Comparing permanent deformation and seismic asperities in the 2015 Illapel earthquake rupture zone

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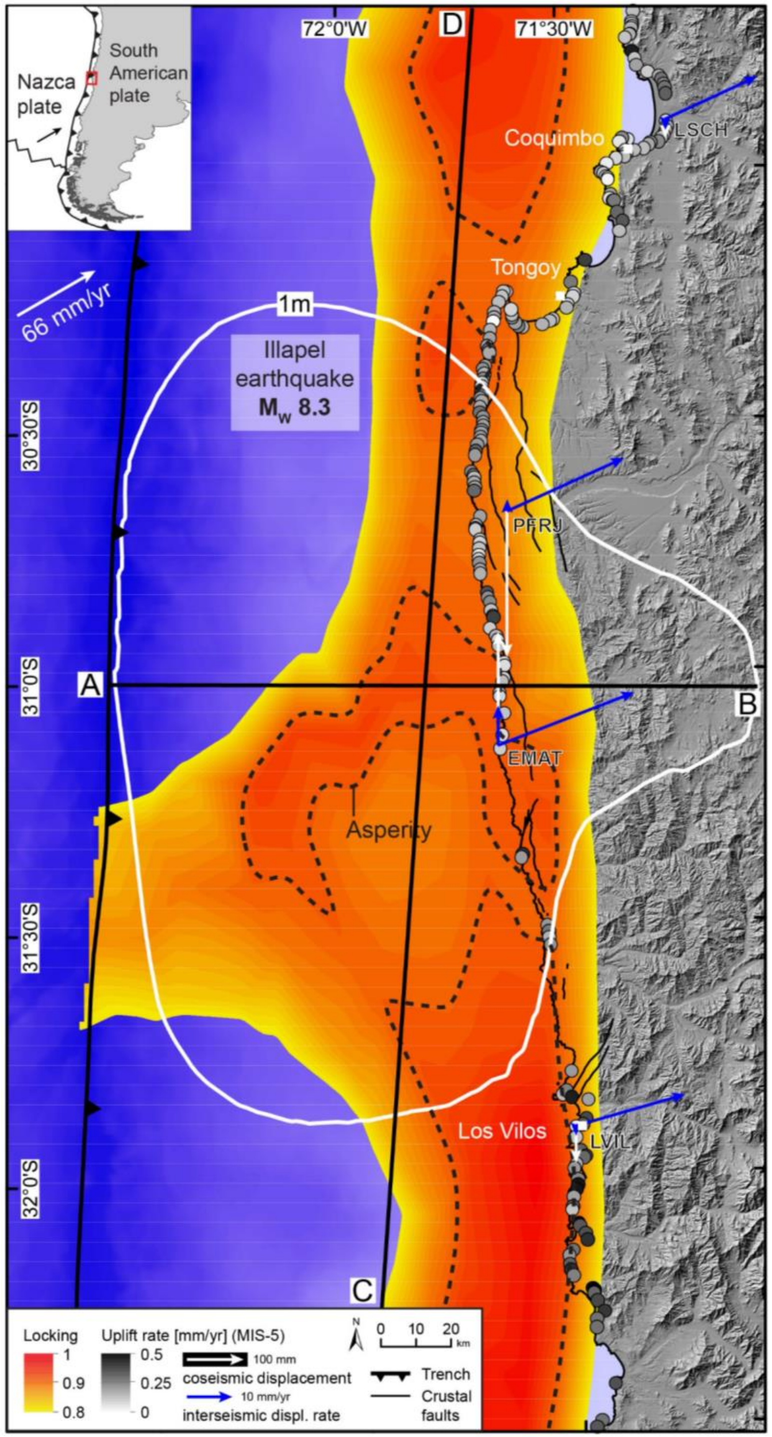
Giant subduction earthquakes: non-uniform slip distribution, regions of pronounced slip → asperities

Asperities: persistent geologic features **or** the cause for dynamic processes of elastic strain release?

