Variable Ground Deformation Rates Since May 2022 at Chiles-Potrerillos Volcanoes, Ecuadorian-Colombia Border

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Oral Presentation for Session- Volcanoes II, 13 Sept., 14h00-15h40

Motivation:

- What is the cause of the strong ground deformation (9 cm/yr) at these volcanoes without an eruption in 15,000 yrs?

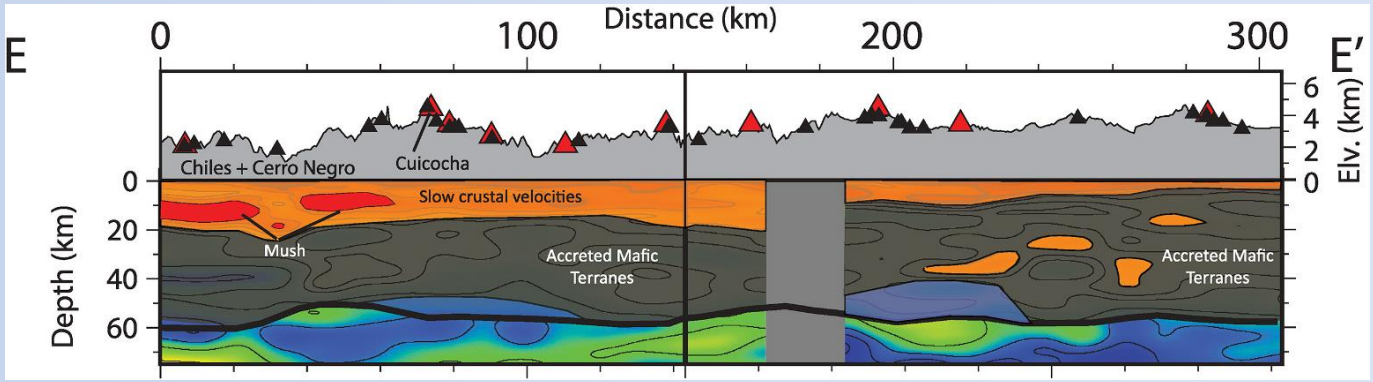
- What patterns do we see between ground deformation and seismicity in the two activity nests?

- By combining InSAR and GPS time series, can we derive improved propagation models?

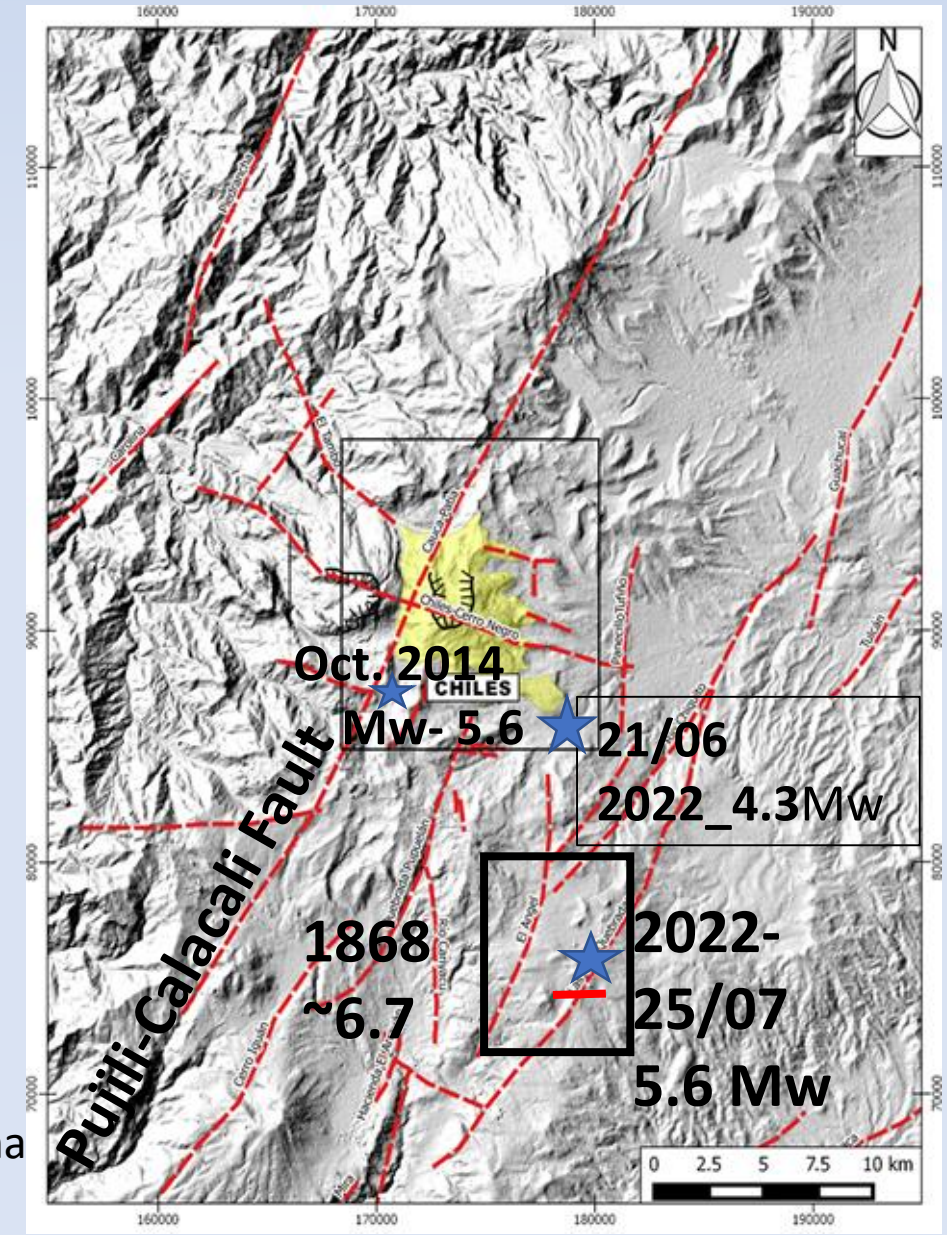
- What other volcanoes are analogs for this case? Campi Flegrei?

