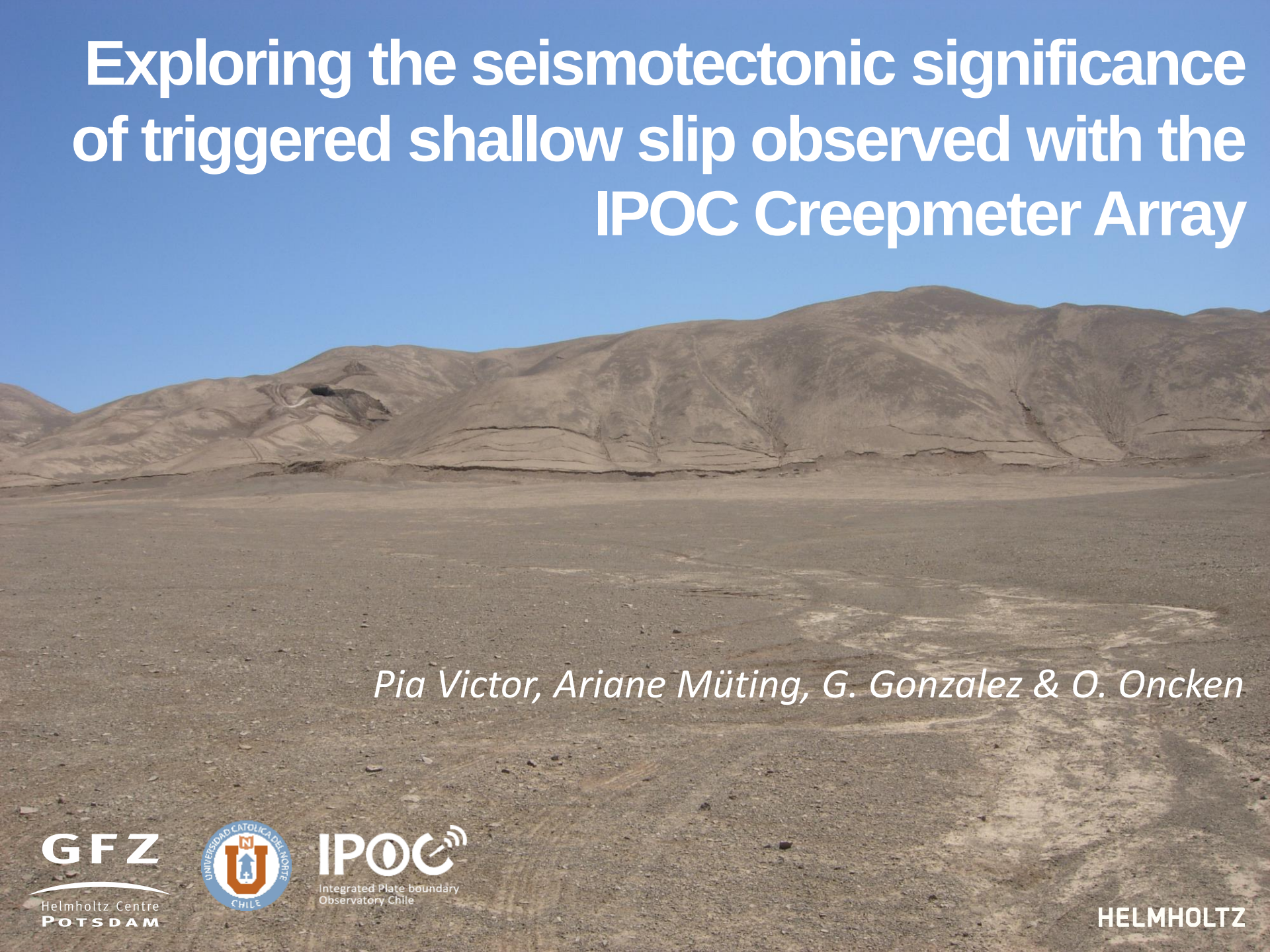
Exploring the seismotectonic significance of triggered shallow slip observed with the IPOC Creepmeter Array



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San Andreas Fault – Atacama Fault System

Surface rupture caused by the 2010 El Mayor-Cucapah EQ in Baja California, Mexico (photo: . Rockwell)

Surface rupture caused by a prehistoric EQ on the Salar del Carmen Segment of the AFS.

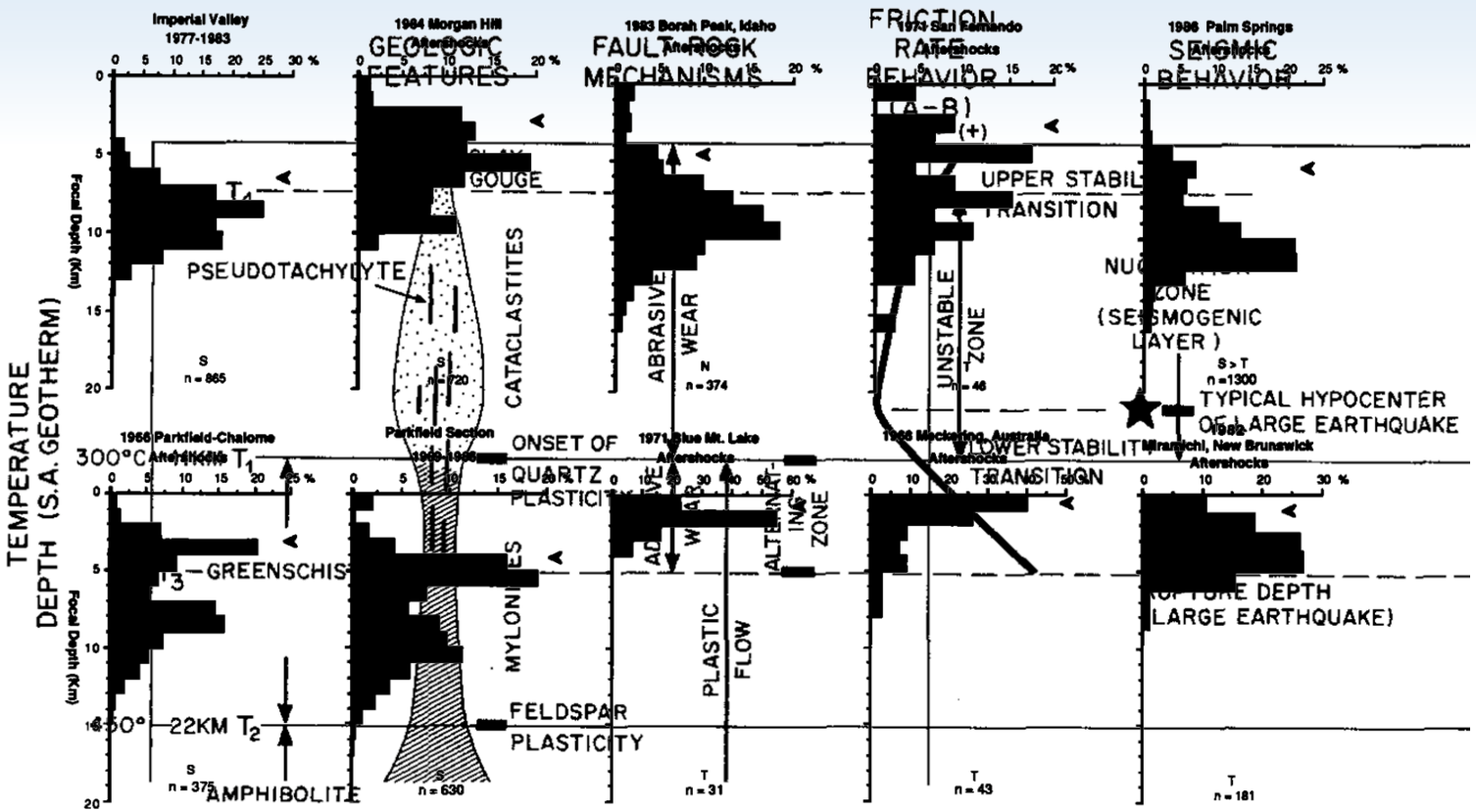
- Plate Boundary Fault
- Localized seismicity on fault plane
- High slip rates (< 40 mm/yr)