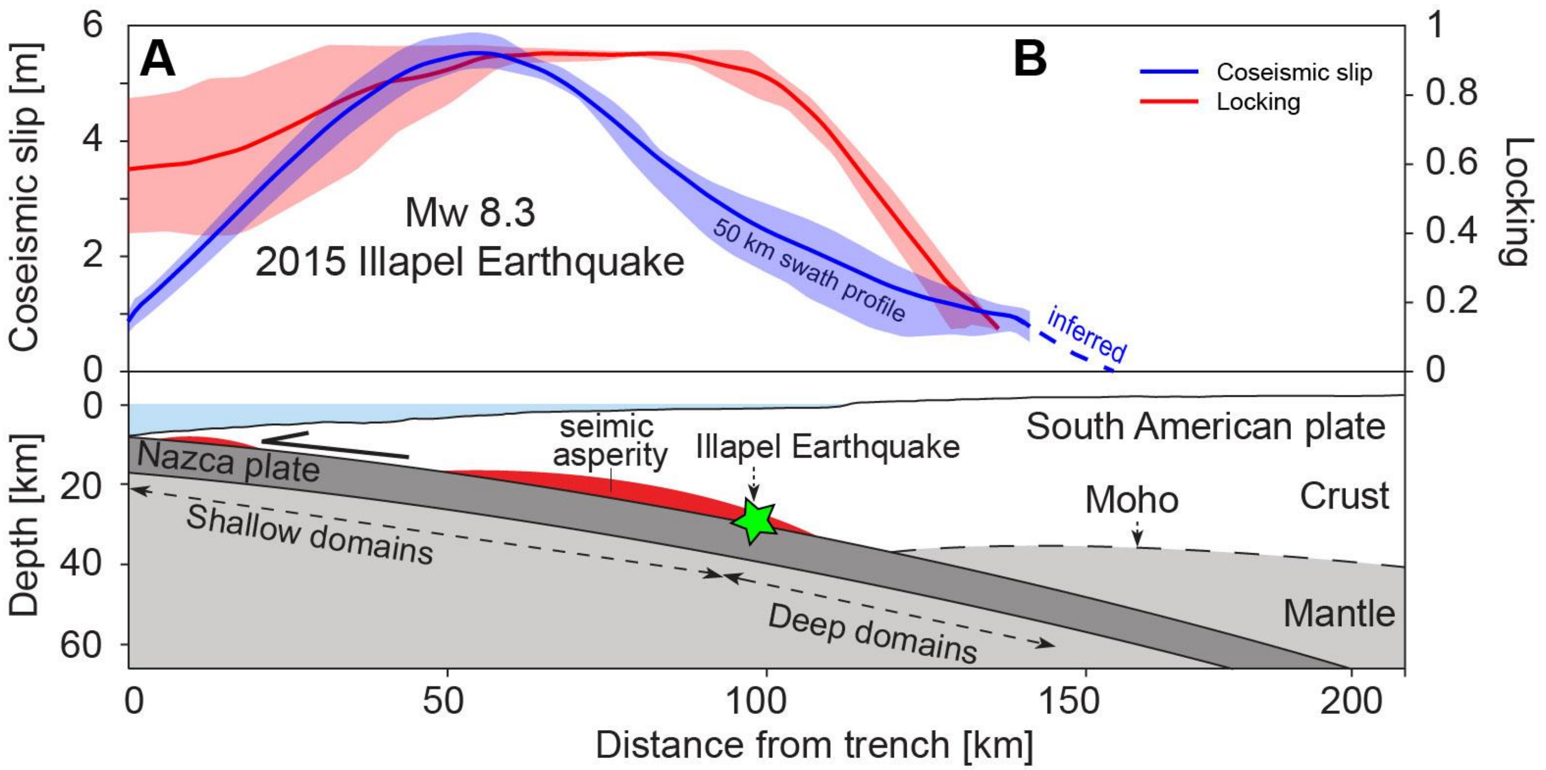
Study seismic asperities at different time scales: geodetic GPS time series **vs.** permanent deformation (emerged marine terraces)



Segmentation of subduction-zone megathrusts in down-dip failure domains

→ interaction during the seismic cycle?