- Producing at times 5000 fracture EQ´s/day, (600,000 EQs since 2014). Will this volcanic system erupt?

Setting:



Koch et al., 2021—Slow velocity zones suggest mush accumulation under the Chiles area.



E. Telanchana 2017

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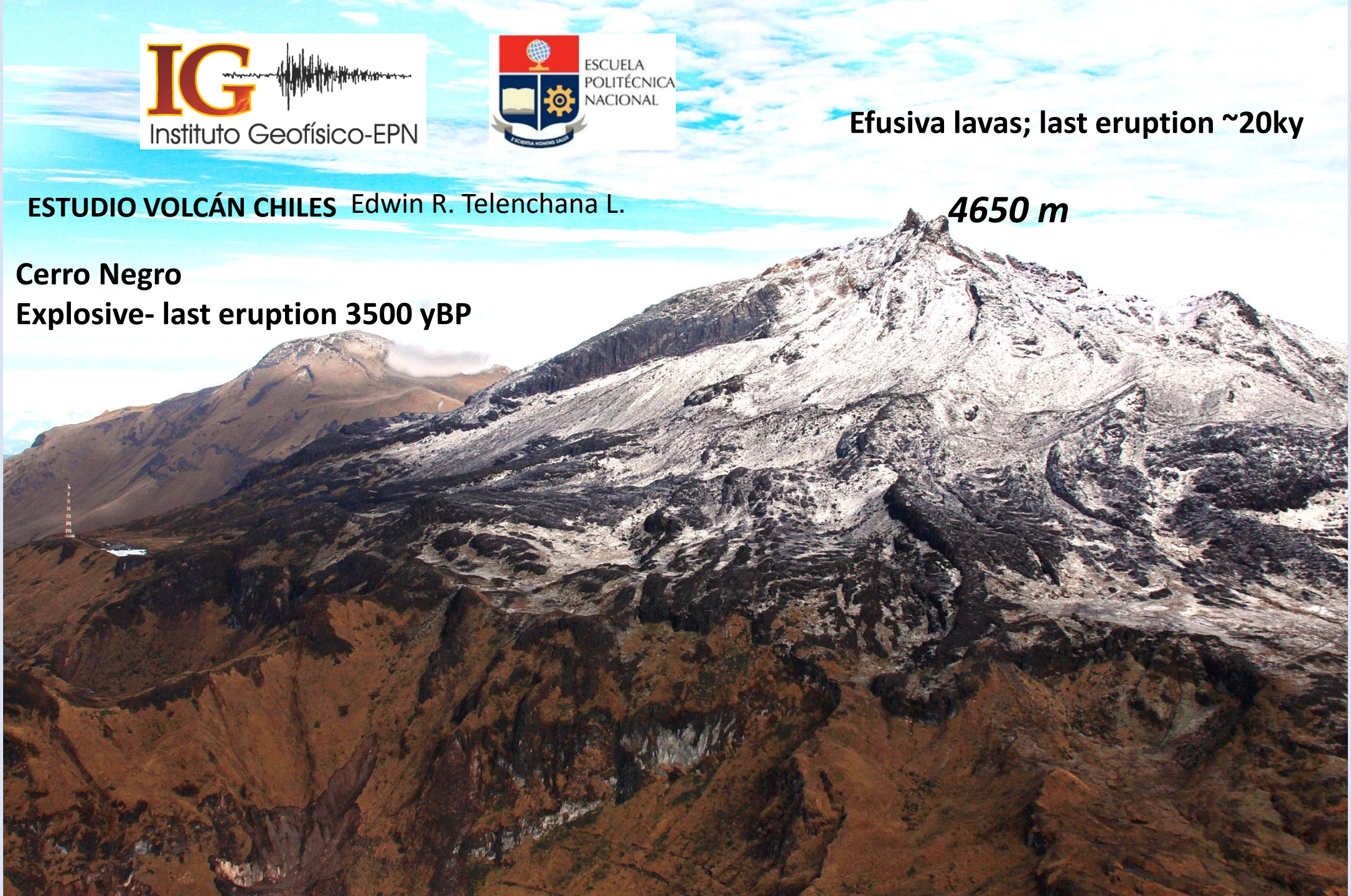
ESTUDIO VOLCÁN CHILES Edwin R. Telenchana L.

