

Supplementary Information: Integrated Geodetic
and Seismic Constraints on Deformation at
Nevados de Chillán, 2015–2025

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27 This supplementary material provides additional figures supporting the results
 28 presented in the main text. Figures are organized following the structure of the paper:
 29 seismic data (Fig. S1), GNSS observations (Figs. S2–S4), InSAR data (Figs. S5–S6),
 30 and source modeling (Figs. S7–S9).

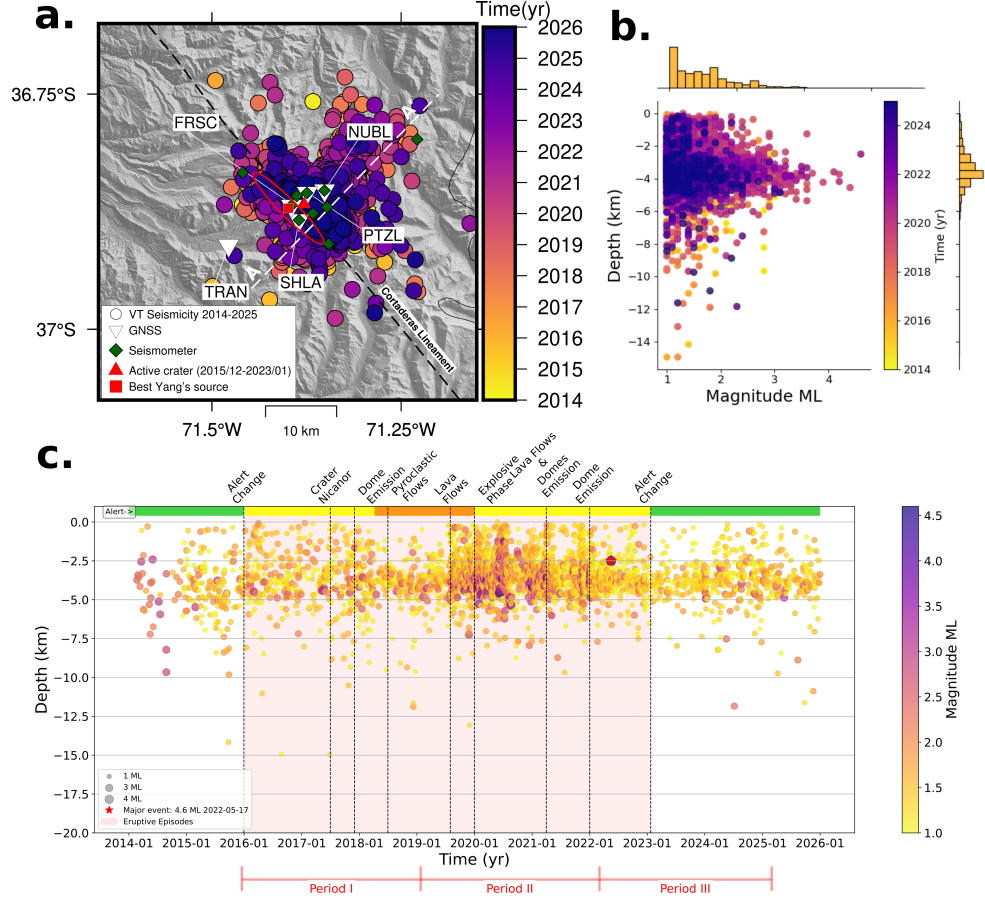


Fig. S1 Daily volcano-tectonic (VT) seismicity at the NChVC from 2014 to 2025. (a) Spatial distribution of seismicity, with circle colors representing temporal progression. Inverted white triangles indicate GNSS stations, green diamonds mark seismometers, the red triangle shows the active crater, and the red square marks the preferred Yang source location. The black dashed line marks the Cortaderas Lineament. (b) Depth profile of seismicity correlated with event magnitudes, accompanied by histograms of magnitude distribution. (c) Temporal evolution of seismicity depth, color-coded by magnitude, with the largest magnitude event (M_L 4.6, May 2022) marked with a red star.

