USGS
science for a changing world

EarthScope Consortium

Migrating USGS creepmeter data and processing workflows to the cloud

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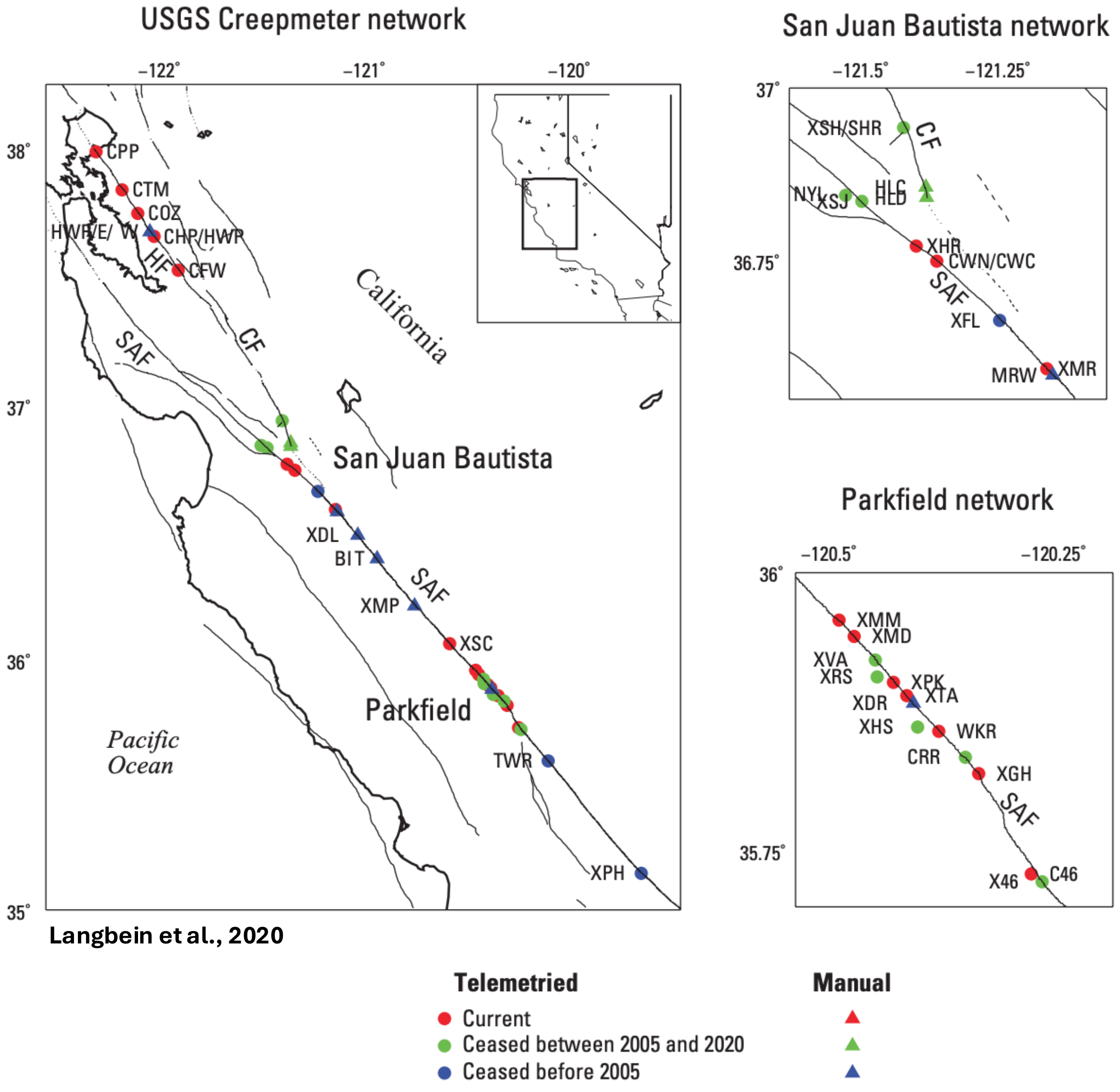
U.S. Geological Survey

PHOTOGRAPH BY GEOFF MANAUGH / BLDGBLOG

Recap: creepmeter measurements at the USGS



Langbein et al., 2020

Creepmeter data acquisition and archival began in the 1960's and extends through present-day.

- *Oldest active creepmeter:*

  Cienega Winery (Nov., 1968)

Creepmeter design and data acquisition has evolved dramatically since the first installations.

- *Todd and Rogers' talks discussed different designs*

Today, the USGS supports 15 active creepmeter sites. 14 creepmeter sites have been retired.

To date, internal processing workflows have been adapted to accommodate the evolving network…

Creepmeter Processing Workflow

Measurement

Data Products

Creepmeter Processing Workflow

Measurement

Data Products

How are creepmeter measurements processed and ported to USGS access portals?

Creepmeter Processing Workflow

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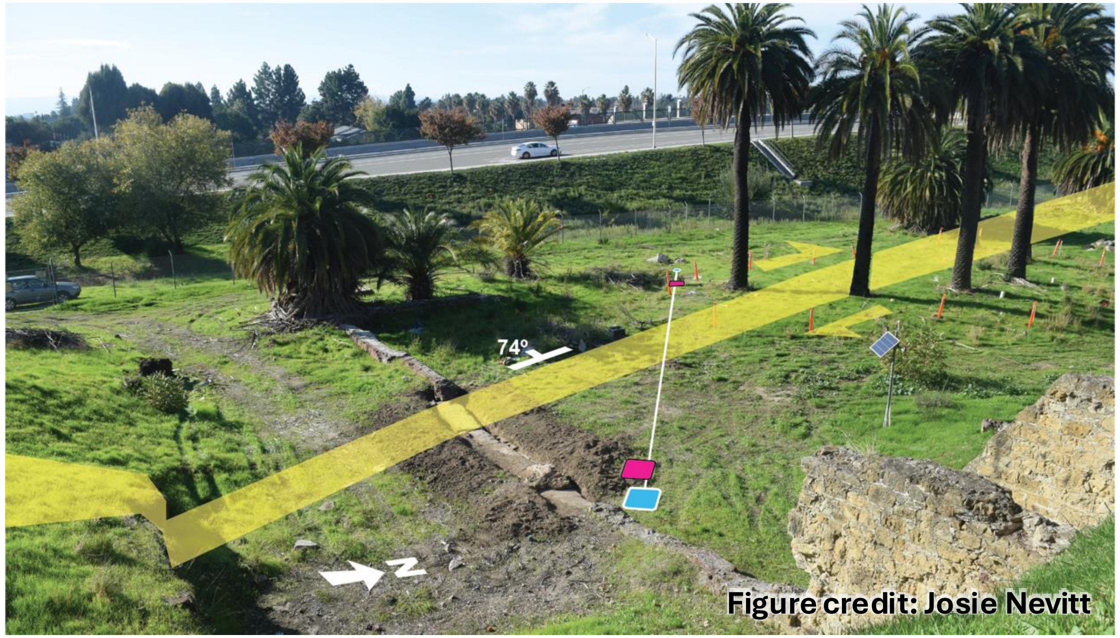
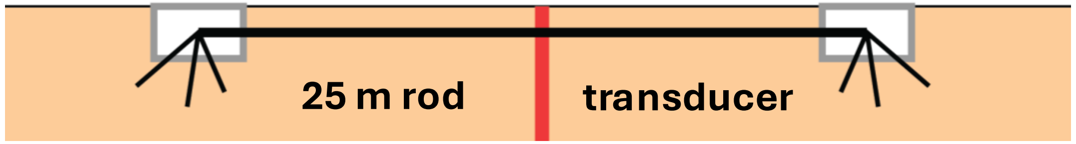
Recap: Creepmeter Details