Efusiva lavas; last eruption ~20ky

4650 m

Cerro Negro
Explosive- last eruption 3500 yBP



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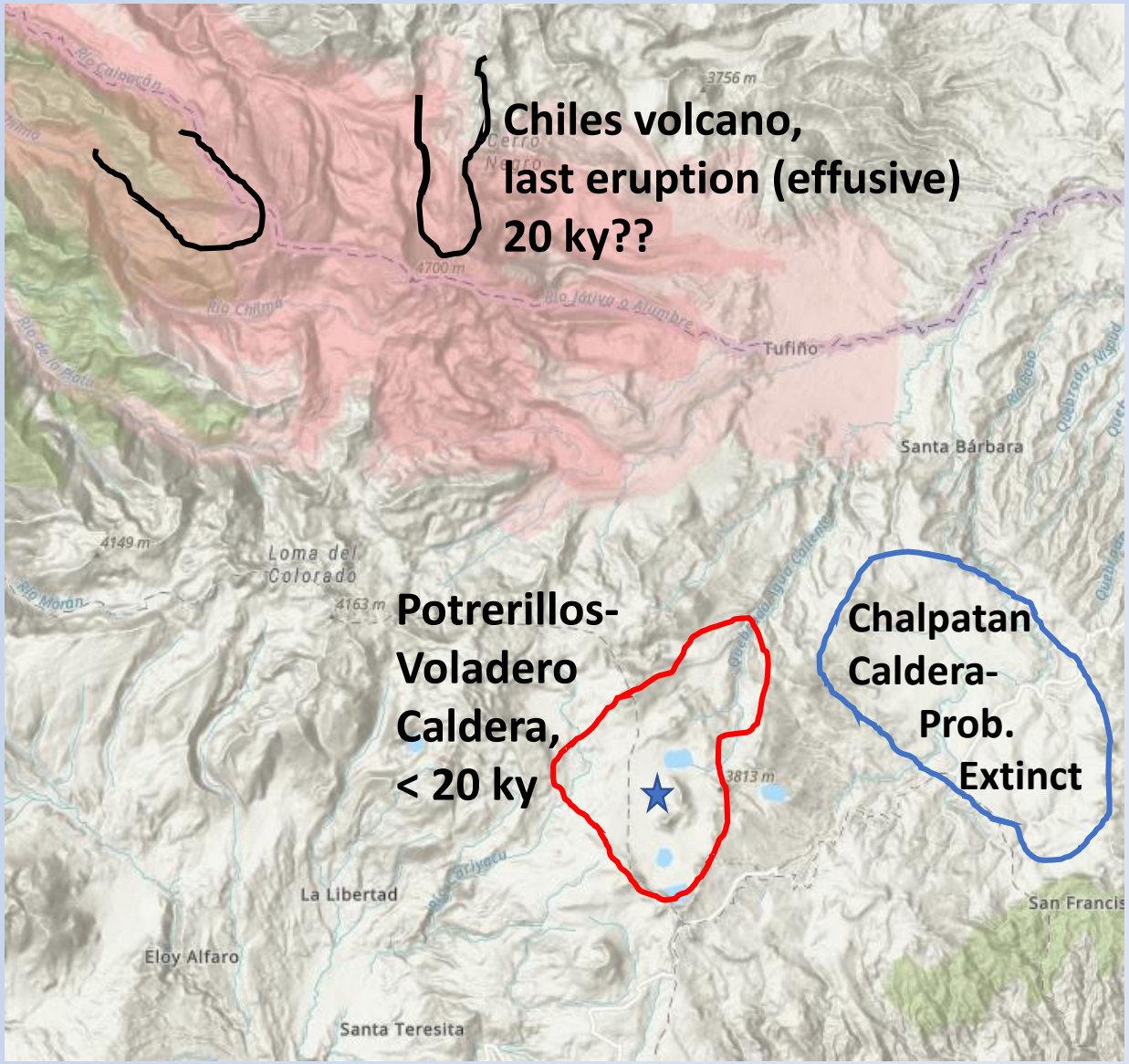
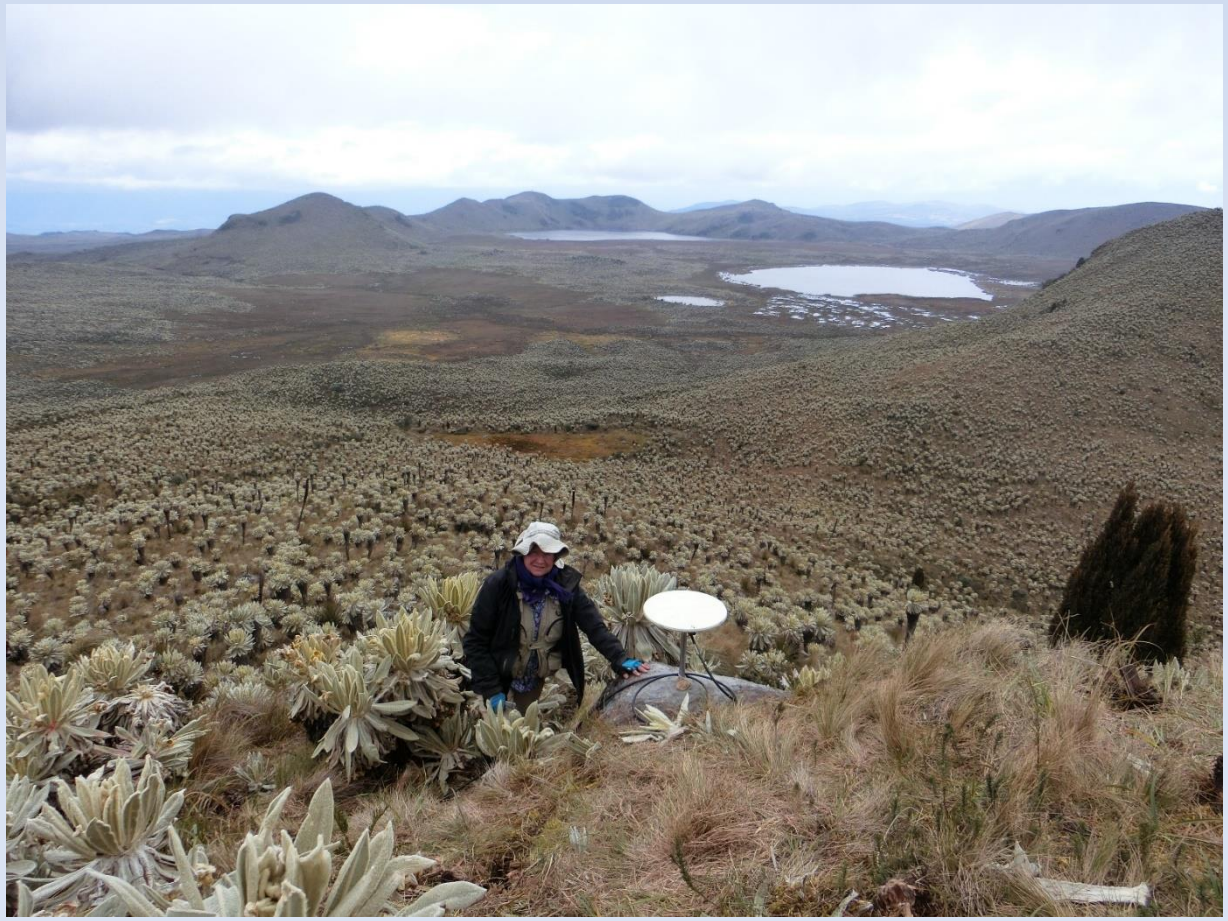
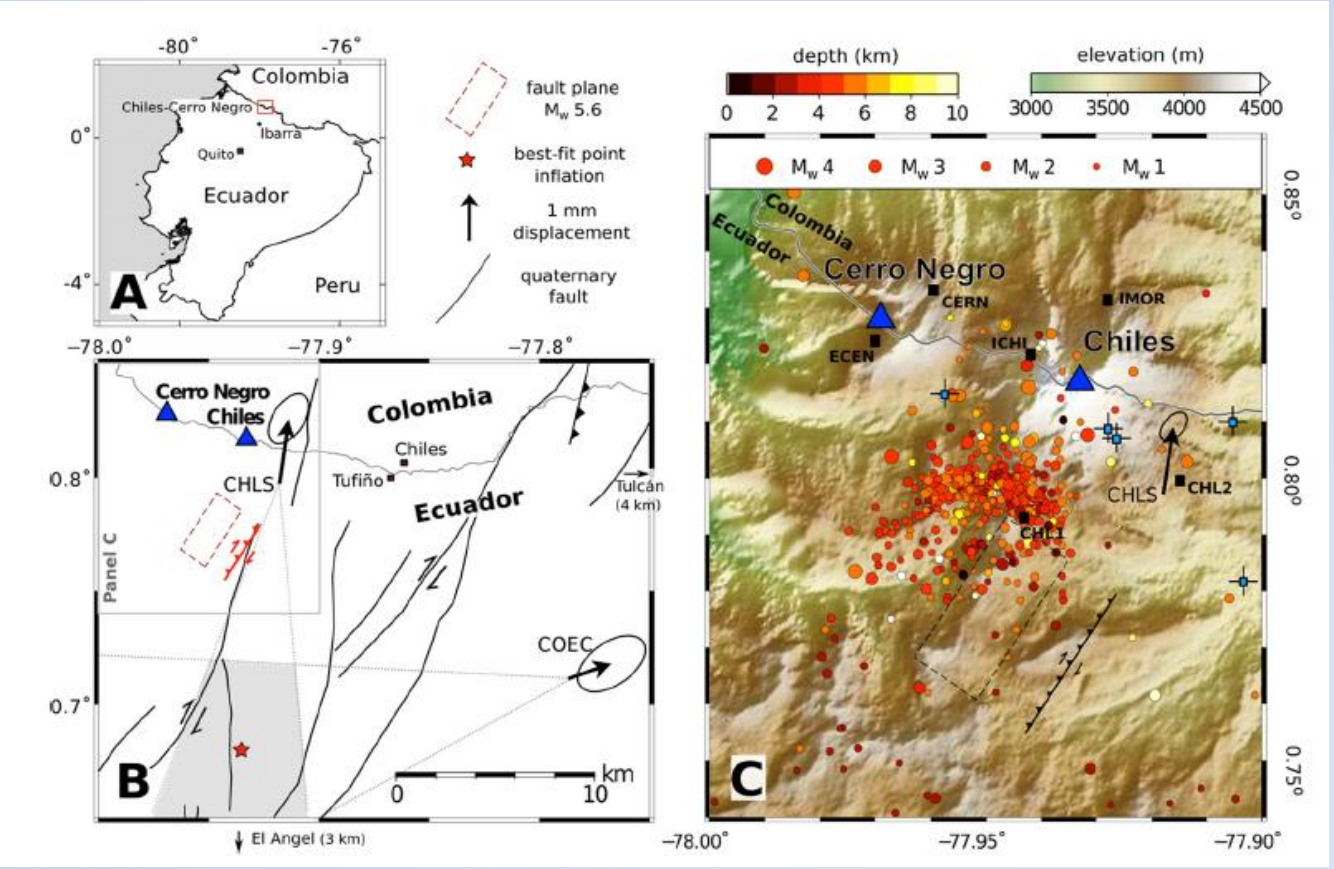
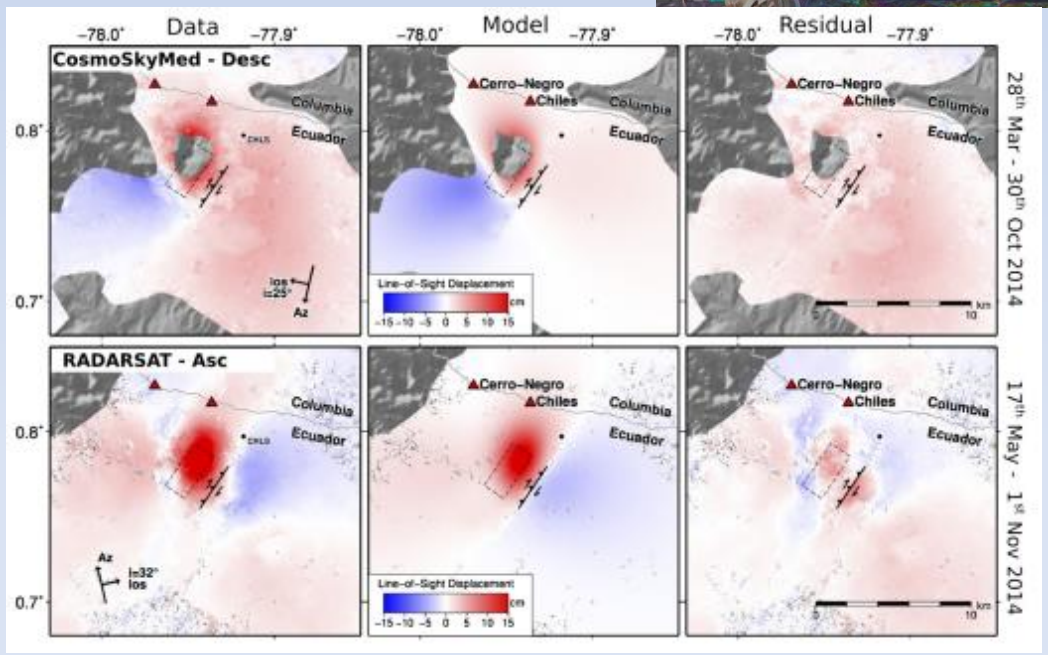


