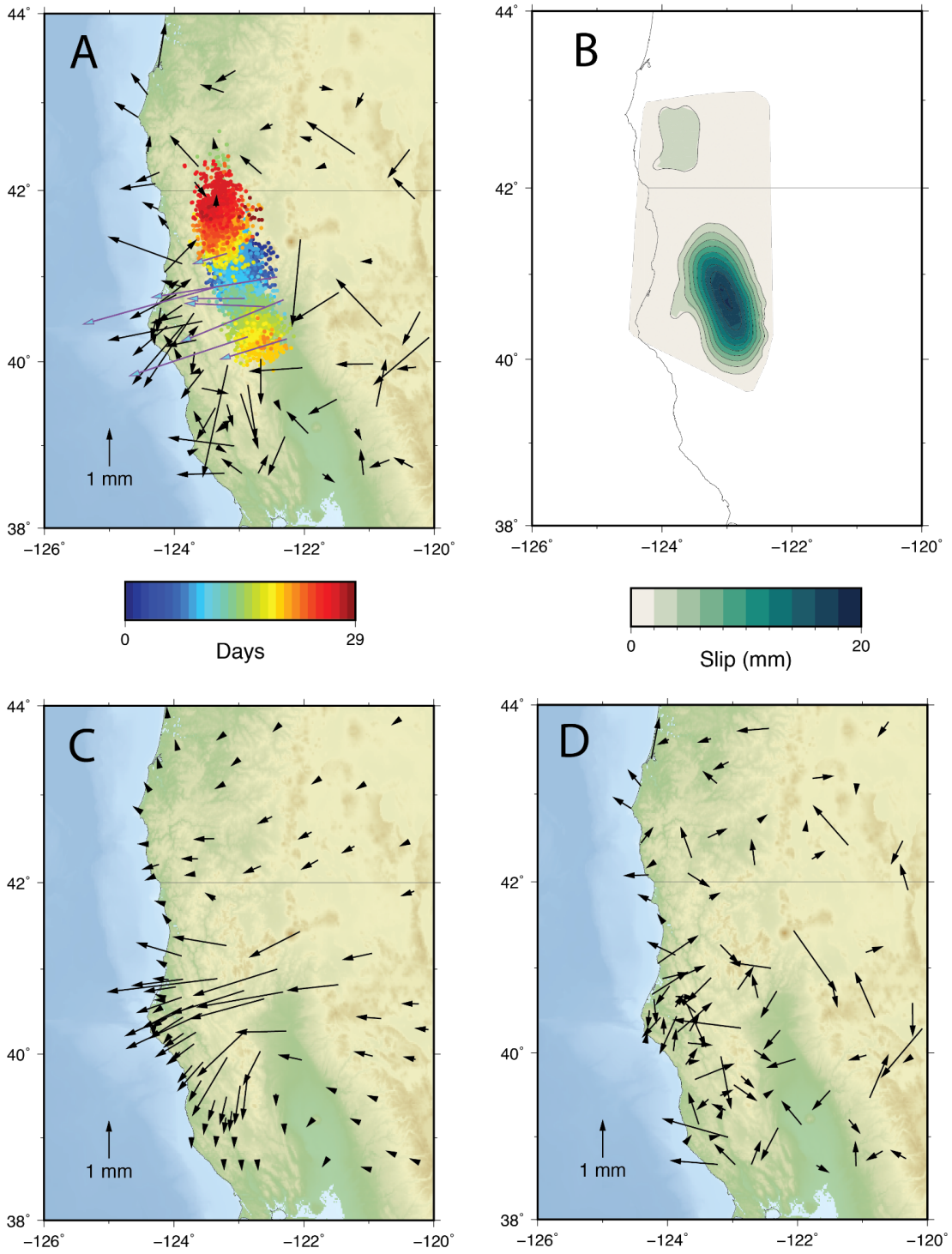

Figure S21. Model results for ETS Event 19 (September 2021). Panels are the same as Figure S3.