<u>**Yesterday's field trip: Gallegos Winery**</u>





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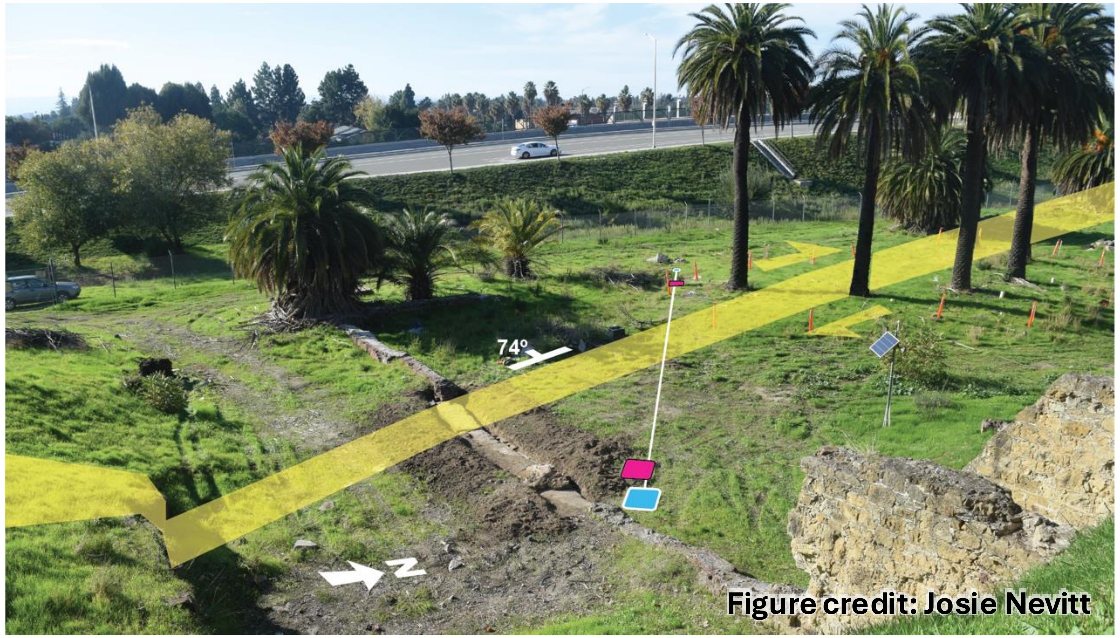

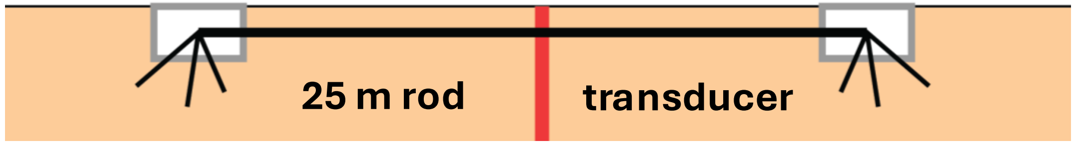

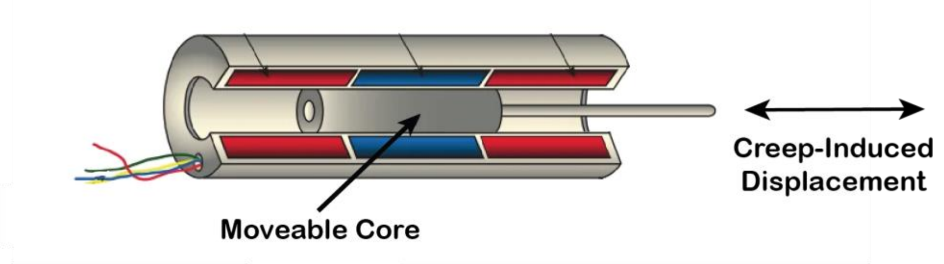

Creep-induced rod extension produces a voltage change.

Recap: Creepmeter Details

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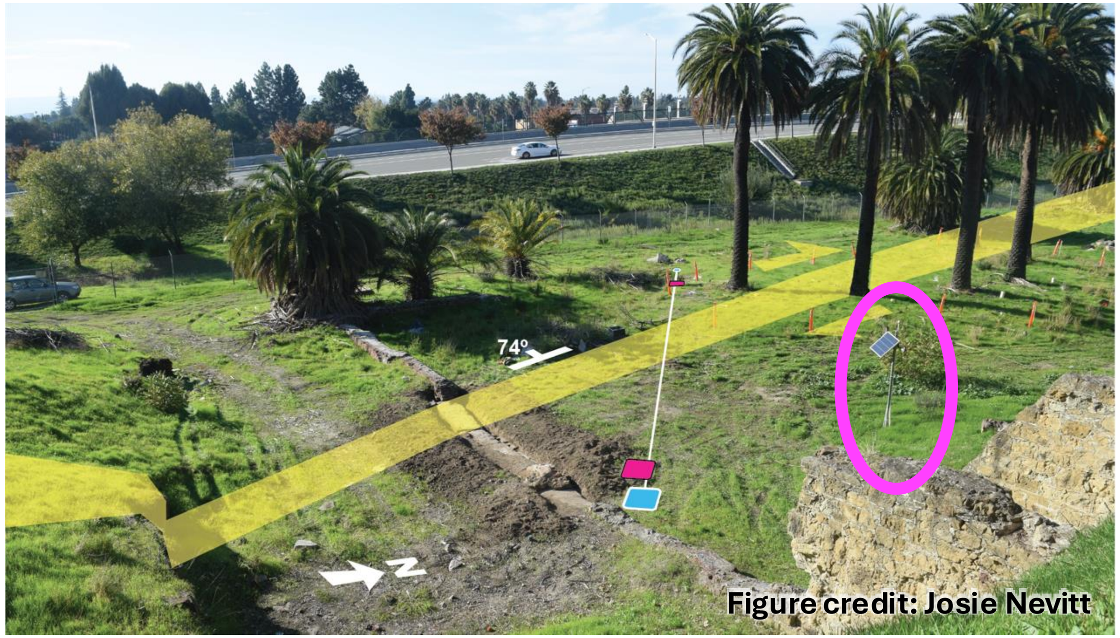

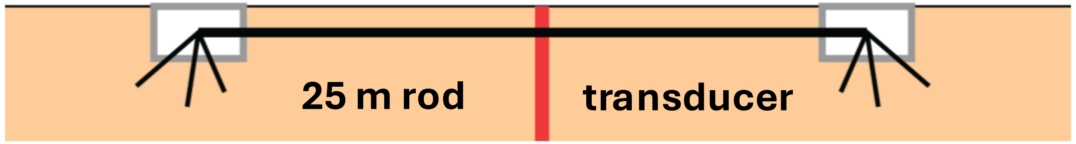

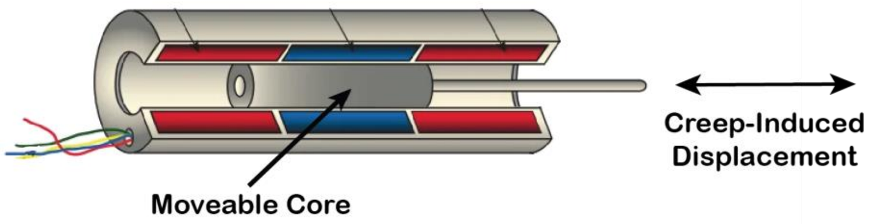

Creep-induced rod extension produces a voltage change.

Voltage readings and other system metrics are recorded every 1 (or 10) min, and telemetered via GOES satellites (or via HOBO-link for recent Bilham installs).