- Triggered Slip
- Surface Breaks

- Trench linked fault zone
- Upper plate seismicity absent, very little around one segment
- Very low slip rates (< 1mm/yr)

- Triggered Slip
- Surface Breaks

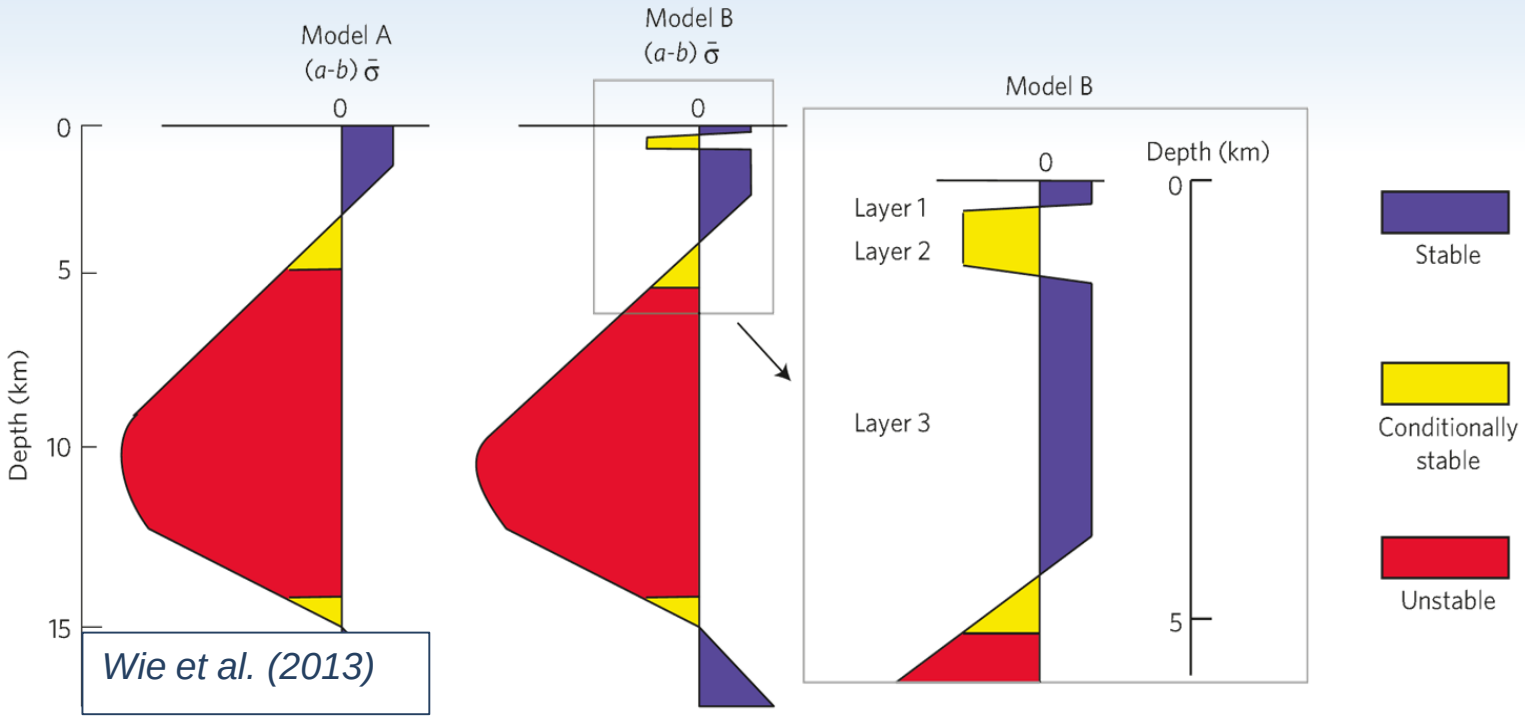
Synoptic shear zone model



Common assumption: Faults creep close to the earths‘ surface due to low confining pressure and clay rich fault gouge (Scholz, 1988).