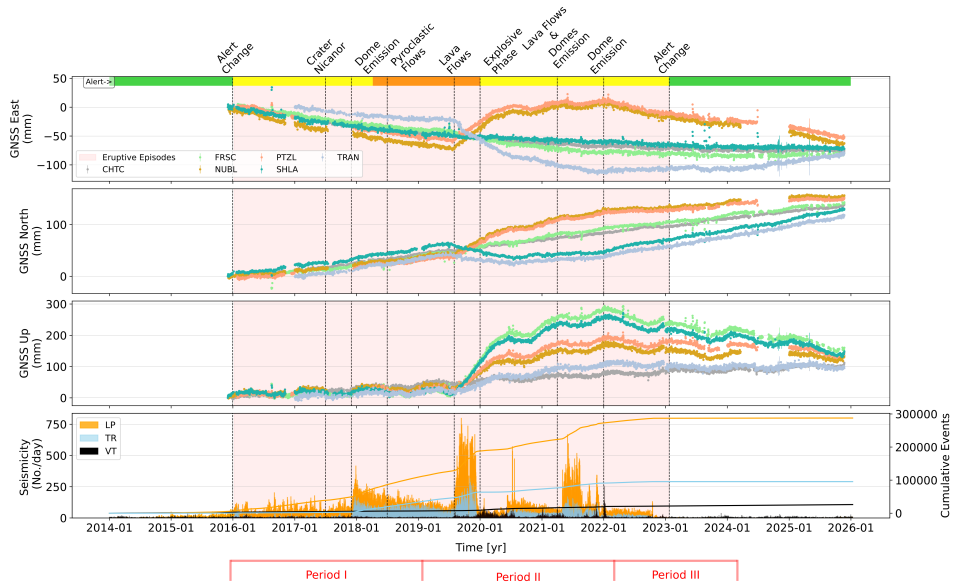


Fig. S2 Time series of original GNSS data recorded at stations CHTC, FRSC, NUBL, PTZL, SHLA, and TRAN across the three displacement components (East, North, and Vertical). The time series are shown without referencing them to CHTC. The distinct stages of eruptive activity are color-coded according to their corresponding alert levels (yellow, orange, and green). Seismicity is displayed simultaneously, including LP (orange), TR (light blue), and VT (black) event types, along with the cumulative seismic event count (right axis).

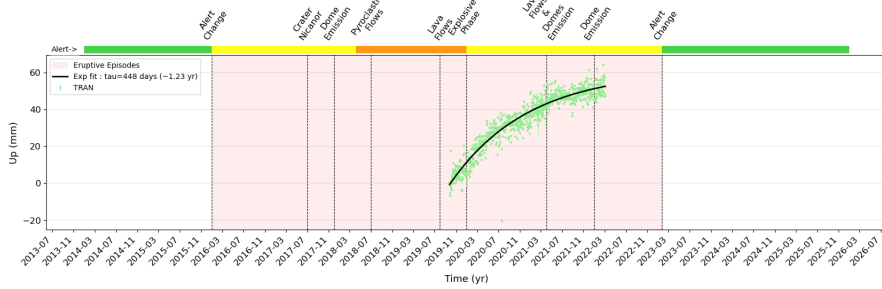


Fig. S3 Vertical displacement time series at GNSS station TRAN, referenced to CHTC, during Period II (2019–2022). Green dots show daily position estimates, and the black dashed line shows the best-fit exponential function ($\tau = 448$ days, equivalent to ~ 1.23 yr). Colored bars at the top indicate alert levels and eruptive episodes.

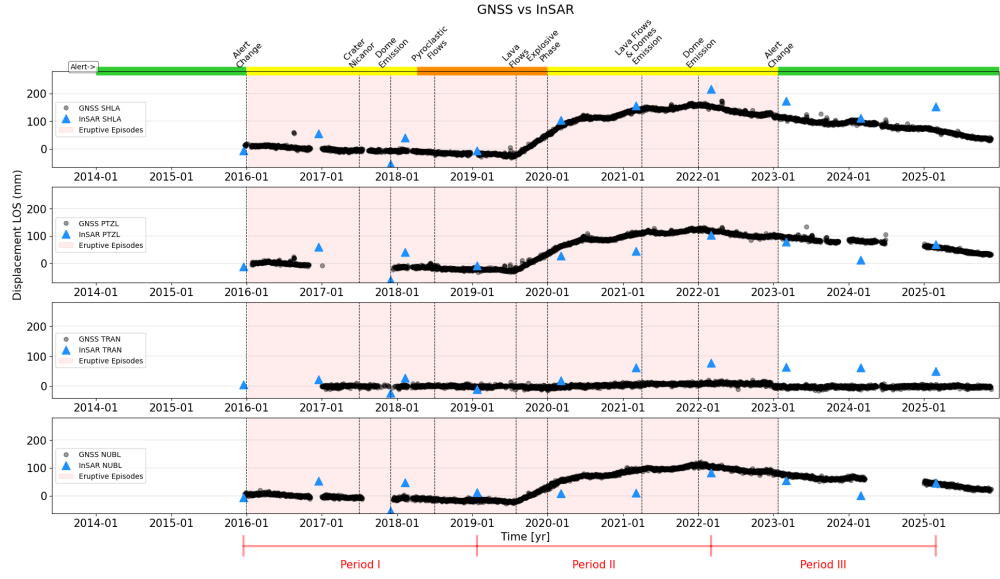


Fig. S4 LOS displacement time series comparing GNSS (black) and ALOS-2 InSAR (blue) at the four near-field GNSS stations, both referenced to CHTC, along with eruptive episodes and alert level changes.