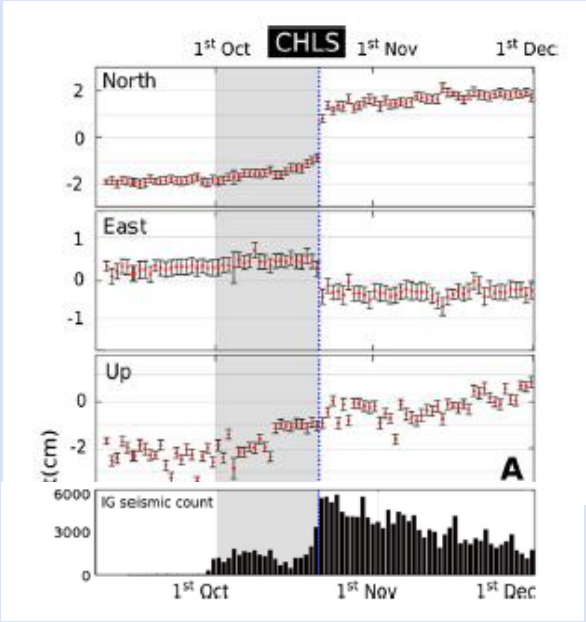


Tetilas GPS station; view south to Voladero lake and Southern caldera rim

Earlier Work_2016 (Ebmeier et al, 2016)



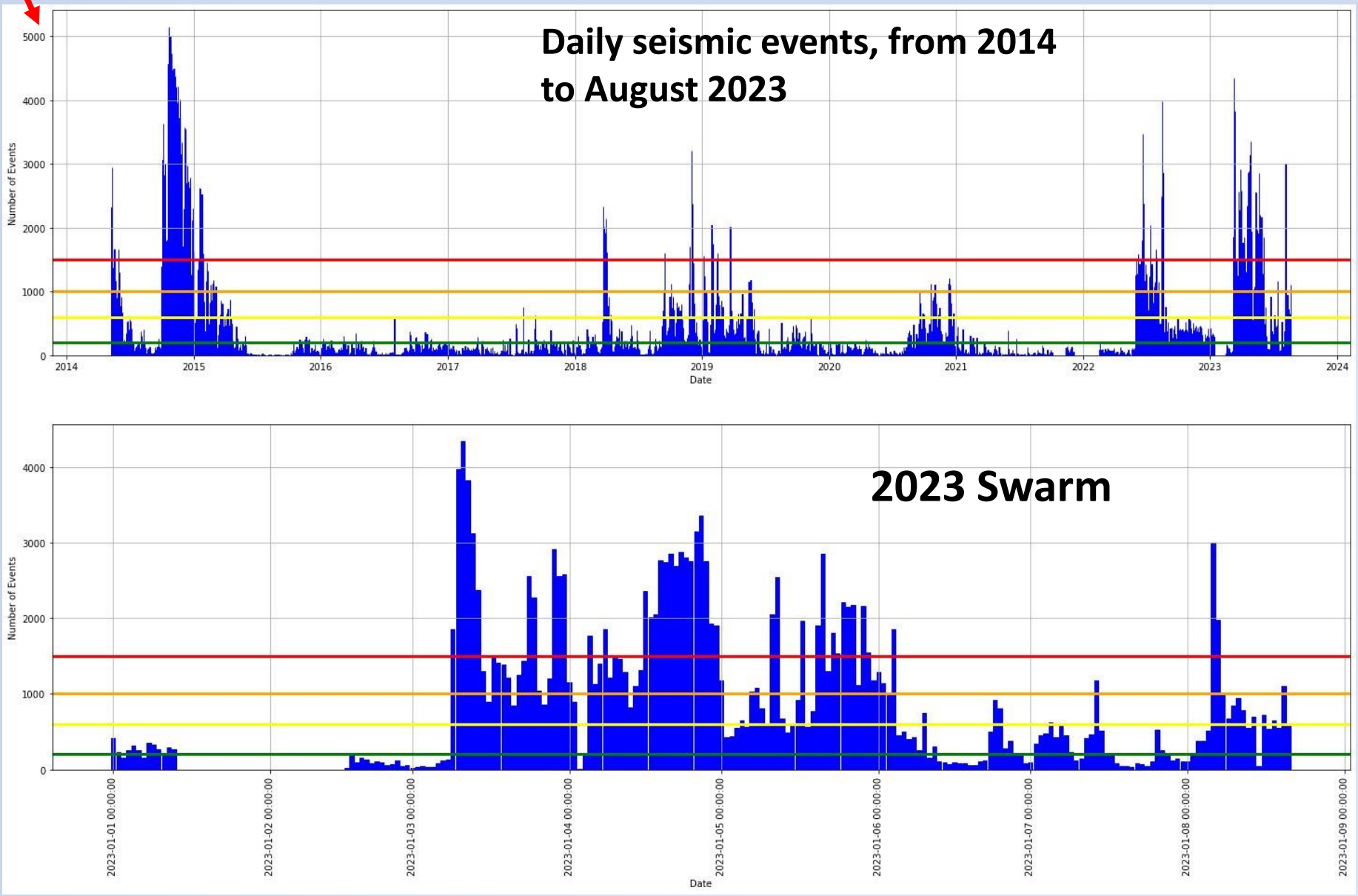




Starting on 01 Oct. 2014 an abrupt-onset EQ swarm of >5000 events/day and GPS ground displacements of ~1 cm Hort. & ~1.5 cm Vert. preceded a 5.6 Mw EQ. Afterwards, the system went quiet for 2.5 yr.