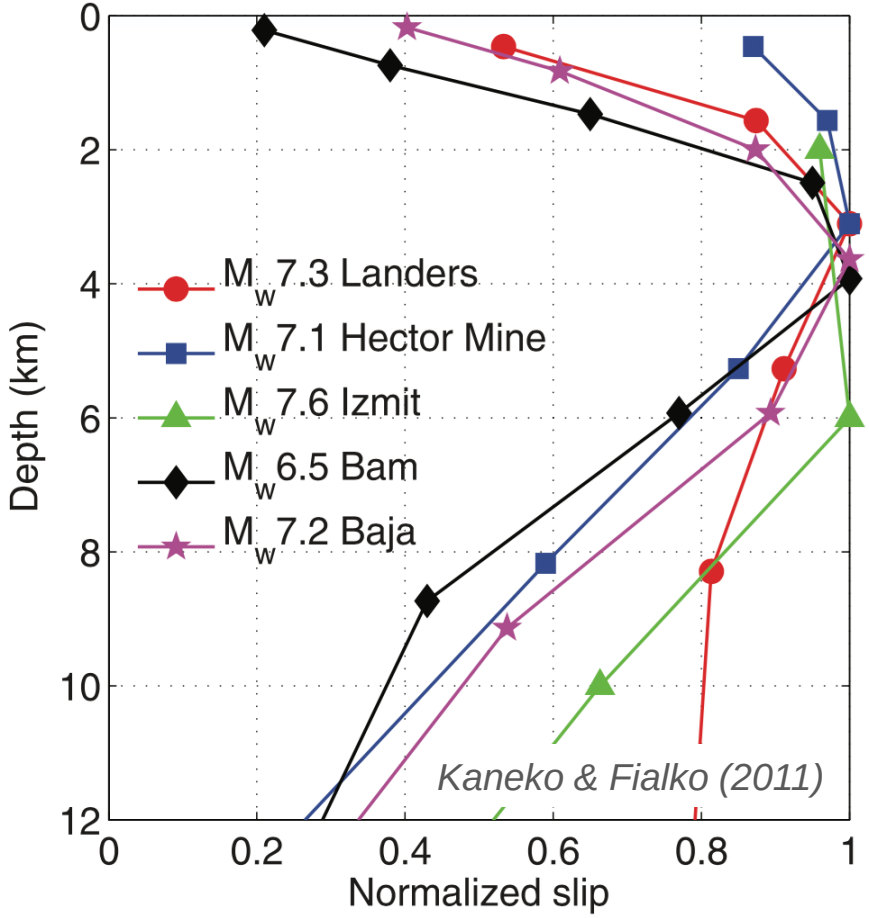
➡ The normal stress argument is not consistent with this observation (Marone & Scholz, 1988).

Shallow frictional heterogeneity



Geodetic observations from strike slip faults in California show a large variability in shallow slip behaviour. Numerical models show that this behaviour is best reproduced if an additional unstable layer is embedded within the stable zone. This layer results from fine scale lithological heterogeneities

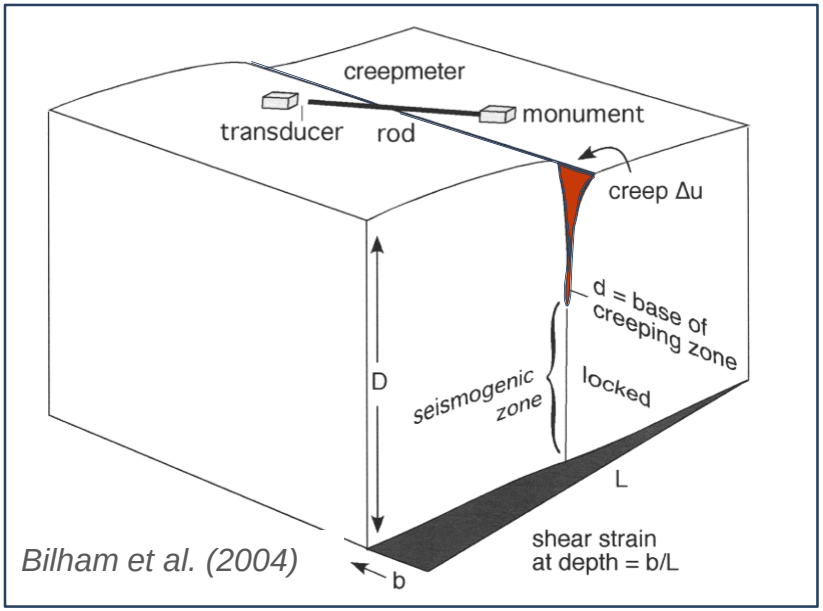
Existence of Shallow Slip Deficit



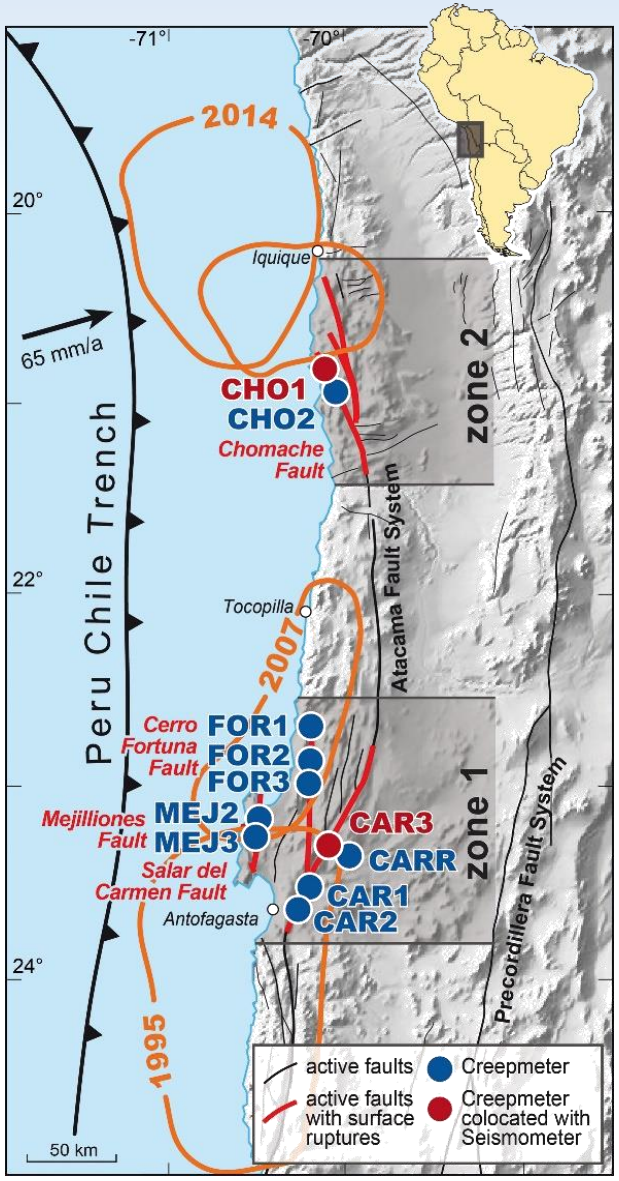
- Coseismic slip decreases sharply towards the earth surface
- Consistent with lab experiments showing that uppermost levels of the crust are velocity strengthening
- Deficit needs to be compensated by afterslip or interseismic creep
- **But** this is not observed for investigated examples

How can we we contribute with Creepmeter observations ?