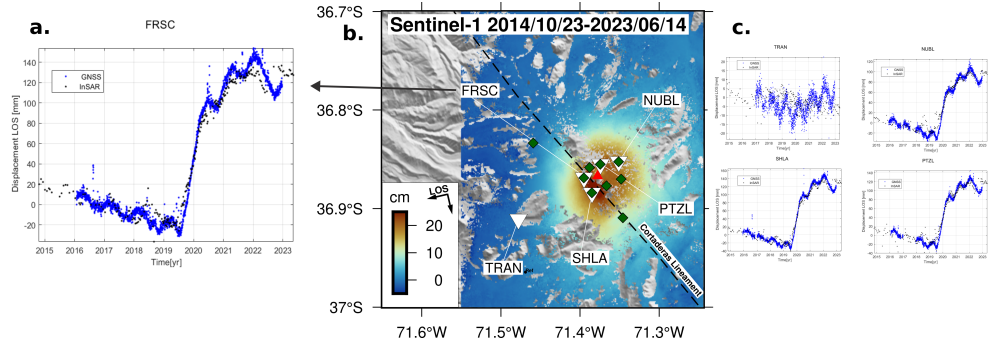


Fig. S5 Sentinel-1 LOS displacement and GNSS-derived LOS time series. (a) LOS time series at FRSC. (b) Cumulative Sentinel-1 LOS displacement for descending track 83 between 2014/10/23 and 2023/06/14. (c) LOS time series at TRAN, NUBL, SHLA, and PTZL. GNSS time series (blue) were projected into the Sentinel-1 LOS, whereas InSAR time series are shown in black. The black point marks the InSAR reference location. Inverted white triangles mark GNSS stations, green diamonds mark seismometers, the red triangle indicates the active crater, and the black dashed line marks the Cortaderas Lineament.

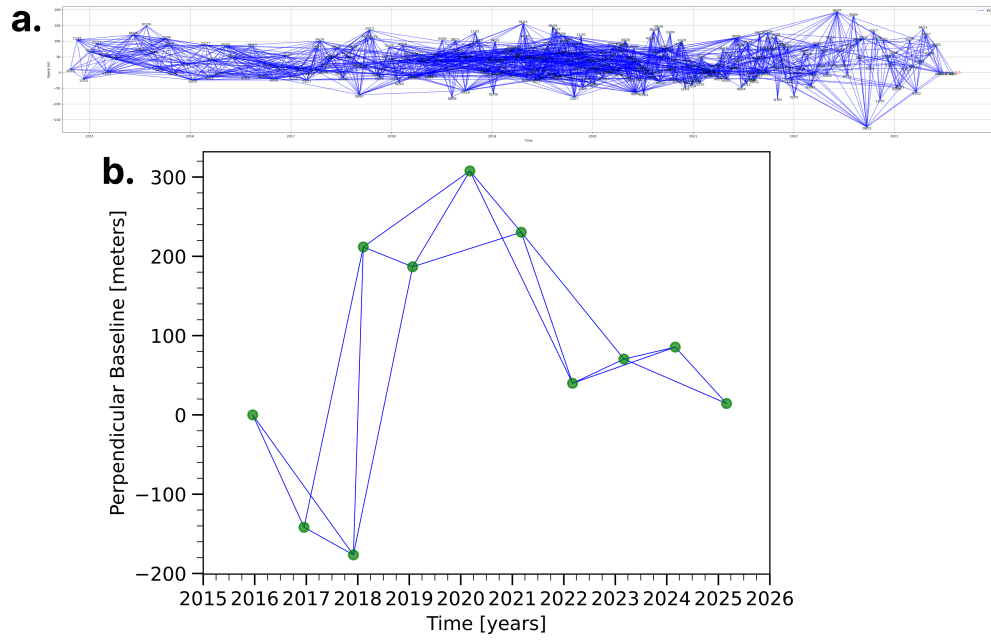


Fig. S6 Interferometric networks for (a) Sentinel-1 and (b) ALOS-2. Blue lines connect the acquisitions used to form interferograms.