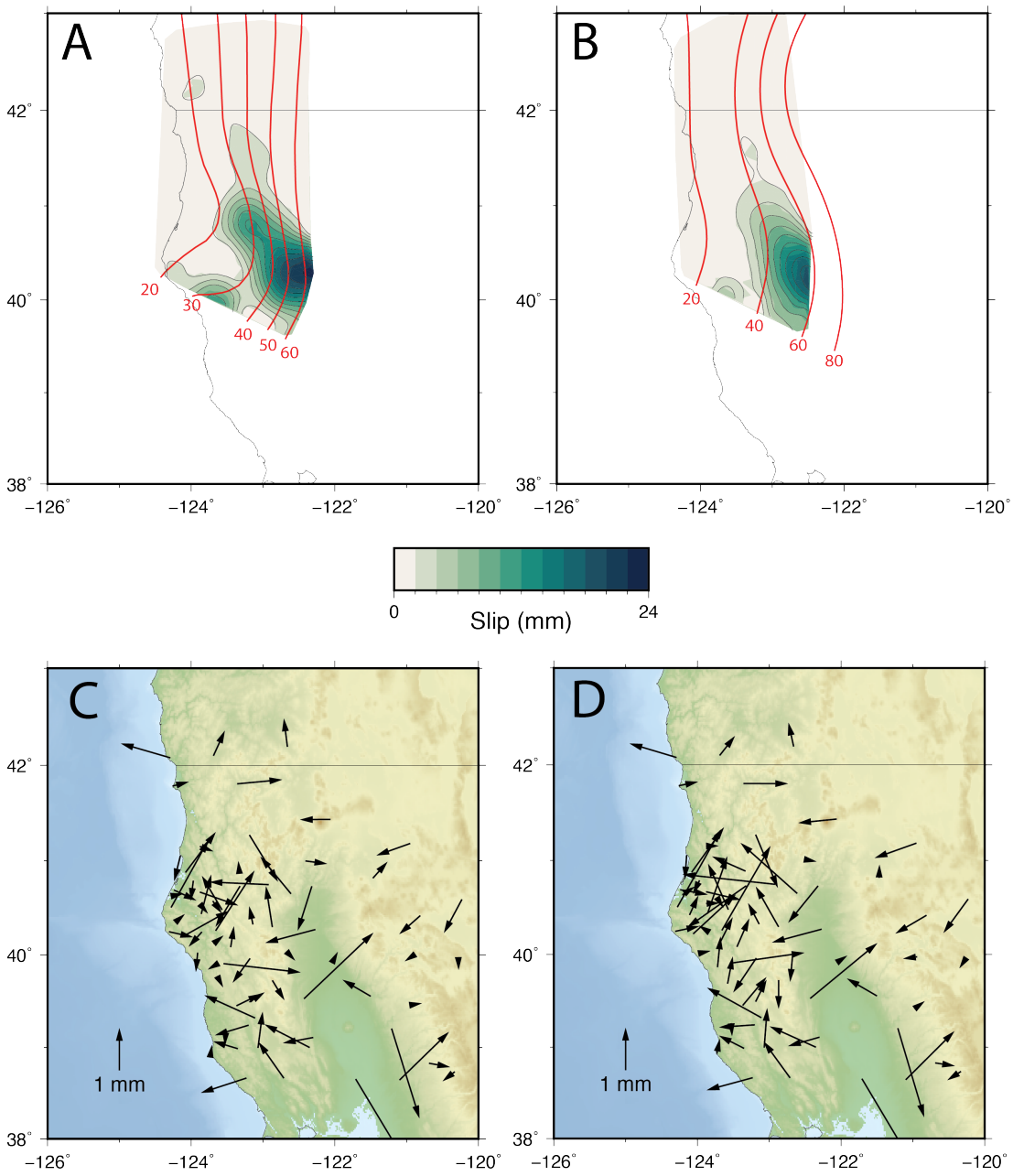

Figure S22. Comparison of slip model results for ETS Event 15 (June 2020) using different slab models. **A** Distributed slip model using McCrory et al. (2012) slab model with red lines delineating slab contours and black lines with green shading outlining every 2 mm of fault slip. **B** Distributed slip model using Slab2 model from Hayes (2018) with red lines delineating slab contours and black lines with green shading outlining every 2 mm of fault slip. **C** Vector map showing the misfit between the observed and predicted surface displacements resulting from the slip model in panel A. **D** Vector map showing the misfit between the observed and predicted surface displacements resulting from the slip model in panel B.