- **Observation of shallow triggered slip events**
- **Investigation of decomposed creepmeter time series**
- **Integration of creepmeter data and field data to infer properties of shallow slip**



IPOC Creepmeter Array



Length : < 10 m

Sampling Rate: 2/min

Time Scale: 10^1 years

Resolution: 1 µm

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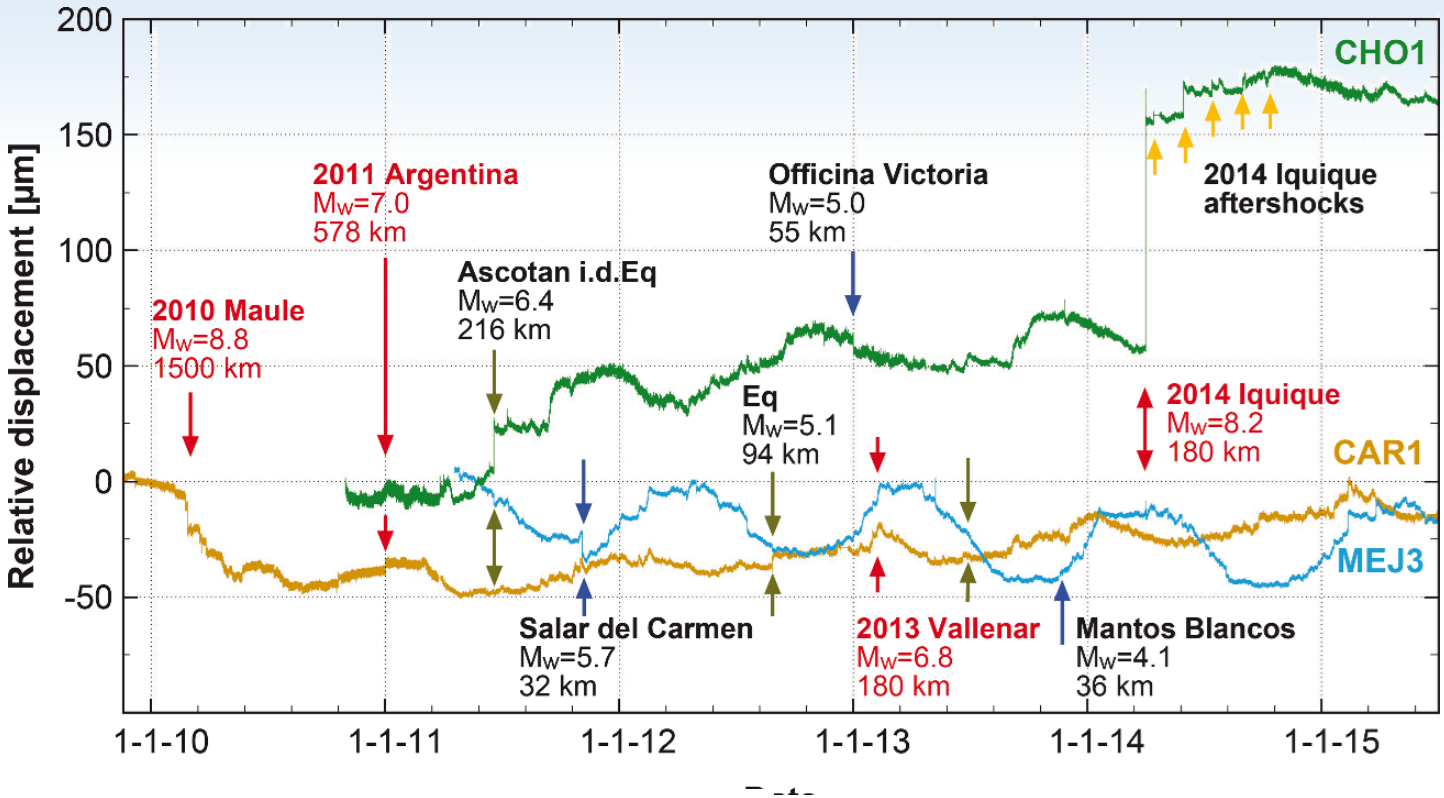
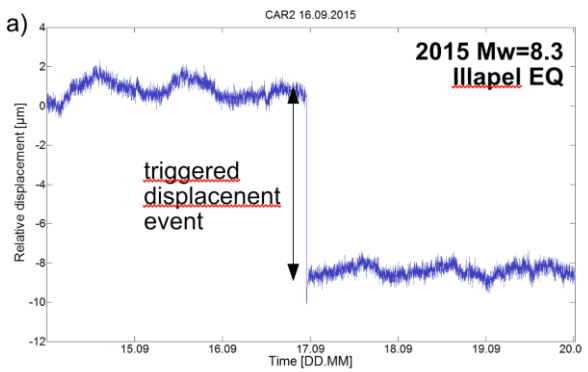
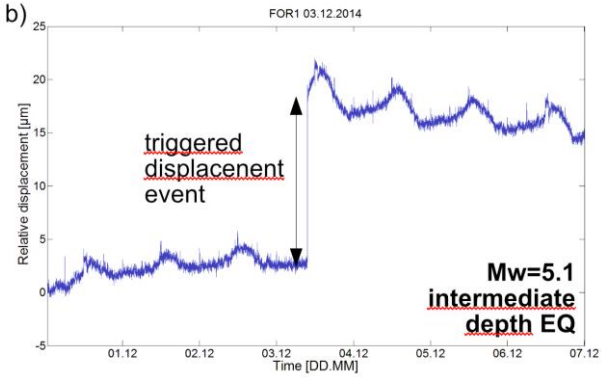
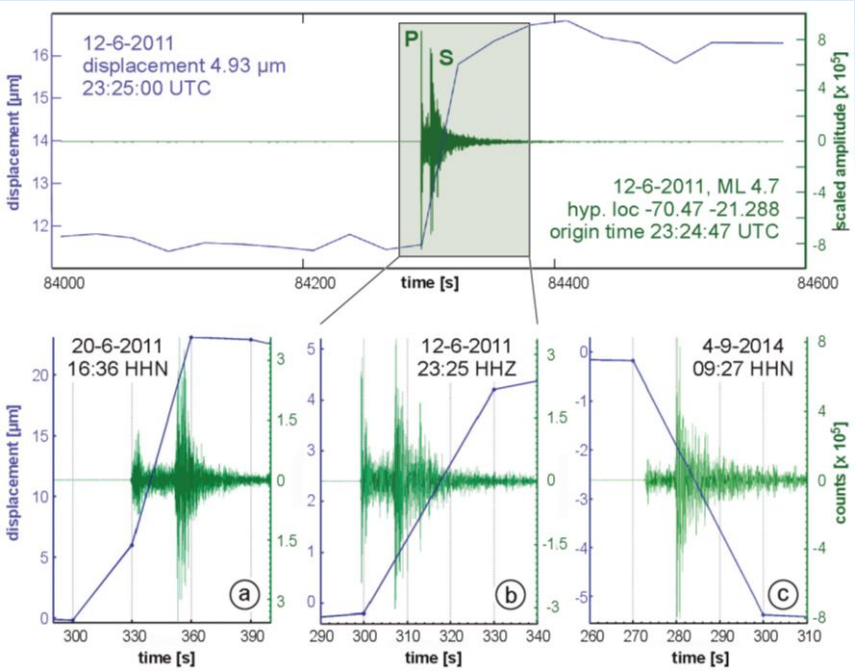
Time Series from IPOC Creep







