**Abstract**

Fault creep is observed along many faults worldwide (Titus et al., 2011). Aseismic slip does not always accumulate at a steady background rate; instead, it accumulates in bursts known as creep events (Gladwin et al., 1994). Despite observations of creep events dating back to the mid-1900s, the size and importance of creep events remain unclear. Some researchers treat them as short near-surface events (Figure 1a) (Gladwin et al., 1994); however, others suggest that creep events may reach 4km depth and connect the surface to the seismogenic zone (Figure 1c) (Bilham et al., 2016). Here we present ongoing work aiming to determine the typical rupture extent and depth of creep events along the central San Andreas Fault.

![Diagrams](https://example.com/fig1.png)

**Figure 1:** Schematic Diagram of creep event scenarios. a) Short and shallow events. b) Long and shallow events. c) Long and deep events.

**Data**

- We use data from 18 USGS creepmeters installed along the creeping section of the San Andreas Fault (Figure 2).
- The creepmeter records are decades-long time-series datasets with slip values recorded every 10 minutes.

![Map](https://example.com/fig2.png)

**Figure 2:** Map creepmeter locations used in this study. Faults in central California are shown in gray with the San Andreas fault highlighted in black.

**Detection**

- We detect creep events using a cross-correlation approach.
- We identify places of high similarity within the creep record that also have significant amounts of slip.
- We identify 2120 creep events in the creepmeter record and determine their slip and duration (Figure 3a).
- We find an anticorrelation between the number of events at a creepmeter (Figure 3a) and the median slip and duration of those events (Figure 3b & c).

![Graph](https://example.com/fig3.png)

**Figure 3:** Properties of the creep events at each creepmeter. a) Number of detected events. b) Median creep event slip. c) Median creep event duration.

**Propagations**

- We identify that creep events at different creepmeters occur at closely spaced locations (Figure 4).
- We conduct bootstrapping on one of the creepmeters to calculate 70% confidence intervals for the percentage of events this creepmeter occurring at the other (Figure 5a).
- We test the null hypothesis that creep events are unrelated. We do this by time shifting the entire record of one creepmeter and again calculate the 70% confidence intervals for the percentage of creep events found at one creepmeter occurring at the other (Figure 5b).
- We subtract this time-shifted distribution from the bootstrapped distribution to calculate the `real` percentage of events that occur at both creepmeters.
- We also visually inspect the creep event catalogues and find 306 multi-creepmeter events which are characterised by 4 behaviors: isolated events, small (<2km) events, medium-sized (3-6km) events and large (>10km) events.

![Graph](https://example.com/fig4.png)

**Figure 4:** Creep records for the 21 to 25th May 2016 at (a) Cienega Winery (CWN), (b) Harris Ranch (XHR), and (c) San Juan Bautista (XJS). The figure illustrates our approach to detecting closely timed events. For each event at Cienega Winery (panel a), we search for events at (b) Harris Ranch and (c) San Juan Bautista that occur within 24 hours of the Cienega Winery event (gray regions in panels b and c).

**Detection and Proportion**

![Graph](https://example.com/fig5.png)

**Figure 5:** a) Probability distributions of the percentage of CWN creep events observed at XHR (orange) and XJS (green) within 24hrs, based on bootstrapping. b) Probability distributions of the percentage of CWN events that occurred at XHR and XJS within 24hrs for a physical reason.

**Affects of short-term rainfall**

- We have investigated how rainfall affects our results.
- We repeated our propagation analysis but removed events that had rainfall in the 3, 7 and 14 days prior to the event.
- We have found that rainfall had 3 affects: percentage of events decreases (Figure 7a), the percentage is unchanged (Figure 7b), or the percentage of events increases (Figure 7c).
- The most common behavior we observe is that the percentage of events remains unchanged which implies that many of our coincidently timed events are not driven by rainfall.

**Summary/Discussion**

- We have identified 2120 creep events in the creepmeter record using cross-correlation techniques and have identified that some of these events occur across multiple creepmeters, allowing us to identify 306 multi-creepmeter events.
- We identify 5 groups of event: isolated events, small (<2km) events, medium-sized (3-6km) events, large (>10km) events and multi-creepmeter events.
- We find the vast majority of these events are not affected by rainfall with correlations persisting when rainfall influences are excluded.
- The lengths of these creep events will help us to assess the different driving models for creep events.
- Ongoing work is focussed on estimating the depth of these km long creep events.

**References**


**Acknowledgements**

This work was supported by the UKRI Natural Environment Research Council grant number NE/S007474/1. Creep data are provided by the United States Geological Survey and are available at [https://earthquake.usgs.gov/monitoring/diginfo/data/download.php](https://earthquake.usgs.gov/monitoring/diginfo/data/download.php). The plotted fault lines are taken from the Catalog of faults and fault databases for the United States, provided by the USGS and the California Geodetic Survey and accessed from the USGS website [https://www.usgs.gov/natural-hazards/earthquake-hazards/faults](https://www.usgs.gov/natural-hazards/earthquake-hazards/faults). Rainfall data are provided by the National Oceanic and Atmospheric Administration and are available at [https://www.ncdc.noaa.gov/cdo-web/datasets](https://www.ncdc.noaa.gov/cdo-web/datasets).