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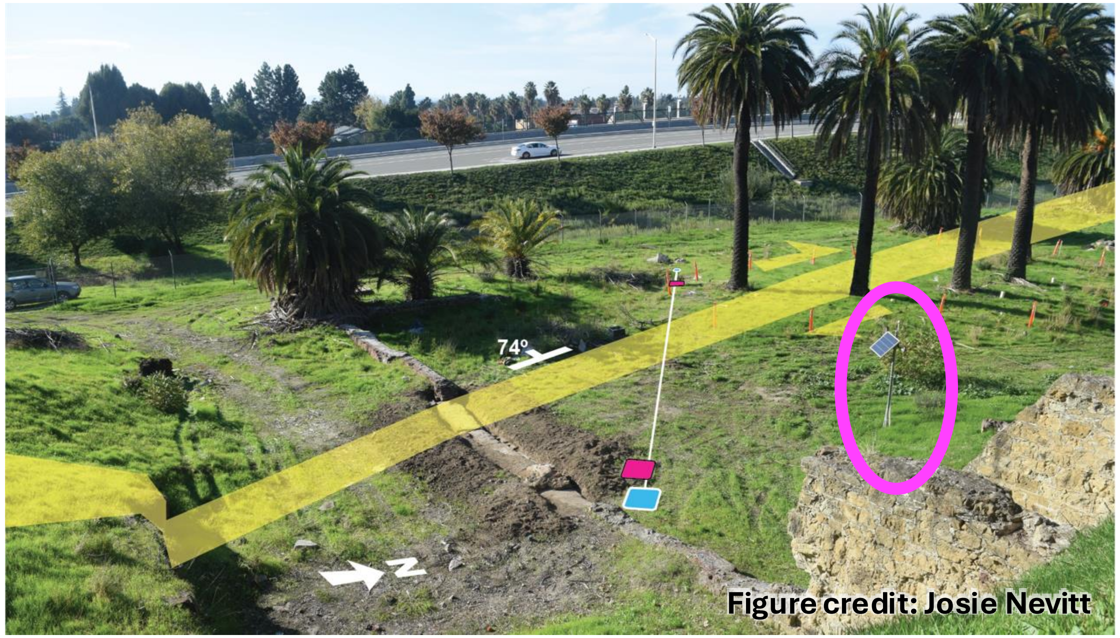
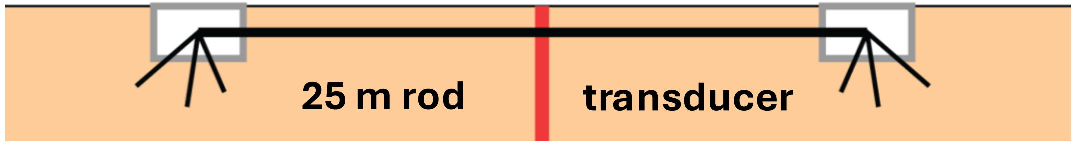
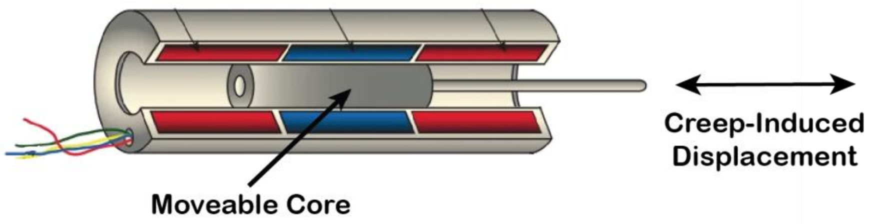


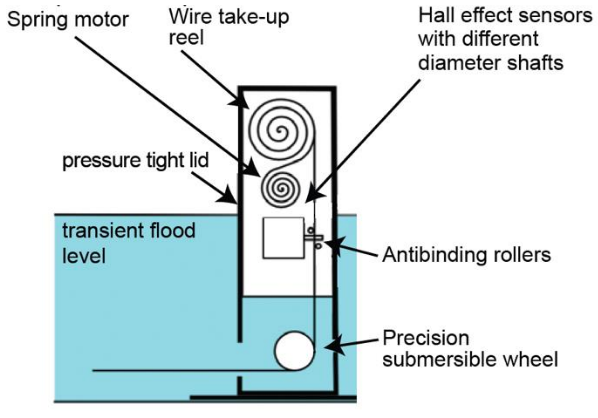




USGS wire creepmeters
(SJB, Parkfield)

Bilham creepmeters
(Bay Area)

Rupture meters
(select sites)



Langbein, 2014

Creep-induced rod extension produces a voltage change.

Voltage readings and other system metrics are recorded every 1 (or 10) min, and telemetered via GOES satellites (or via HOBO-link for recent Bilham installs).

The creepmeter network hosts multiple instrument designs (and generations therein) that uniquely encode voltage changes.

Creepmeter Processing Workflow

Field-based	*Measurement*	*Creep-induced displacement produces change in voltage*
	Telemetry	*Instrument readings are telemetered via GOES satellite or via HOBO-link*
	Data Products	

Creepmeter Processing Workflow

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Measurement — *Creep-induced displacement produces change in voltage*

Telemetry — *Instrument readings are telemetered via GOES satellite or via HOBO-link*

Acquisition — ***Telemetered voltages and system metrics are streamed from the EROS data center (USGS telemetry via GOES) or fetched from HOBO-link (Bilham installs).***

Data Products

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All data are transcribed to compact binary-format files (‘bottled’) using custom USGS-hosted scripts and workflows

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Local USGS servers

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Data Products

Based on the workflows developed and managed by John Langbein (USGS emeritus) and others

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Data Products — ***Scheduled jobs on local servers access Ascii time-series files to produce web-based creep plots and downloadable time series over various timescales (7, 10, 100 days, ... 10 years).***

Based on the workflows developed and managed by John Langbein (USGS emeritus) and others