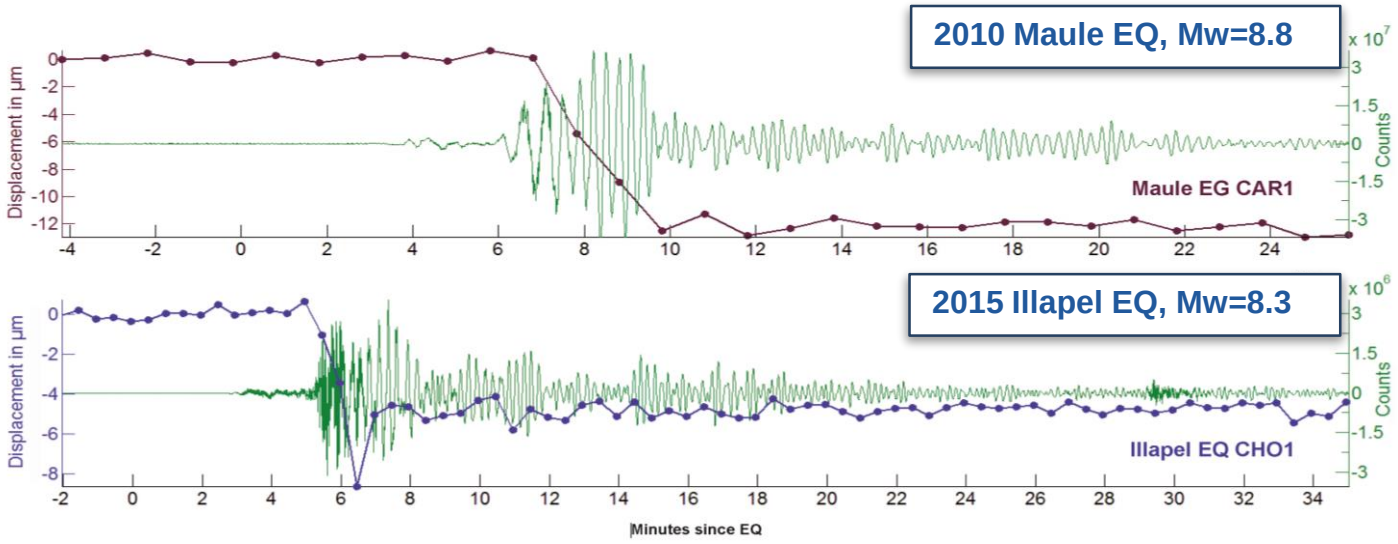
SDEs Document Dynamic Triggering



1 **Triggering of shallow slip by EQ in the vicinity**

slip velocity
0,0002 mm/sec

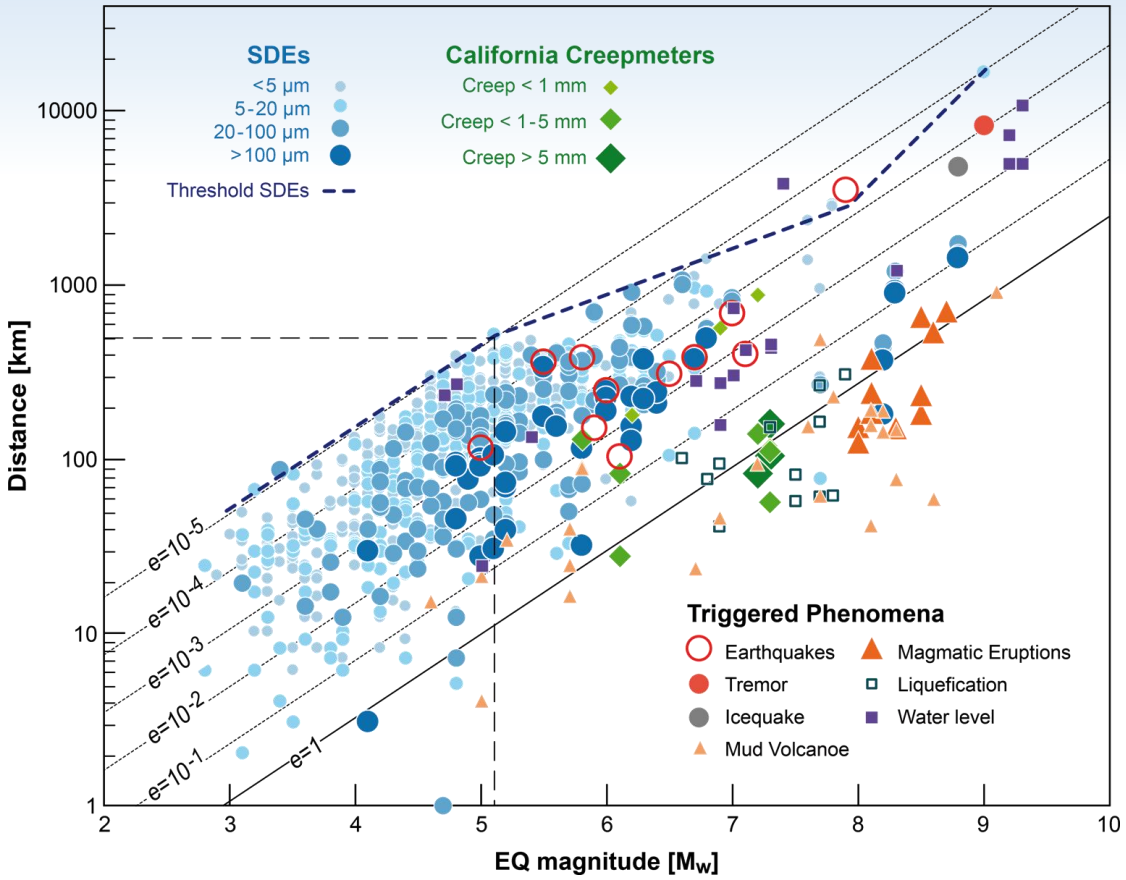
2 **Remote triggering of shallow slip**



slip velocity
0,00006 mm/sec

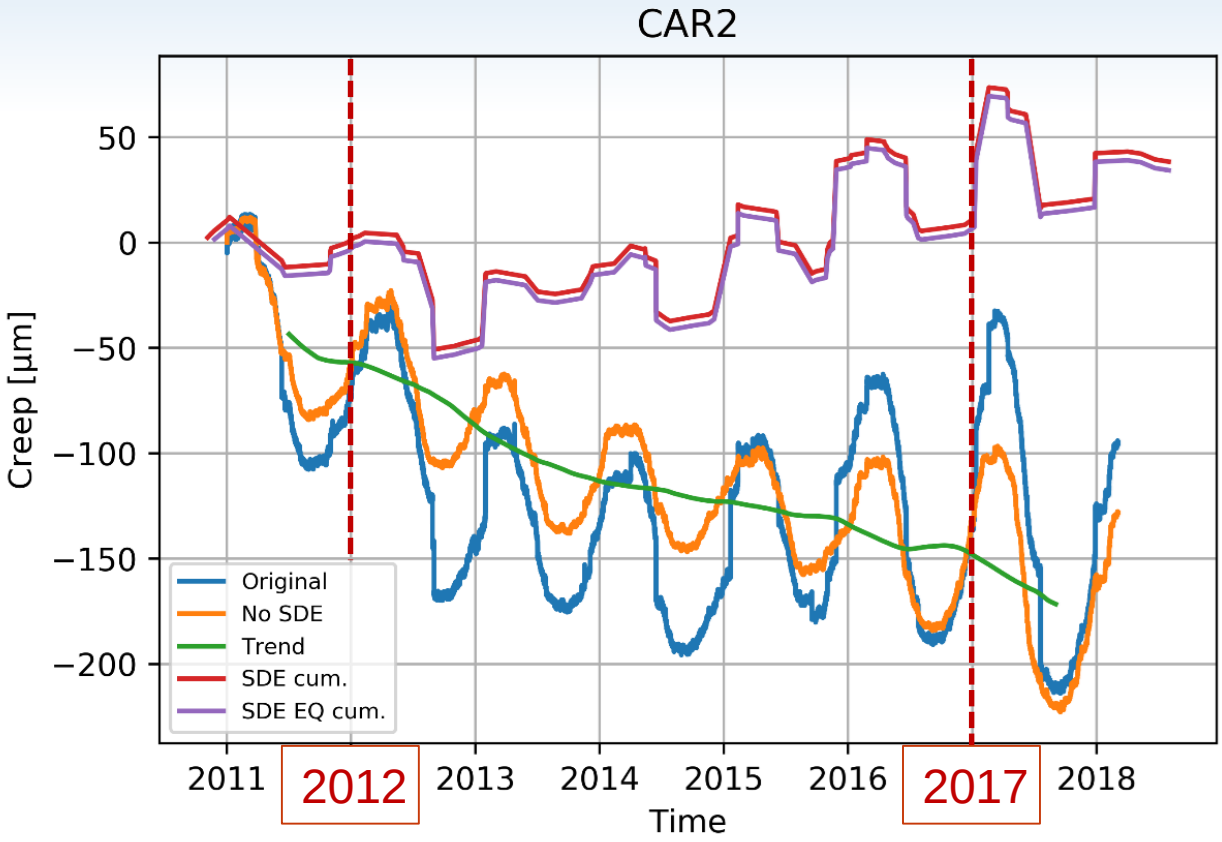
slip velocity
0,004mm/sec

Scaling Relation of SDEs



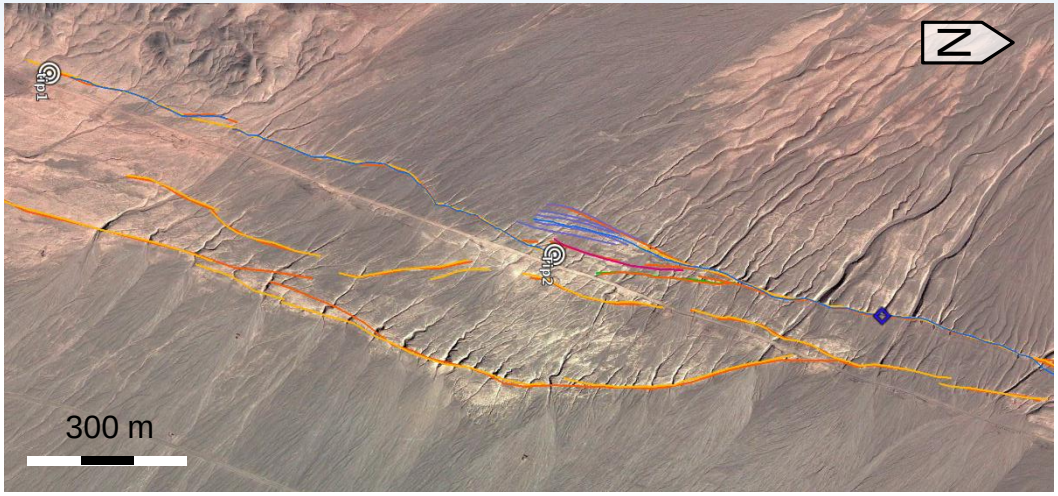