Permanent deformation may be accumulated during giant EQ



Deformation cycle not completely elastic, strain partly stored as permanent deformation

Questions

(1) *During which phase of the seismic cycle does permanent coastal uplift accumulate?*

(2) *What mechanisms control the accumulation of permanent deformation? What is the role of seismic asperities in the accumulation of permanent deformation?*

(3) *Are seismic asperities sustained over time scales involving several 10^3 to 10^5 years?*

Methods

(1) *Determination of shoreline-angle elevations from wave-cut marine terraces using TerraceM software for MATLAB® (Jara-Muñoz et al., 2016) and TanDEM-X data*

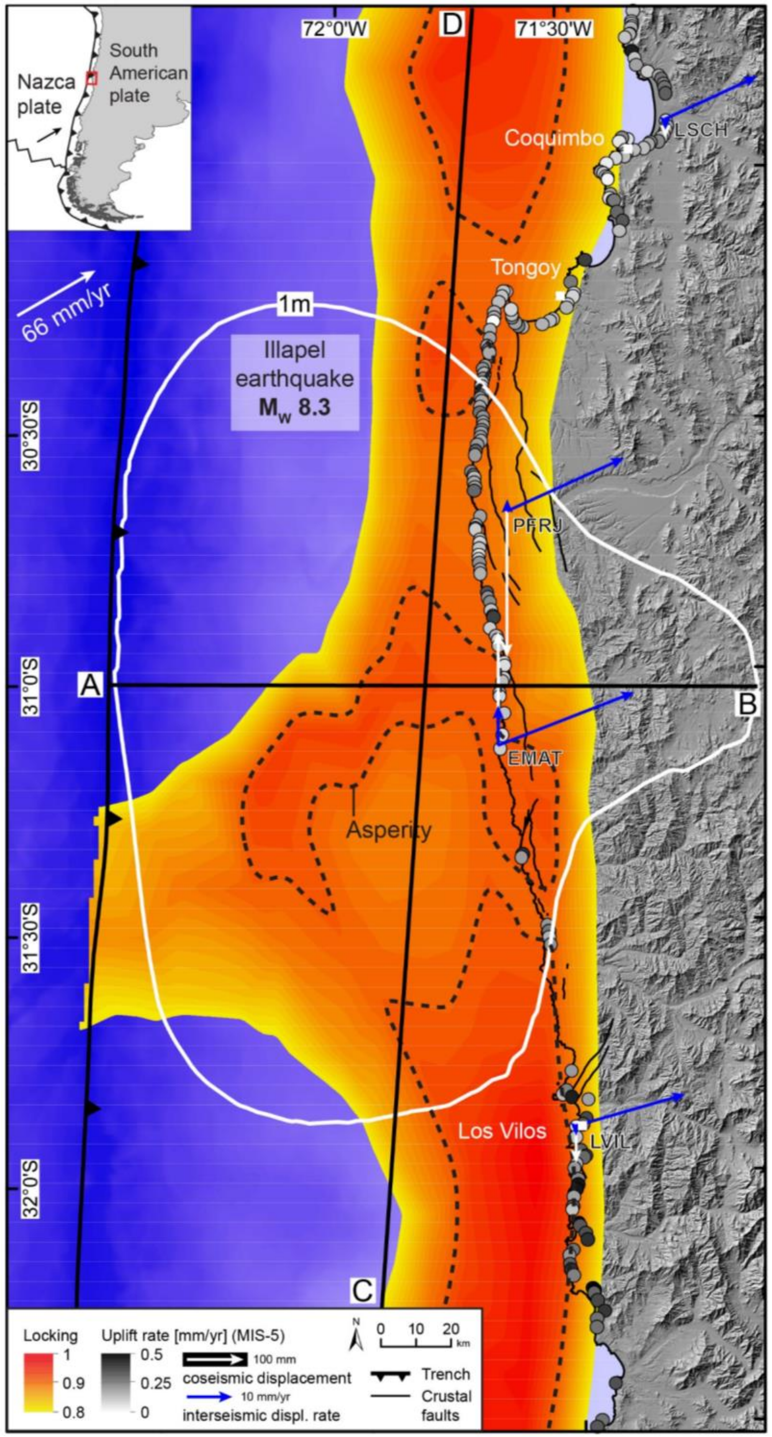
(2) *Time-series analysis of permanent GPS stations*