Creepmeter Processing Workflow

Field-based	***Measurement***	*Creep-induced displacement produces change in voltage*
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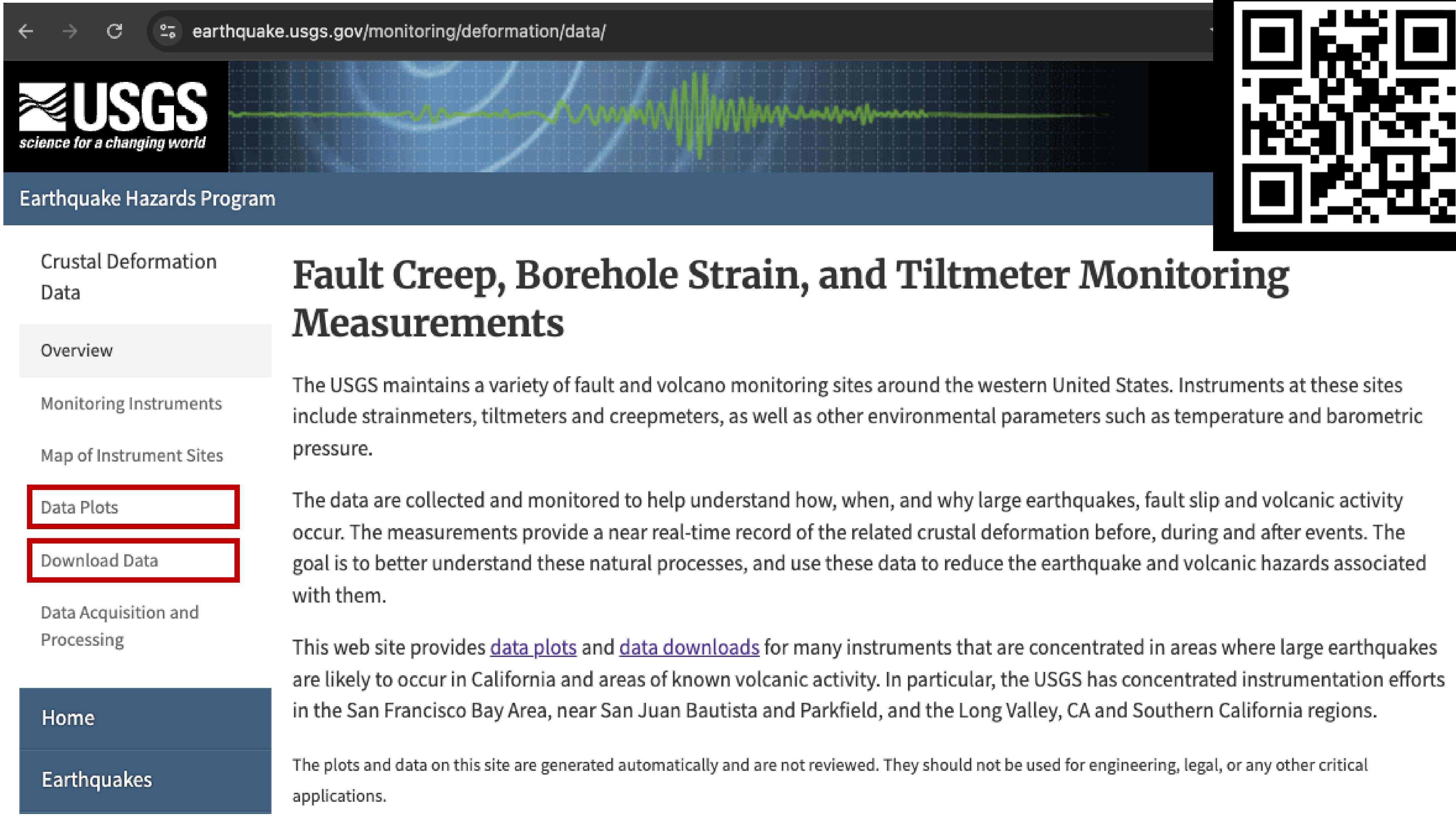
Accessing USGS creepmeter data


earthquake.usgs.gov/monitoring/deformation/data/

USGS
science for a changing world

Earthquake Hazards Program

Crustal Deformation Data

- Overview
- Monitoring Instruments
- Map of Instrument Sites
- Data Plots
- Download Data
- Data Acquisition and Processing

Home

Earthquakes

Fault Creep, Borehole Strain, and Tiltmeter Monitoring Measurements

The USGS maintains a variety of fault and volcano monitoring sites around the western United States. Instruments at these sites include strainmeters, tiltmeters and creepmeters, as well as other environmental parameters such as temperature and barometric pressure.

The data are collected and monitored to help understand how, when, and why large earthquakes, fault slip and volcanic activity occur. The measurements provide a near real-time record of the related crustal deformation before, during and after events. The goal is to better understand these natural processes, and use these data to reduce the earthquake and volcanic hazards associated with them.

This web site provides data plots and data downloads for many instruments that are concentrated in areas where large earthquakes are likely to occur in California and areas of known volcanic activity. In particular, the USGS has concentrated instrumentation efforts in the San Francisco Bay Area, near San Juan Bautista and Parkfield, and the Long Valley, CA and Southern California regions.

The plots and data on this site are generated automatically and are not reviewed. They should not be used for engineering, legal, or any other critical applications.

Web Products (data plots)

Website appearance and data access

Parkfield

Since the Parkfield area is a region of fairly frequent, moderate-sized earthquakes, the USGS installed a variety of instruments that measure strain changes and slip. On September 28, 2004 a Magnitude 6.0 earthquake occurred 11 kilometers southeast of the town of Parkfield. The USGS continues to monitor these instruments to document the deformation prior to, during, and after such events. The role that these earthquakes play in the eventual failure of the locked section of the San Andreas fault just to the south is also of great interest.

Instrument	Plots					
Creepmeters	Past 7 days	Past 30 days	Past 100 days	Past 2 years	Past 3.2 years	Past 10 years
Dilatometers	Past 7 days	Past 30 days	Past 100 days	⊘	⊘	⊘

San Francisco Bay Area

The San Francisco Bay area has been identified in a recent report as a region where a magnitude 6.7 or greater earthquake is likely to occur in the next 30 years. USGS installed a variety of instruments that measure strain changes and fault slip near the many active earthquake faults in the region.

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Creepmeters	Past 7 days	Past 30 days	Past 100 days	Past 2 years	Past 3.2 years	Past 10 years
Dilatometers	Past 7 days	Past 30 days	Past 100 days	⊘	⊘	⊘
DTM Tensor	Past 7 days	Past 30 days	Past 100 days	⊘	⊘	⊘

San Juan Bautista

The San Juan Bautista area covers the junction between the northern end of the creeping section of the San Andreas Fault and the southern section of the (now locked) region of the fault that last ruptured during the great 1906 San Francisco earthquake. The region thus forms a natural laboratory where the processes of stable sliding (creep) and unstable sliding (earthquakes) is closely monitored. Moderate magnitude earthquakes have occurred quite frequently in this region in the past. The largest and most recent event was the 1989 M7.1 Loma Prieta earthquake.

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Data Plots:
https://earthquake.usgs.gov/monitoring/deformation/data/download.php

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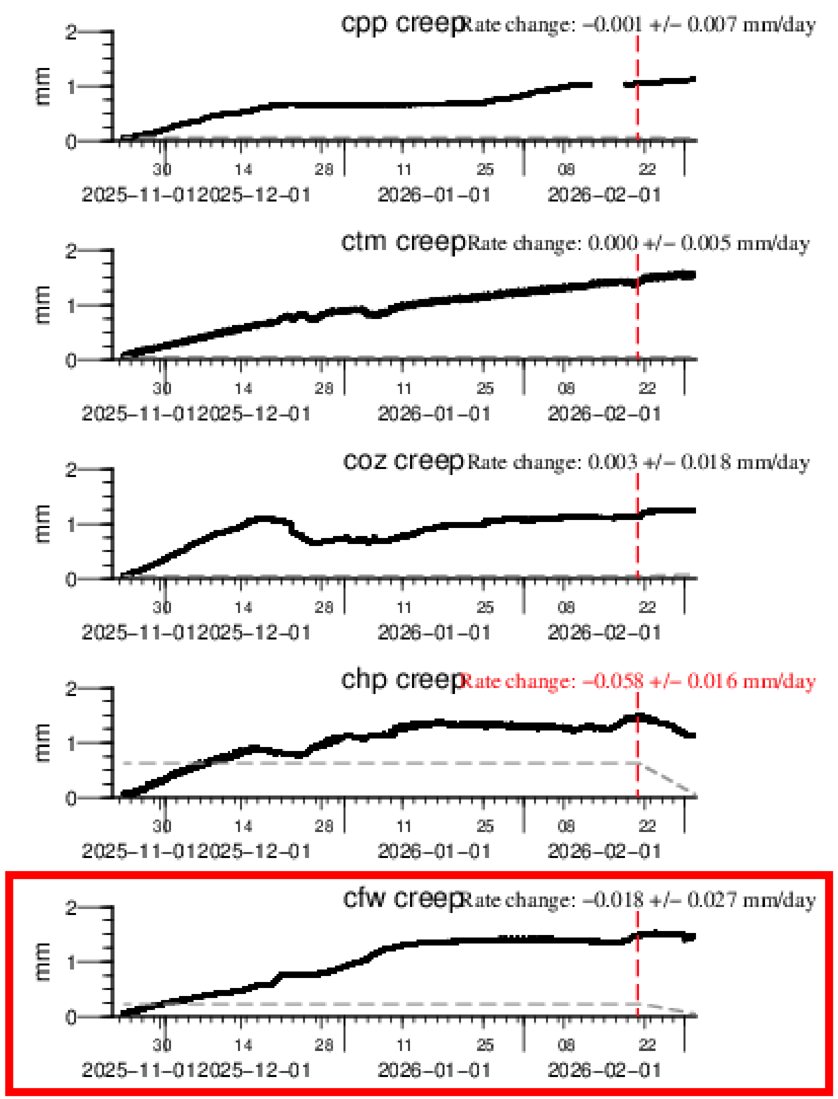
SF Bay Area Creep (past 100 days)