Triggered shallow slip observed on IPOC Creepmeters scale with seismic energy density and compare well with triggered slip observed on California Creepmeters. Both follow the same seismic energy density contours as other triggered phenomena.

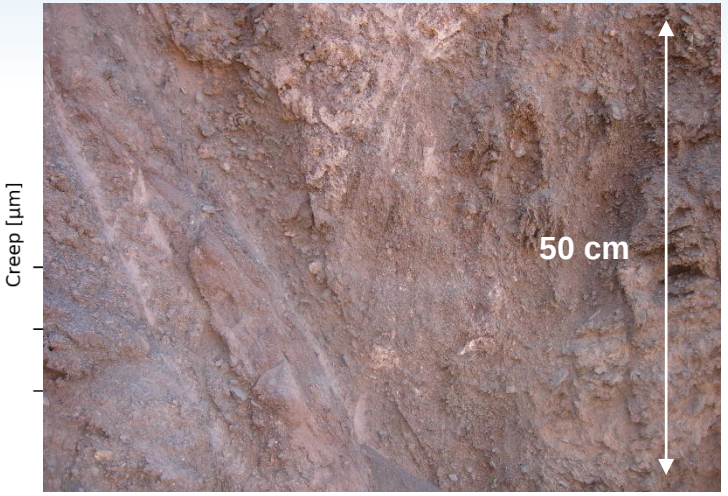
Creep Trend and SDEs - Salar del Carmen



Salar del Carmen Fault shows slow extensional trend after seasonal correction (190 μm) and little cumulative net slip from SDEs due to opposite sign in movement direction.