(3) *In preparation: IRSL dating, U/Th series dating of pedogenic carbonate rinds to determine the terrace chronology*

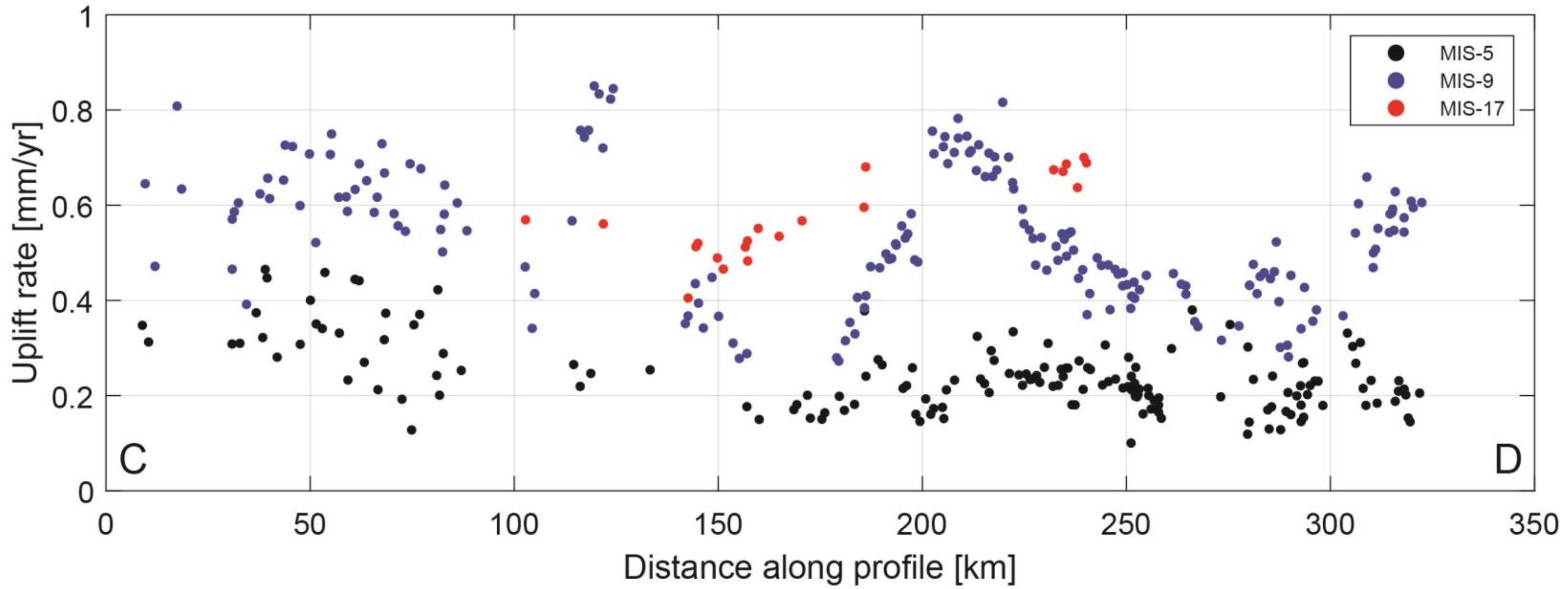
Interseismic locking before the Illapel eathquake and coseismic slip (after Melnick et al., 2017)

Circles (black/white gradient) indicate uplift rates calculated from MIS-5 terrace elevations