Web Products (data downloads)

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Name	Code	Latitude	Longitude	Initial obs.	Notes	Manual data	10-minute sampling	1-day sampling
Calaveras Fault								
Shore Rd #1	XSH1	36.9430	-121.4450	1971	⬇	⬇	⬇	⬇
Shore Rd #2	SHR2	36.9430	-121.4450	Apr-86	⊘	⬇	⊘	⊘
Hollister Central	HLC1	36.8570	-121.4050	Apr-70	⊘	⬇	⊘	⊘
Hollister D St	HLD1	36.8420	-121.4030	Apr-70	⊘	⬇	⊘	⊘
Hayward Fault								
Pt Pinole	CPP1	37.9900	-122.3560	Aug. 1995	⬇	⊘	⬇	⊘
Temescal	CTM1	37.8440	-122.2270	Mar. 1997	⬇	⊘	⬇	⊘
Oakland Zoo	COZ1	37.7530	-122.1500	Nov. 1996	⬇	⊘	⬇	⊘
Hayward, Rose St #1	HWR1	37.6800	-122.0920	Apr-68	⊘	⬇	⊘	⊘
Hayward, Rose St #2	HWR2	37.6800	-122.0920	Apr-68	⊘	⬇	⊘	⊘
Hayward, D St #1	HWE1	37.6700	-122.0800	Apr-68	⊘	⬇	⊘	⊘
Hayward, D St #2	HWW1	37.6700	-122.0800	Apr-68	⊘	⬇	⊘	⊘
Hayward, Palisades St #1	HWP1	37.6630	-122.0740	Apr-68	⊘	⬇	⊘	⊘
Hayward, Palisades St #2	CHP1	37.6630	-122.0740	Apr-94	⬇	⊘	⬇	⊘
Fremont Winery	CFW1	37.5320	-121.9520	Dec. 1993	⬇	⊘	⬇	⊘

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Hayward, Rose St #2	HWR2	37.6800	-122.0920	Apr-68	⊘	↓	⊘	⊘
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Fremont Winery	CFW1	37.5320	-121.9520	Dec. 1993	↓	⊘	↓	⊘

Downloaded data - examples

CFW1 - 10 minute sampling

Yr	Jd	Offset	....
2026	56.771527778	215.80100	0.100
2026	56.772222222	215.80100	0.100
2026	56.772916667	215.80100	0.100
2026	56.773611111	215.80000	0.100
2026	56.774305556	215.80000	0.100
2026	56.775000000	215.80100	0.100
2026	56.775694444	215.80100	0.100
2026	56.776388889	215.80100	0.100
2026	56.777083333	215.80100	0.100
2026	56.777777778	215.80100	0.100
2026	56.778472222	215.80100	0.100
2026	56.779166667	215.80100	0.100
2026	56.779861111	215.80100	0.100
2026	56.780555556	215.80100	0.100
2026	56.781250000	215.80100	0.100
2026	56.781944444	215.80100	0.100
2026	56.782638889	215.80100	0.100
2026	56.783333333	215.80100	0.100
2026	56.784027778	215.80200	0.100
2026	56.784722222	215.80100	0.100
2026	56.785416667	215.80100	0.100
2026	56.786111111	215.80100	0.100
2026	56.786805556	215.80100	0.100
2026	56.787500000	215.80100	0.100
2026	56.788194444	215.80100	0.100
2026	56.788888889	215.80100	0.100
2026	56.789583333	215.80100	0.100

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Downloaded data - examples

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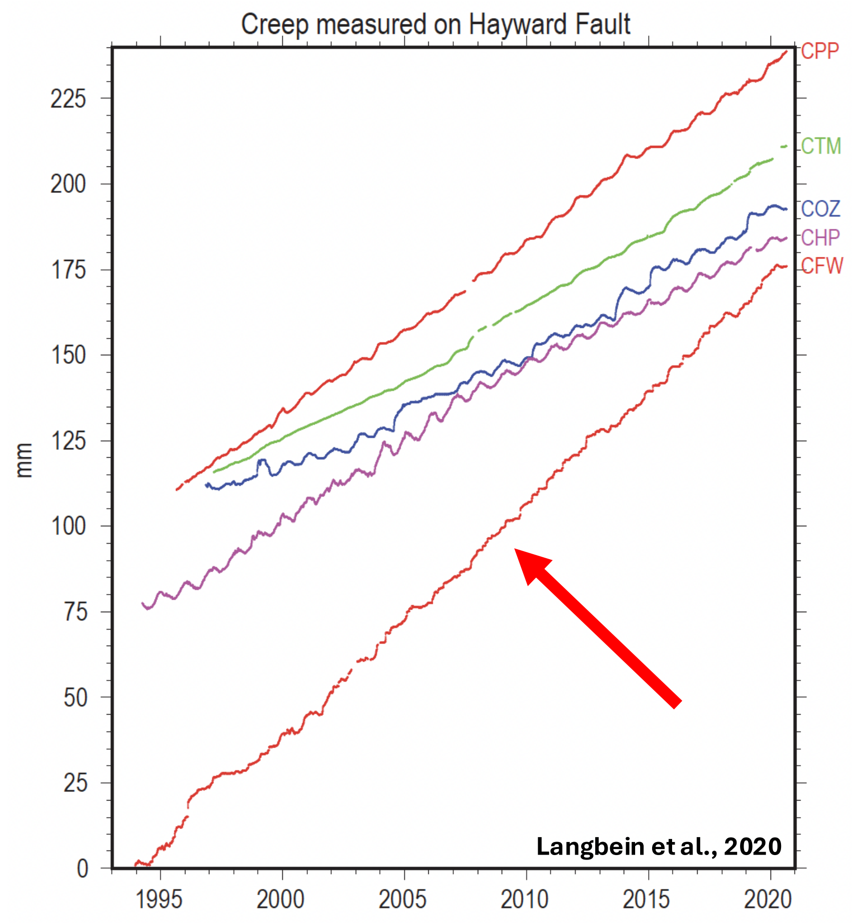