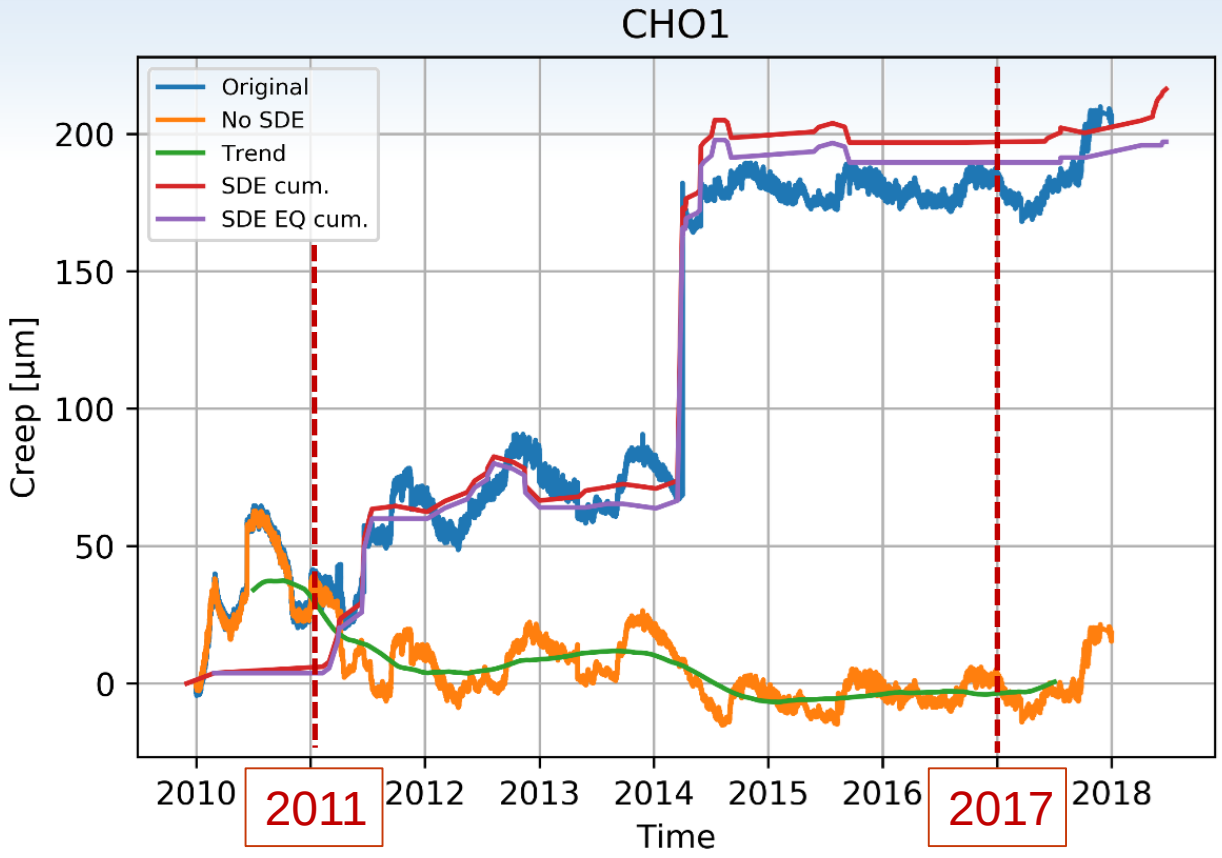
Geological slip rates and properties Salar del Carmen





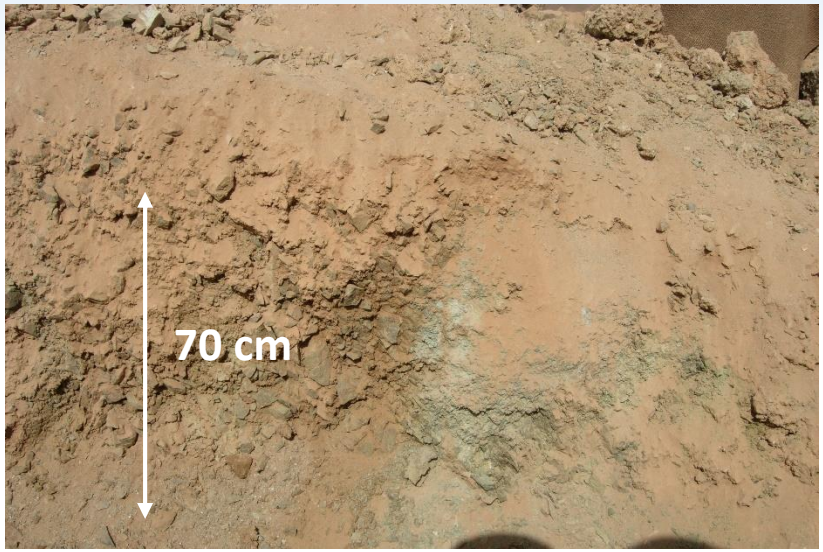
- Localized fault
- Lithified alluvial fan
- Fault gouge developed
- Fault Zone width >10 cm
- Long term slip rate 0.1 – 0.2 mm/yr

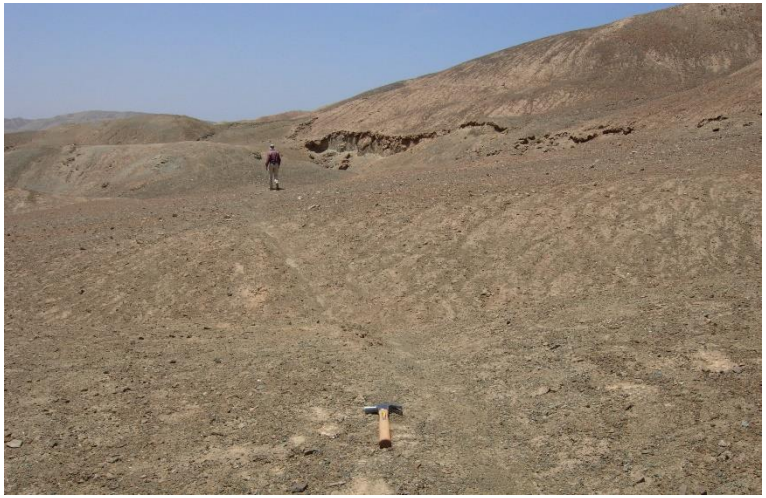
Creep Trend and SDEs - Chomache



Chomache Fault does not show a significant continuous trend after seasonal correction but accumulation of slip (200 µm contraction) from SDEs mainly from Iquique EQ and its aftershocks.