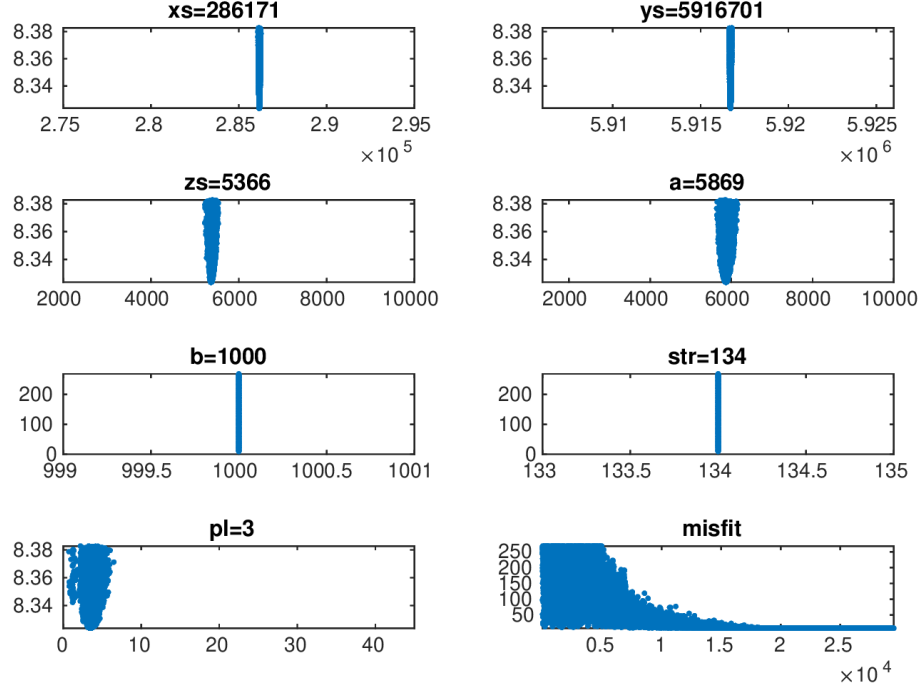


Fig. S7 Parameter space explored by the neighborhood algorithm for the prolate spheroid source model. Each panel shows the mean squared misfit as a function of one model parameter: source easting (x_s , m), northing (y_s , m), depth (z_s , m), major semi-axis (a , m), minor semi-axis (b , m), strike (str , °), and plunge (pl , °). For the free parameters, only the lowest third of the explored misfit range is displayed to highlight the region around the minimum. The minor semi-axis was fixed at 1000 m, and the strike was fixed at 134° in the final inversions; therefore, these panels appear as vertical lines and display the full misfit range. The lower-right panel shows the evolution of the misfit over the model iterations. The parameter values used in the preferred model are indicated in each panel title.