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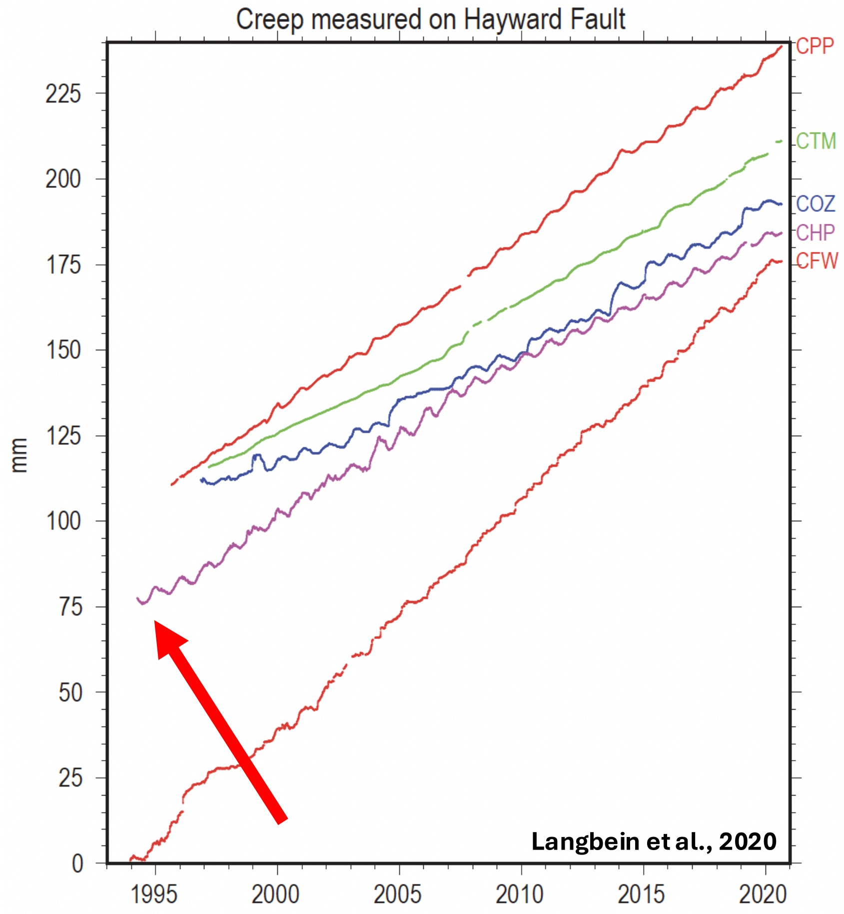
Shore Rd #1	XSH1	36.9430	-121.4450	1971	⬇	⬇	⬇	⬇
Shore Rd #2	SHR2	36.9430	-121.4450	Apr-86	⊘	⬇	⊘	⊘
Hollister Central	HLC1	36.8570	-121.4050	Apr-70	⊘	⬇	⊘	⊘
Hollister D St	HLD1	36.8420	-121.4030	Apr-70	⊘	⬇	⊘	⊘
Hayward Fault								
Pt Pinole	CPP1	37.9900	-122.3560	Aug. 1995	⬇	⊘	⬇	⊘
Temescal	CTM1	37.8440	-122.2270	Mar. 1997	⬇	⊘	⬇	⊘
Oakland Zoo	COZ1	37.7530	-122.1500	Nov. 1996	⬇	⊘	⬇	⊘
Hayward, Rose St #1	HWR1	37.6800	-122.0920	Apr-68	⊘	⬇	⊘	⊘
Hayward, Rose St #2	HWR2	37.6800	-122.0920	Apr-68	⊘	⬇	⊘	⊘
Hayward, D St #1	HWE1	37.6700	-122.0800	Apr-68	⊘	⬇	⊘	⊘
Hayward, D St #2	HWW1	37.6700	-122.0800	Apr-68	⊘	⬇	⊘	⊘
Hayward, Palisades St #1	HWP1	37.6630	-122.0740	Apr-68	⊘	⬇	⊘	⊘
Hayward, Palisades St #2	CHP1	37.6630	-122.0740	Apr-94	⬇	⊘	⬇	⊘
Fremont Winery	CFW1	37.5320	-121.9520	Dec. 1993	⬇	⊘	⬇	⊘

Downloaded data - examples

CHP1 - 10 minute sampling



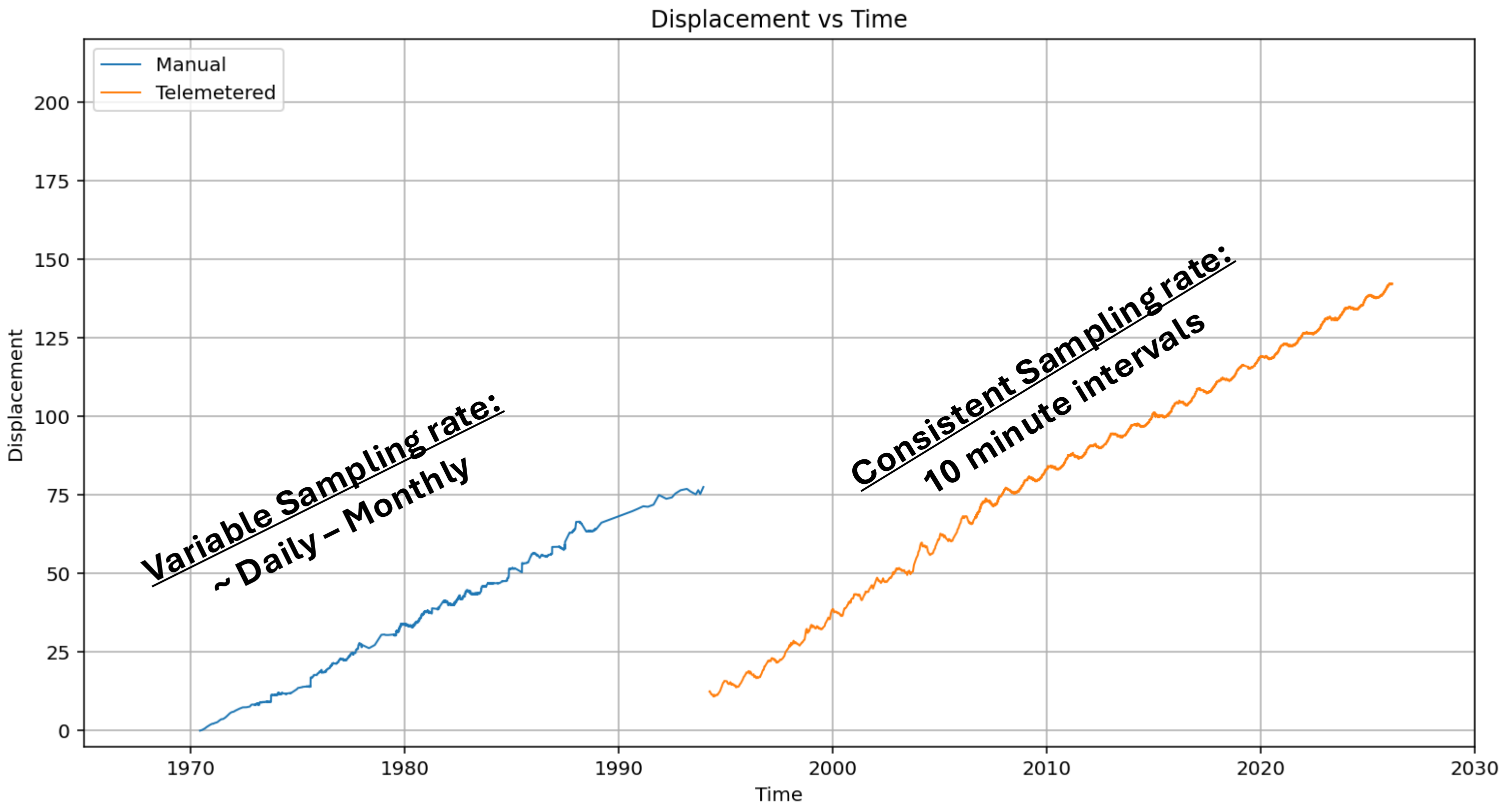
Data Downloads:
https://earthquake.usgs.gov/monitoring/deformation/data/download.php

Hayward Fault Creep – Palisades St

<u>The Hayward fault: hiding in plain site</u>

Hayward Fault Creep – Palisades St

The Hayward fault: hiding in plain site



Sampling rates evolve as instrumentation / telemetry capabilities advance.