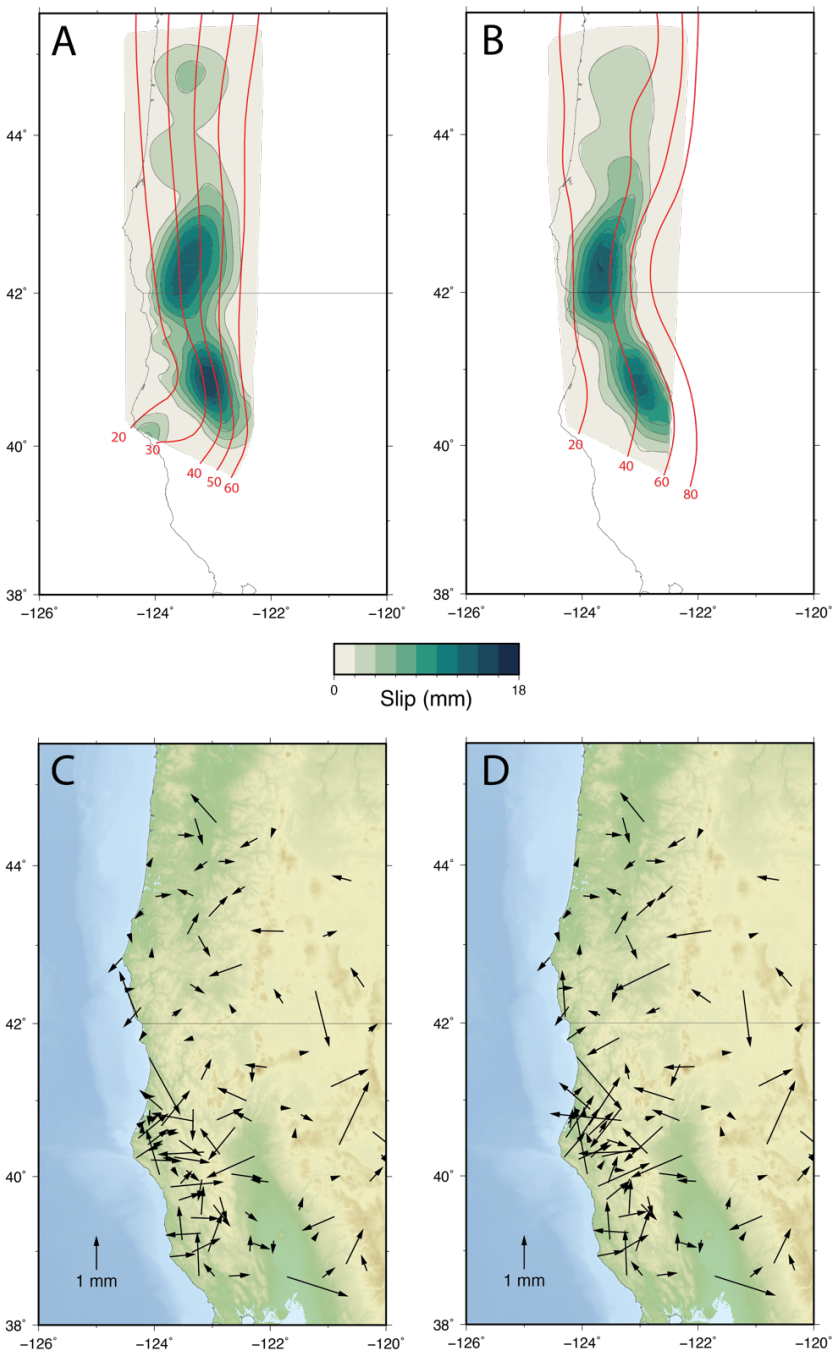

Figure S23. Comparison of distributed slip model results for ETS Event 1 (August 2016) using different slab models. **A** Distributed slip model using McCrory et al. (2012) slab model with red lines delineating slab contours and black lines with green shading outlining every 2 mm of fault slip. **B** Distributed slip model using Slab2 model from Hayes (2018) with red lines delineating slab contours and black lines with green shading outlining every 2 mm of fault slip. **C** Vector map showing the misfit between the observed and predicted surface displacements resulting from the slip model in panel A. **D** Vector map showing the misfit between the observed and predicted surface displacements resulting from the slip model in panel B.

Event # (Date)	**Moment Magnitude (Mw)**	χ^2
1 (August 2016)	6.73	0.66
2 (September 2016)	6.51	0.67
3 (April 2017)	6.60	0.62
4 (July 2017)	6.42	0.55
5 (October 2017)	6.62	0.75
6 (December 2017)	6.72	0.83
7 (May 2018)	6.42	0.64
8 (June 2018)	6.42	0.75
9 (November 2018)	6.51	0.77
10 (February 2019)	6.41	0.73
11 (March 2019)	6.50	0.76
12 (July 2019)	6.47	0.57
13 (November 2019)	6.48	1.00
14 (December 2019)	6.69	1.22
15 (June 2020)	6.49	0.61

16 (September 2020)	6.53	0.82
17 (November 2020)	6.32	1.02
18 (March 2021)	6.85	0.87
19 (September 2021)	6.52	0.60

Table S24. Equivalent moment magnitude (Mw) and chi-squared statistic (χ^2) for each of the 19 ETS events in southern Cascadia.