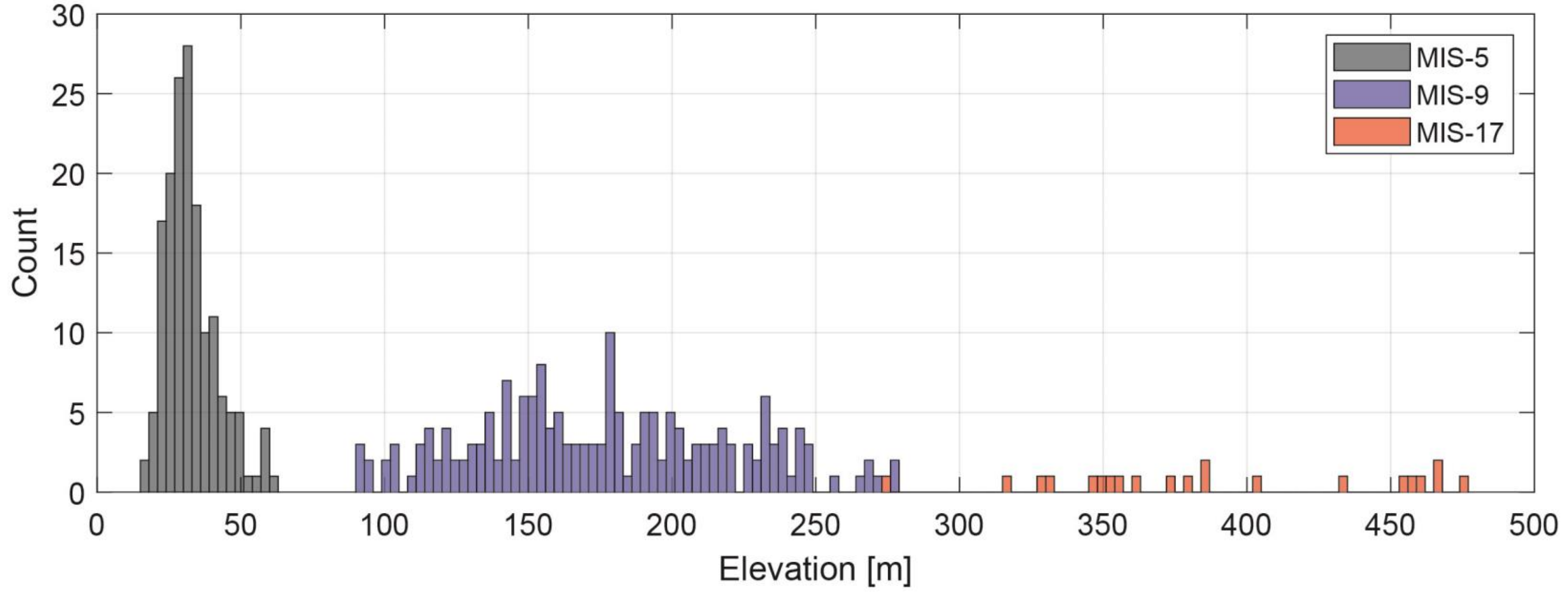
Vectors show interseismic displacement rates (blue) and coseismic vertical displacements (white) estimated from permanent GPS stations



Latitudinally varying uplift rates (profile C-D, see previous figure) and temporal changes between terrace levels