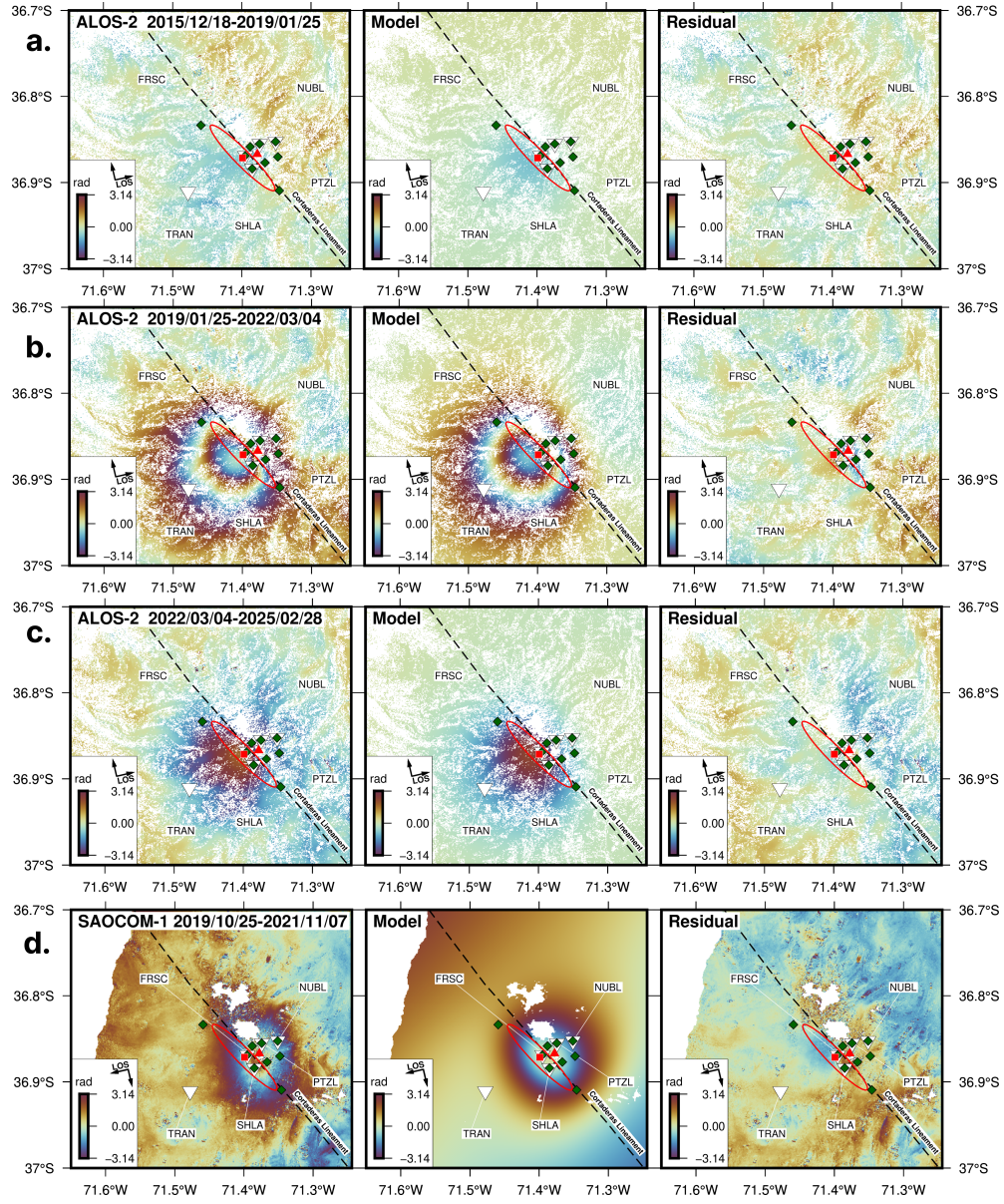


Fig. S8 Wrapped observed, modeled, and residual deformation for the prolate spheroid source model. Rows show (a) ALOS-2 deformation during 2015/12/18–2019/01/25, (b) ALOS-2 deformation during 2019/01/25–2022/03/04, (c) ALOS-2 deformation during 2022/03/04–2025/02/28, and (d) SAOCOM-1 deformation during 2019/10/25–2021/11/07. The columns show the observed deformation, modeled deformation, and residuals calculated as observation minus model, respectively. All interferograms are wrapped between $-\pi$ and π radians to facilitate visual assessment of the agreement between the observations and the model. White areas indicate regions without valid data.

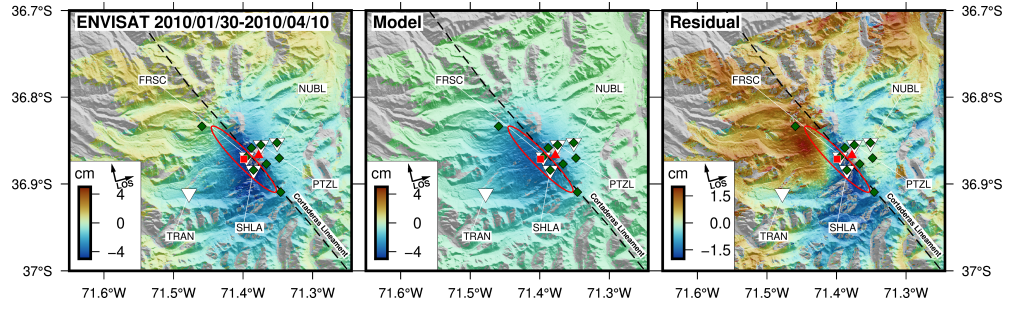


Fig. S9 Map of cumulative LOS displacement from ENVISAT for the period 2010/01/30–2010/04/10 at NChVC, spanning the 2010 M_w 8.8 Maule earthquake. Panels show observed displacement (left), the forward model prediction using the Period II prolate spheroid geometry (center), and residuals (right). The spatial pattern differs from the volcanic deformation observed during Periods I–III, indicating a distinct physical mechanism. Inverted white triangles indicate GNSS stations, green diamonds mark seismometers, and the red triangle shows the active crater. The black dashed line marks the Cortaderas Lineament.