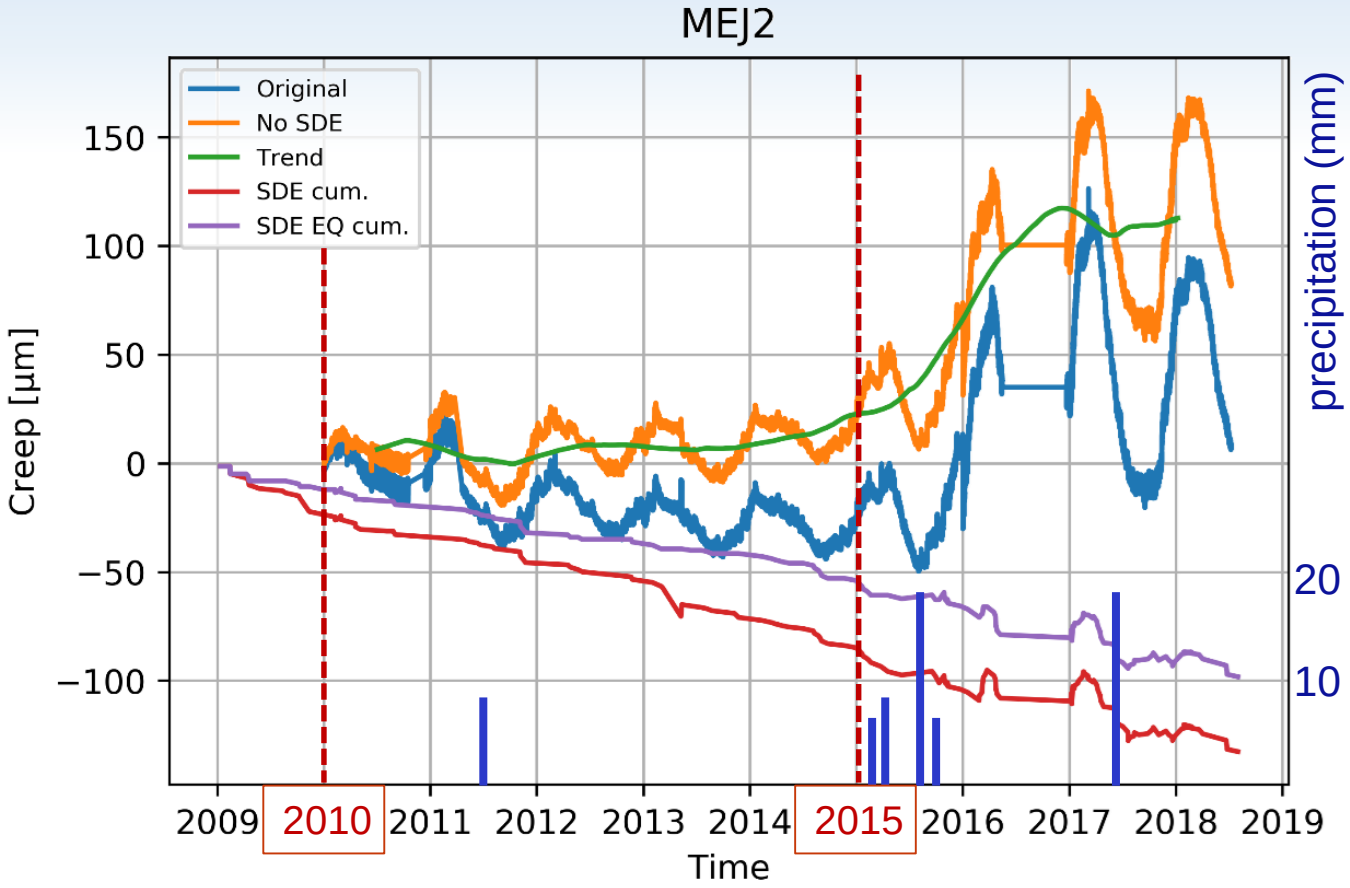
Geological slip rates and properties Chomache





- Localized fault zone
- Bedrock fault scarp
- No fault gouge
- Fault Zone width: < 30 cm
- Slip rate 0.1 – 0.2 mm/yr
- Upper plate seismicity

Creep Trends and SDEs - Mejillones



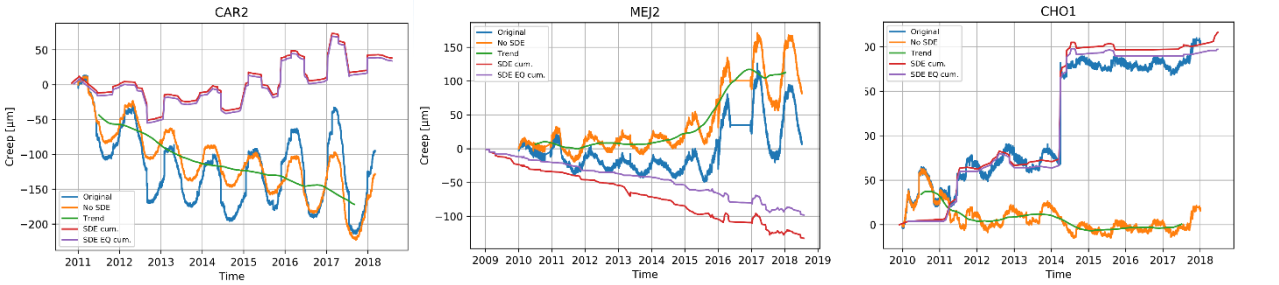
2010-2015: No significant continuous trend after seasonal correction but accumulation of SDEs (80 µm extension). After rainfall in 2015 contractional creep transient and change in SDEs.

Geological slip rates and properties Mejillones Fault

- Well localized fault scarp
- Crosscuts unconsolidated alluvial fan in the upper (< 100 m) meters
- Main fault contact is bedrock/alluvial fan
- No fault gouge
- Fault Zone width < 1 cm
- Slip rate 0.6 mm/yr

Concluding Remarks

Salar del Carmen | Mejillones | Chomache



Velocity strengthening ⟷ **Velocity weakening**

- **Velocity weakening behaviour is observed for shallow slip on AFS on different time scales**
- **A broad frictional instability is inferred from creepmeter time series consistent with prehistoric surface ruptures and triggered slip events**
- **We observe a large variability in shallow fault slip behaviour that is consistent with field observations**