Hayward Fault Creep – Palisades St

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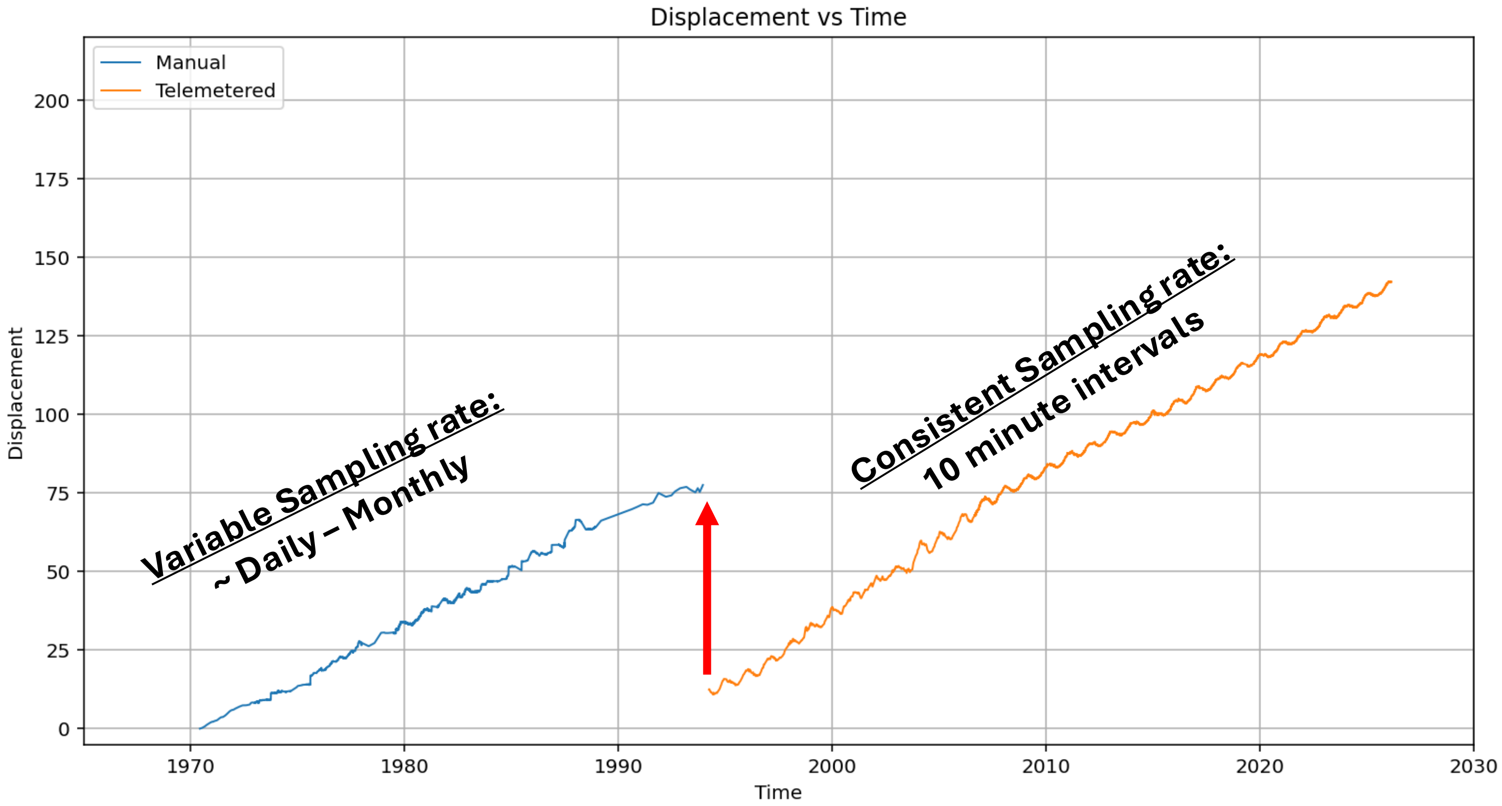

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Cumulative creep displacement since installation can be reconstructed by integrating relative creep measurements from successive instruments.

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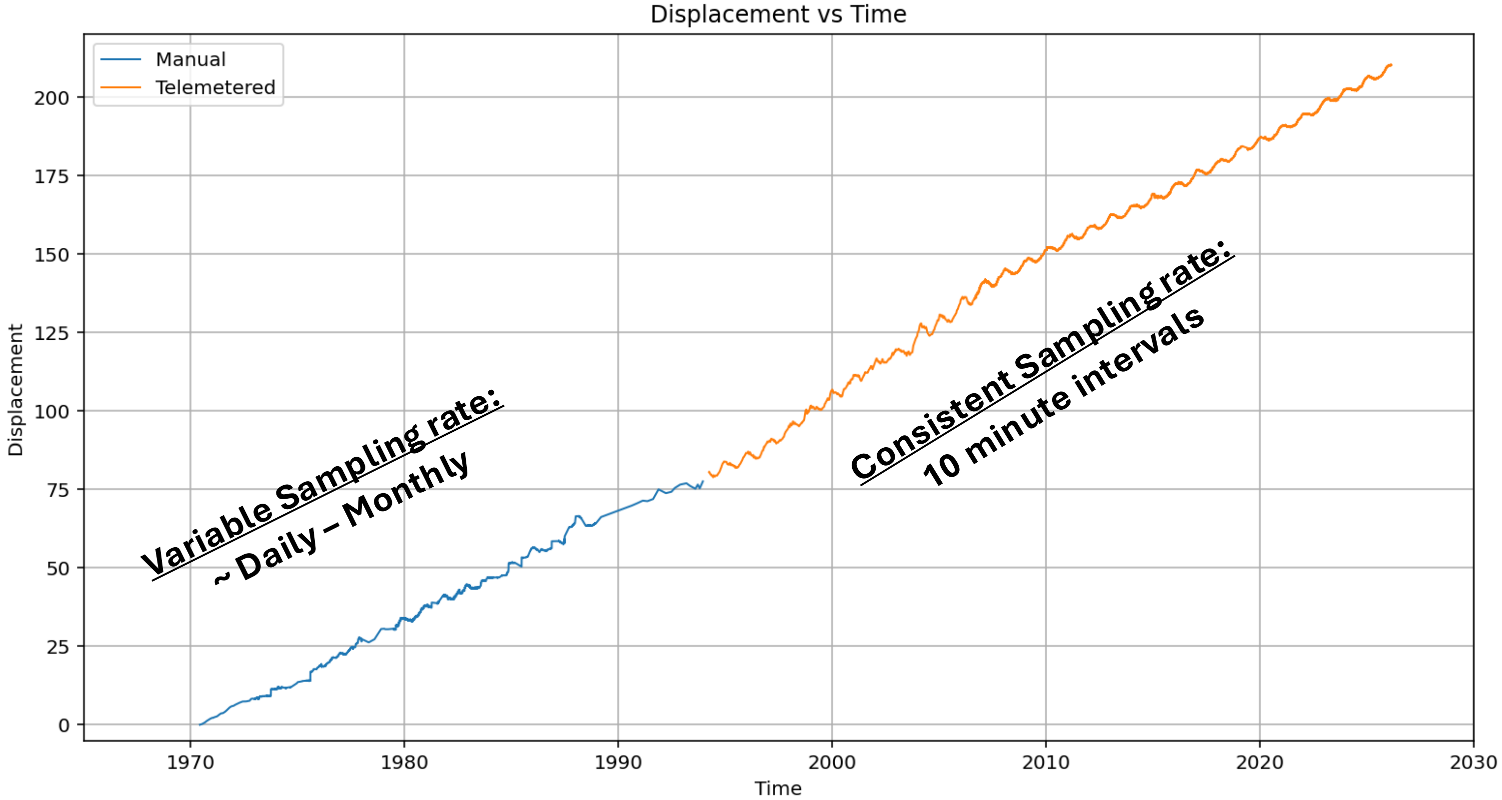

Sampling rates evolve as instrumentation / telemetry capabilities advance.