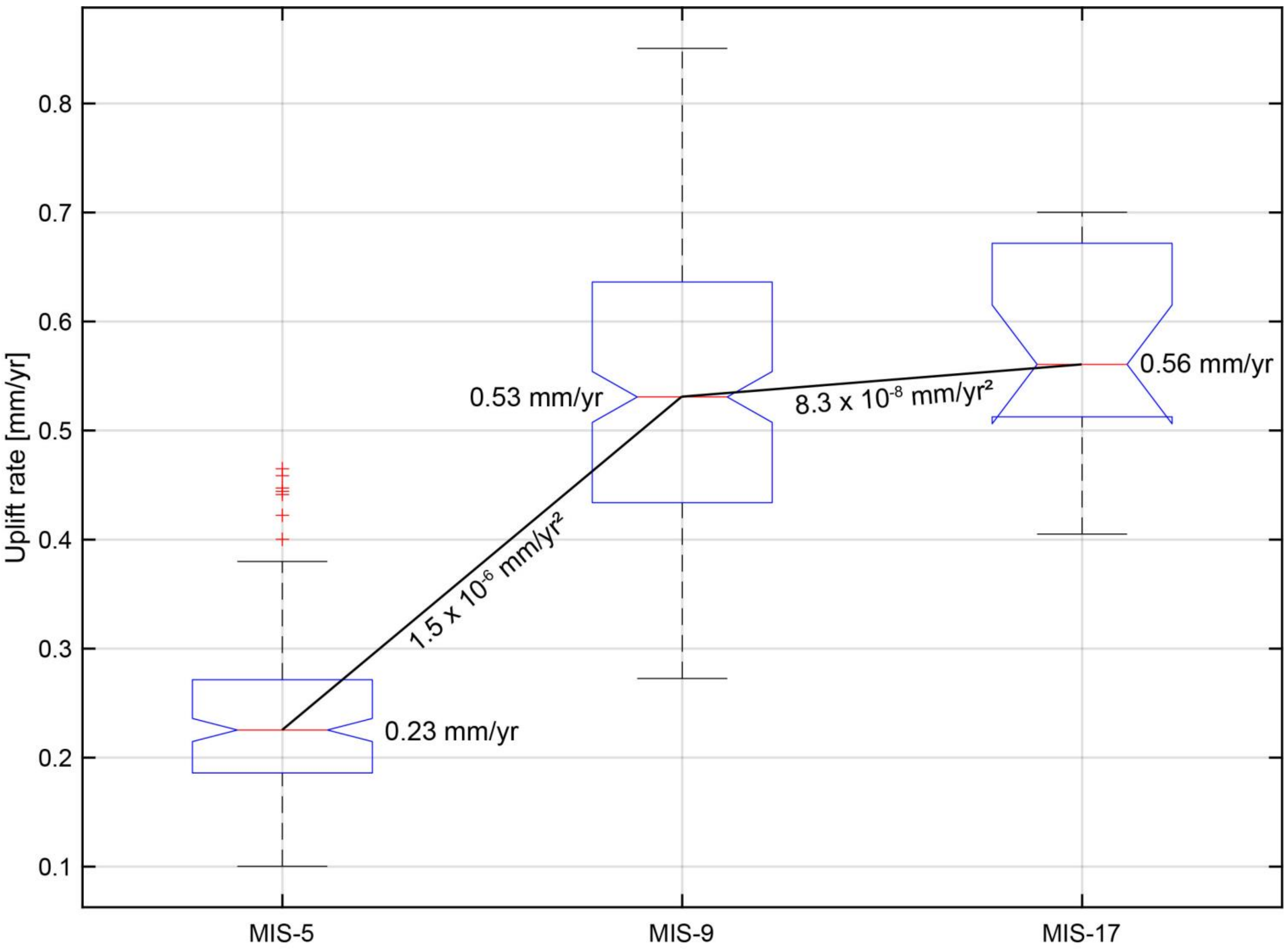


Histogram for terrace elevations of MIS-5, MIS-9, and MIS-17



Median and min./max. uplift rates of the three most prominent terrace levels in the Illapel area

Uplift rates decrease from MIS-17/MIS-9 terrace levels to around 0.23 mm/yr for the MIS-5 terrace level