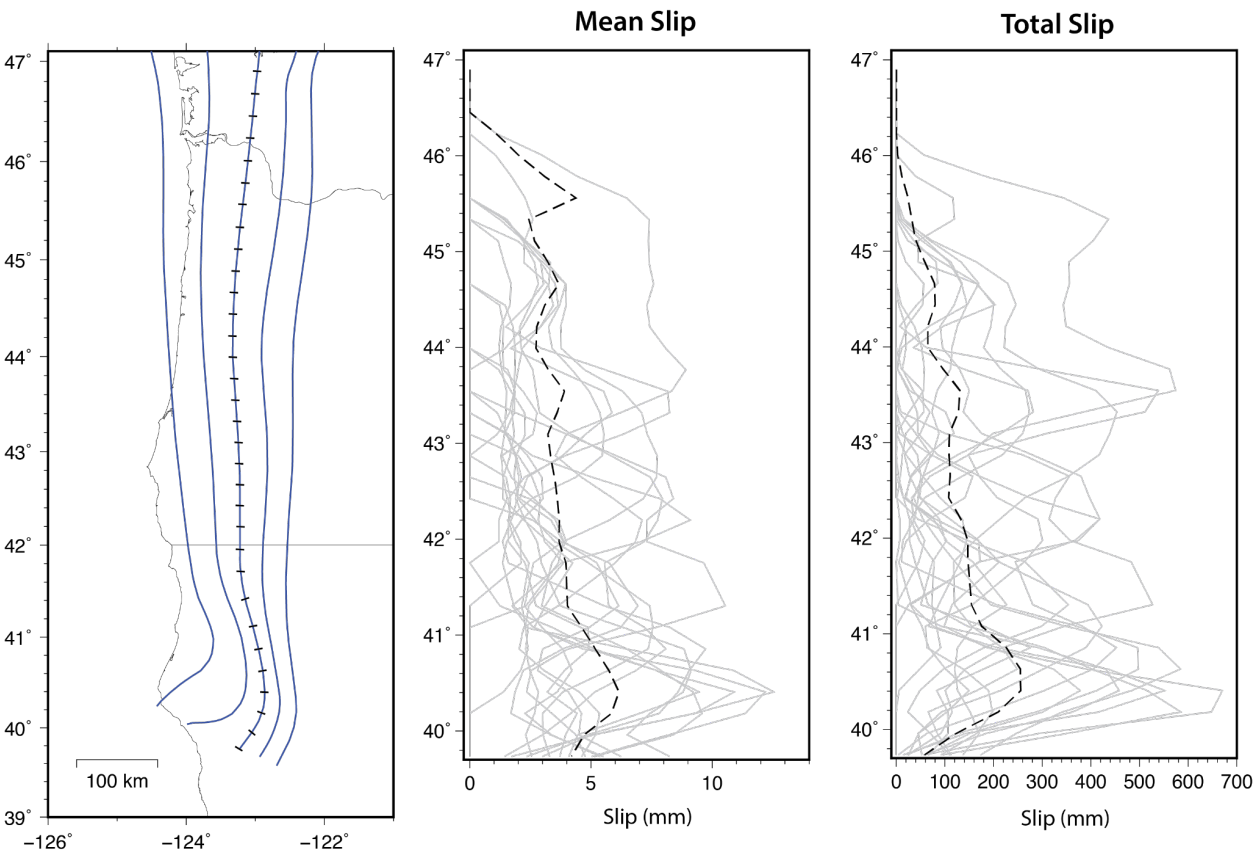

Figure S25. Along-strike measurements of slip for each of the 19 ETS events in southern Cascadia. **Left** Map of Cascadia where the blue lines delineate the 20, 30, 40, 50, and 60 km slab depth contours. Slip measurements are calculated using a spatial moving average, where we only consider fault patches that are located within a moving 300 x 50 km box and have >1 mm of slip. The box is shifted along strike 25 km at a time and the location of the box centers are shown with tick marks on the 40 km depth contour. **Middle** Plot showing the mean slip for each individual event (grey lines) and the average mean slip for all 19 events (dashed black line). **Right** Plot showing the total slip for each individual event (grey lines) and the average total slip for all 19 events (dashed black line).