Cumulative creep displacement since installation can be reconstructed by integrating relative creep measurements from successive instruments.

Generational shifts in metadata standards are easily managed individually, but incremental changes increase storage, processing and reporting complexity that compounds over time.

Creepmeter Processing Workflow

Field-based

Measurement

Telemetry

Acquisition

Local USGS servers

Processing

USGS webpage

Data Products

Based on the workflows developed and managed by John Langbein (USGS emeritus) and others

Creepmeter Processing Workflow

Field-based	*Measurement*
	Telemetry
	Acquisition
Local USGS servers	
	Processing
USGS webpage	*Data Products*

High-precision creepmeter measurements require rigorous metadata organization, documentation, and long-term stewardship.

Archival demands continue to expand as instrument networks evolve, telemetry systems change, and data volumes grow.

The existing USGS processing and access infrastructure is aging and increasingly difficult to sustain.

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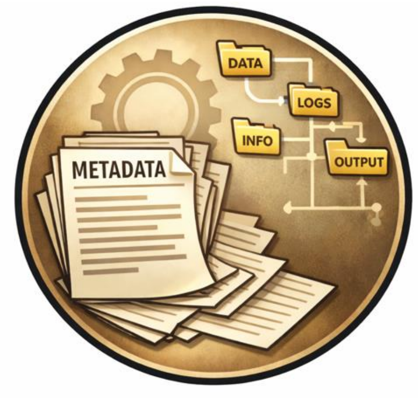
Strained Growth



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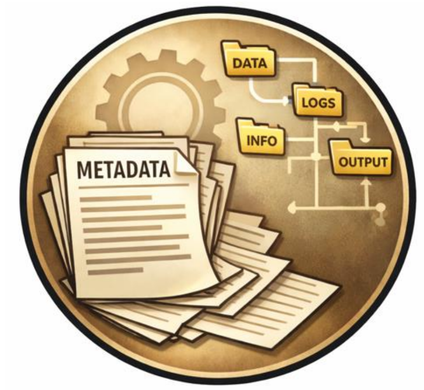

Server Obsolescence

Based on the workflows developed and managed by John Langbein (USGS emeritus) and others

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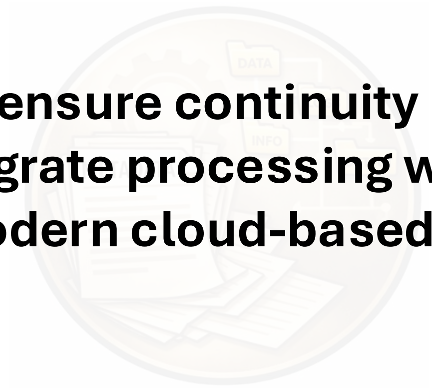

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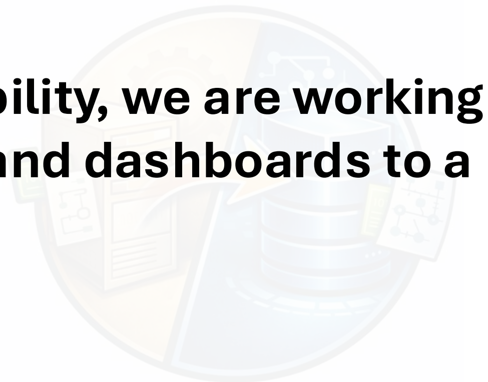

To ensure continuity and scalability, we are working to migrate processing workflows and dashboards to a modern cloud-based platform.

Based on the workflows developed and managed by John Langbein (USGS emeritus) and others

Migrating processing workflows and data storage to the cloud

USGS science for a changing world

EarthScope Consortium

<u>MAIN GOAL</u>: **Develop a cloud-based platform that allows for standardized data access, metadata handling and storage, and data archival procedures for creepmeter processing workflows and data.**

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<u>Flexible, cloud-based data containers</u>

[tile]DB

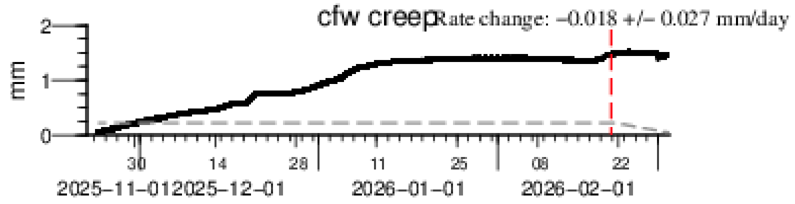
- *A high-performance multidimensional array database designed for large scientific datasets*
- *Supports both dense and sparse arrays, enabling efficient storage of regular grids and irregular data*
- *Cloud native and optimized for parallel IO, chunked storage, and selective data slicing*
- *A scalable data storage option with database style querying capabilities*

Migrating processing workflows and data storage to the cloud

MAIN GOAL: Develop a cloud-based platform that allows for standardized data access, metadata handling and storage, and data archival procedures for creepmeter processing workflows and data.

Modernize and improve the user-facing data access dashboard to facilitate data accessibility and simple pre-analysis visualization and monitoring.

Tentative Improvements to Monitoring and Access Dashboards



e.g., moving from static to interactive plots

- *Dynamic, interactive monitoring dashboard*

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Tentative Improvements to Monitoring and Access Dashboards

Name	Code	Latitude	Longitude	Initial obs.	Notes	Manual data	10-minute sampling	1-day sampling
Fremont Winery	CFW1	37.5320	-121.9520	Dec. 1993	⬇	⊘	⬇	⊘

Instrument details are currently published in Official File Reports and site-specific studies.

- *Dynamic, interactive monitoring dashboard*
- *Consolidated site and metadata reporting and visibility*
    - *Installation details, instrument specifications, and site information*
    - *Instrument state-of-health and expected deployment duration*

Cloud Migration Timeline - Officially Underway!

Shallow Fault Displacement Data: Consolidation and Archiving

Objectives:

1. **Gather archived USGS creepmeter data (raw voltages, metadata, and processed displacements).**
2. Develop a metadata scheme to support data from the shallow fault displacement instruments in operation by the USGS, in particular creepmeters and inclinometers.
3. Develop a modern cloud-friendly data and metadata container (e.g. TileDB) for shallow faulting data.
4. Extract, transfer and load archival creepmeter data into the data container.
5. Archive creepmeter data

Project End-date: September, 2027

6. Develop connectors to automatically receive real-time telemetered data from Onset and Campbell Scientific data loggers and the GOES Data Collection System. *Note: This proposal does not cover field or communications costs of*

(migration may finish sooner)

7. Develop monitoring and/or access dashboards.
8. If resources allow, analyze Langbein's Fortran-based processing code and convert into a modernized, well-documented language/workflow for processing real-time data into displacements.

Cloud Migration Timeline - Officially Underway!

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Conclusions

1. The USGS is in the process of migrating creepmeter data and processing workflows to a cloud-based platform through collaboration with EarthScope. User-facing data access dashboards on USGS pages will also be updated.

2. New cloud-based data containers are flexible storage solutions that will offer standardized data access, metadata storage, and archival for creepmeter data and other measurement records (e.g., strain meters and tilt meters).

3. This new system can be adapted to process and store new data types as technologies and measurement techniques advance.

Contact: cbaden@usgs.gov