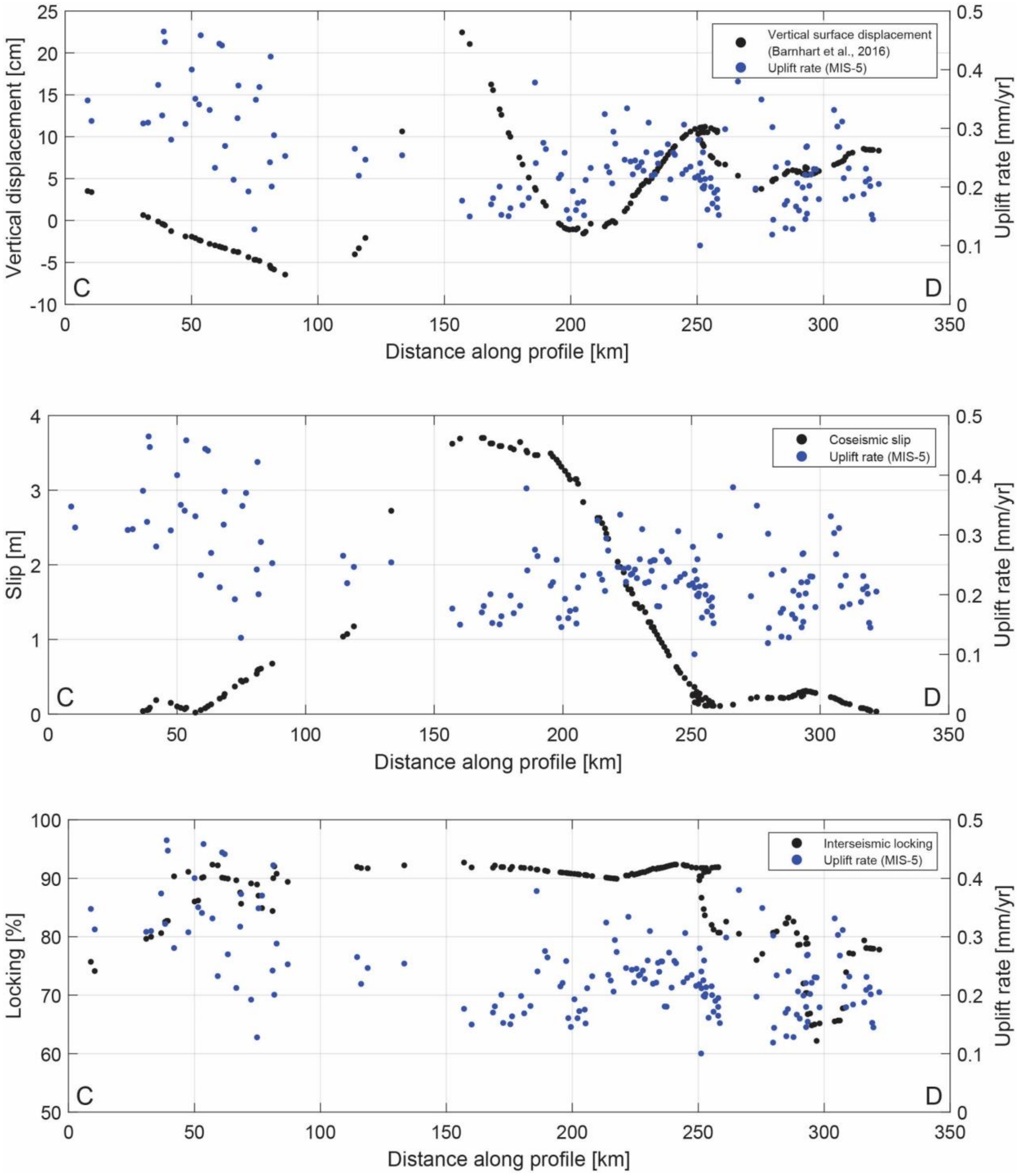


Uplift rate of the MIS-5 terrace level displayed against several coseismic and interseismic deformation estimates (profile C-D)

→ vertical surface displacement (coseismic)

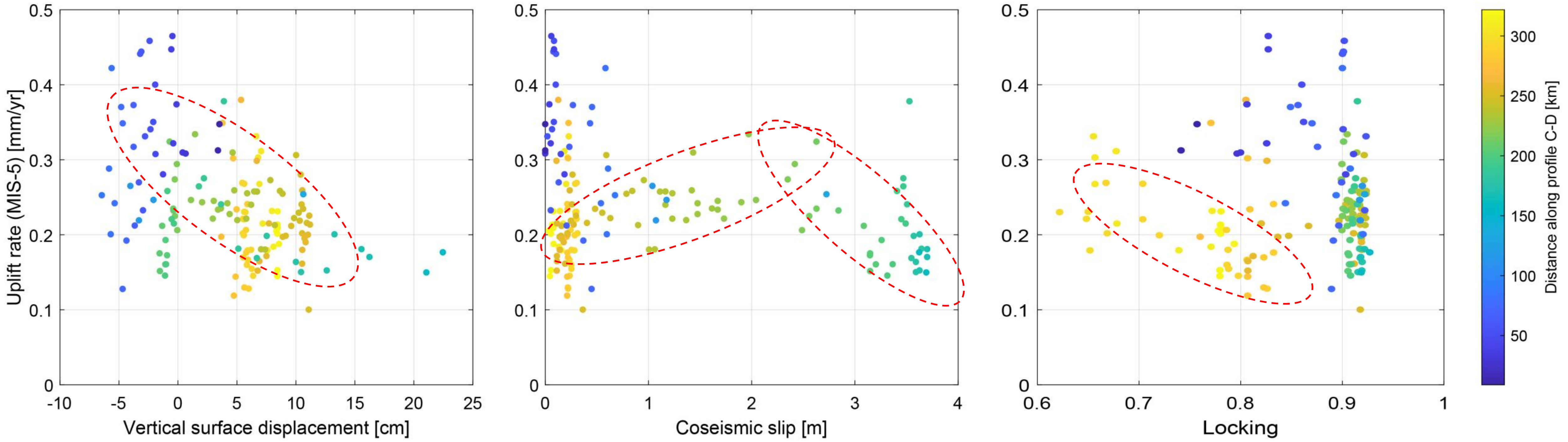
→ coseismic slip

→ interseismic locking



Vertical surface displacement after Barnhart *et al.*, 2016; coseismic slip and locking after Melnick *et al.*, 2017

Uplift rate of the MIS-5 terrace level displayed against several coseismic and interseismic deformation estimates (color-coded by distance along profile C-D): possible trends?



Vertical surface displacement after Barnhart *et al.*, 2016; coseismic slip and locking after Melnick *et al.*, 2017

Conclusions and future work

Uplift rates decreases from older (MIS-9/MIS-17) to younger (MIS-5) terrace levels from 0.53 mm/yr to 0.23 mm/yr

Uplift rates vary latitudinally, more pronounced for MIS-9 than for MIS-5 terrace levels
→ no clear correlation of the youngest level (MIS-5) with seismic cycle deformation patterns

Future work will include:

More GPS time series and shoreline angle mapping of an extended area (27°-34°S)

IRSL and U/Th dating to close gaps in the terrace chronology and varify existing ages

Analysis of high-resolution drone topography, especially for small-scale beach ridges

References

Barnhart, W. D., J. R. Murray, R. W. Briggs, F. Gomez, C. P. J. Miles, J. Svarc, S. Riquelme, and B. J. Stressler (2016), Coseismic slip and early afterslip of the 2015 Illapel, Chile, earthquake: Implications for frictional heterogeneity and coastal uplift, J. Geophys. Res. Solid Earth, 121, 6172–6191, doi:10.1002/2016JB013124.

Jara-Muñoz, J., Melnick, D., and Strecker, M.R., 2016, TerraceM: A MATLAB® tool to analyze marine and lacustrine terraces using high-resolution topography: Geosphere, v. 12, no. 1, p. 176–195, doi: 10.1130/GES01208.1.

Melnick, D., Moreno, M., Quinteros, J., Baez, J.C., Deng, Z., Li, S., and Oncken, O., 2017, The super-interseismic phase of the megathrust earthquake cycle in Chile: Geophysical Research Letters, v. 44, no. 2, p. 784–791, doi: 10.1002/2016GL071845.