Remarkable Seismicity:

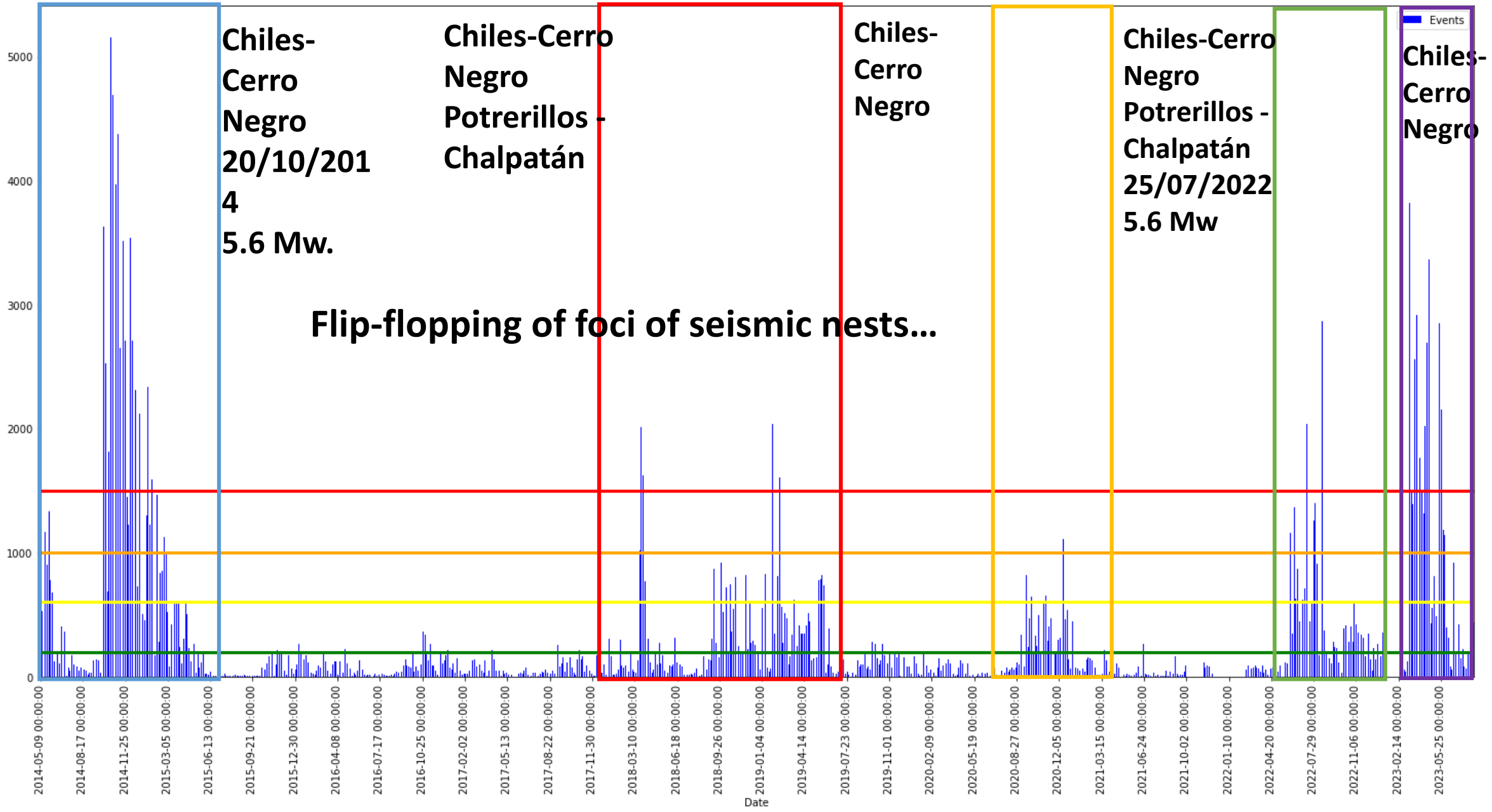
5000 events (Vts- 90%, Lps 10%)



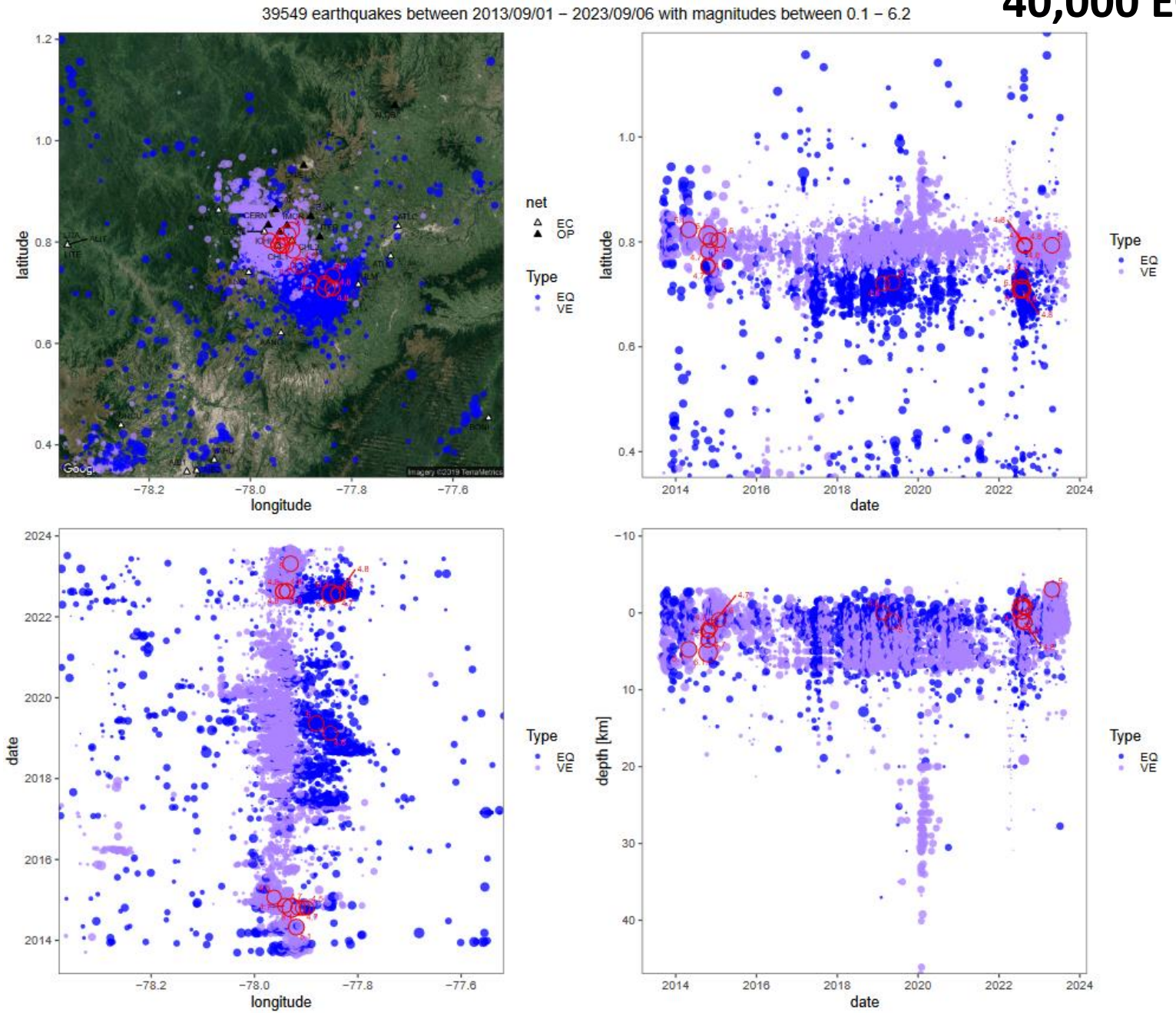
Resume:

-**Abrupt and energetic onset of seismicity from low background..**

- **110,000 EQ´s recorded in 2022-2023**
- **8 large EQ families**
- **Locations in two nests**
- **Depths range from 3-15 km below Chiles Summit**


Chiles-Cerro Negro 20/10/2014 5.6 Mw.
Chiles-Cerro Negro Potrerillos - Chalpatán
Chiles-Cerro Negro
Chiles-Cerro Negro Potrerillos - Chalpatán 25/07/2022 5.6 Mw
Chiles-Cerro Negro
Flip-flopping of foci of seismic nests…
Events
5000
4000
3000
2000
1000
0
2014-05-09 00:00:00
2014-08-17 00:00:00
2014-11-25 00:00:00
2015-03-05 00:00:00
2015-06-13 00:00:00
2015-09-21 00:00:00
2015-12-30 00:00:00
2016-04-08 00:00:00
2016-07-17 00:00:00
2016-10-25 00:00:00
2017-02-02 00:00:00
2017-05-13 00:00:00
2017-08-22 00:00:00
2017-11-30 00:00:00
2018-03-10 00:00:00
2018-06-18 00:00:00
2018-09-26 00:00:00
2019-01-04 00:00:00
2019-04-14 00:00:00
2019-07-23 00:00:00
2019-11-01 00:00:00
2020-02-09 00:00:00
2020-05-19 00:00:00
2020-08-27 00:00:00
2020-12-05 00:00:00
2021-03-15 00:00:00
2021-06-24 00:00:00
2021-10-02 00:00:00
2022-01-10 00:00:00
2022-04-20 00:00:00
2022-07-29 00:00:00
2022-11-06 00:00:00
2023-02-14 00:00:00
2023-05-25 00:00:00
Date

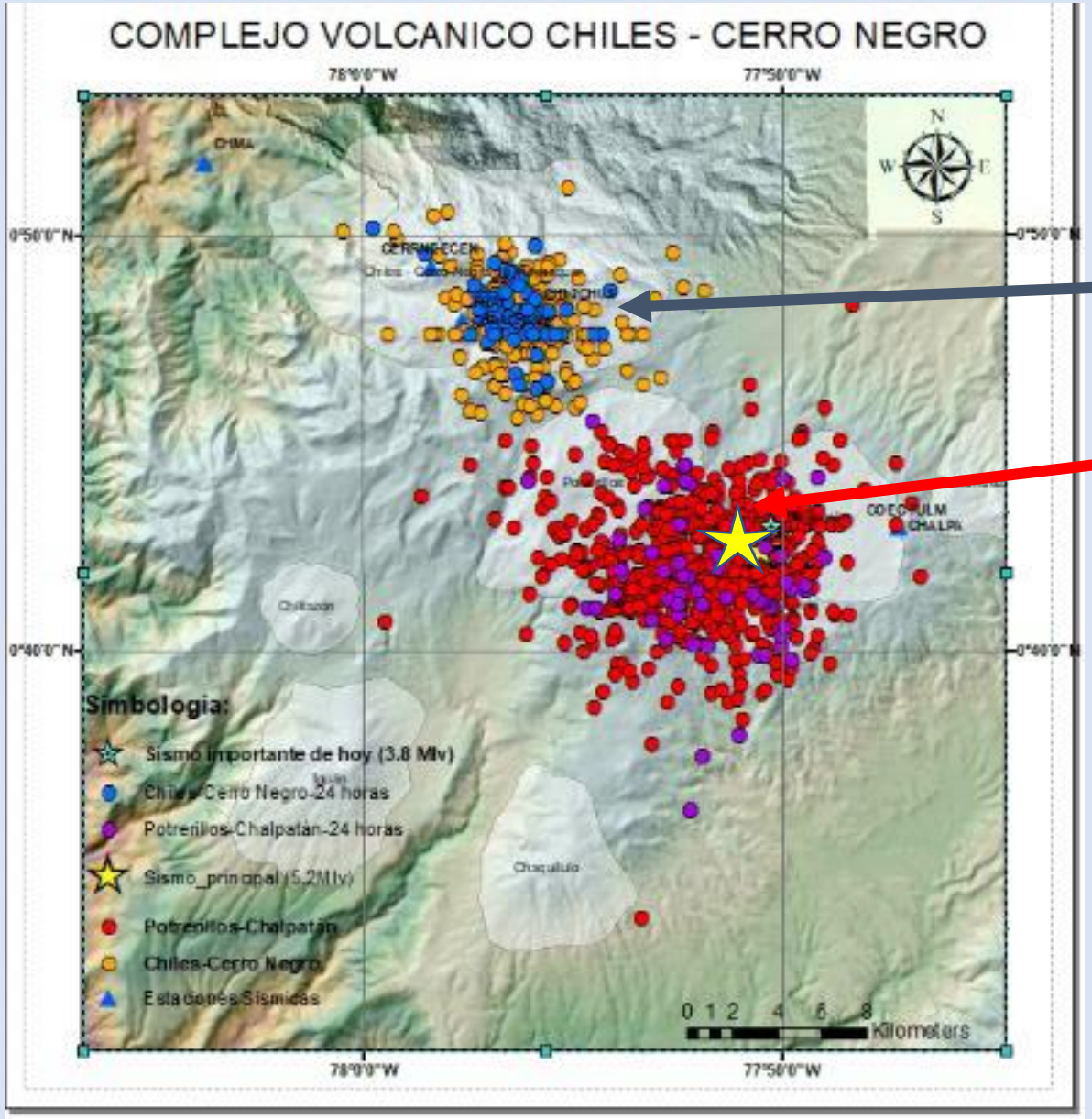
40,000 EQ locations



Located EQ´s- Two nests:

- **Southern flank of Chiles volcano.** – This zone presents continuous activity since 2013 with several events larger than 4.5 MLv (red circles).

- **Potrerillos.-** This activity started in 2016 to 2021 and in 2022, with several events larger than 4.5 MLv (red circles).



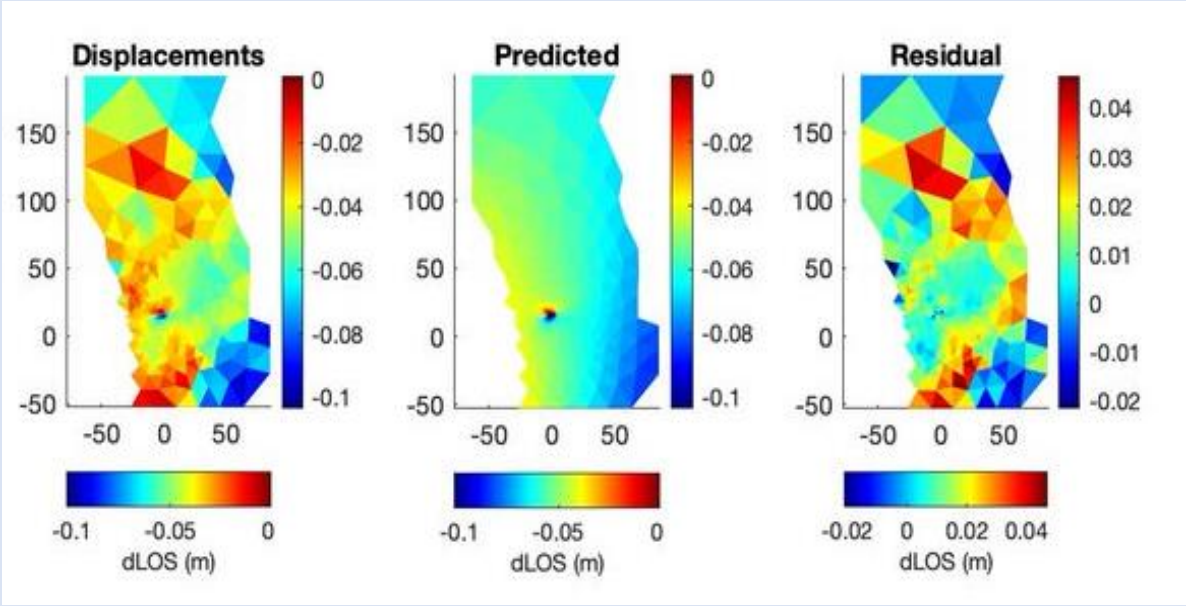
2022 EQ Swarm _May to December

The activity began on May 27, at the southern flank of Chiles volcano.

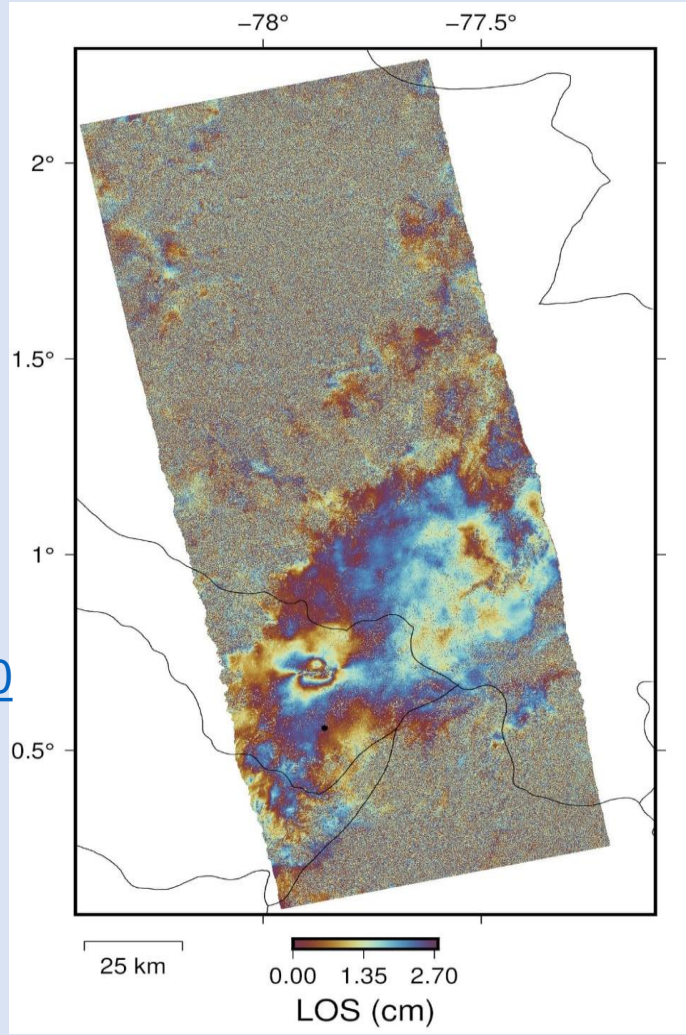
Later, on 12 June, 2022, an increase of seismic activity was detected under the Potrerillos area, simultaneously with the seismicity registered at Chiles Volcano.

In this period an earthquake occurred south of Potrerillos, of 5.6 Mw (Yellow Star).

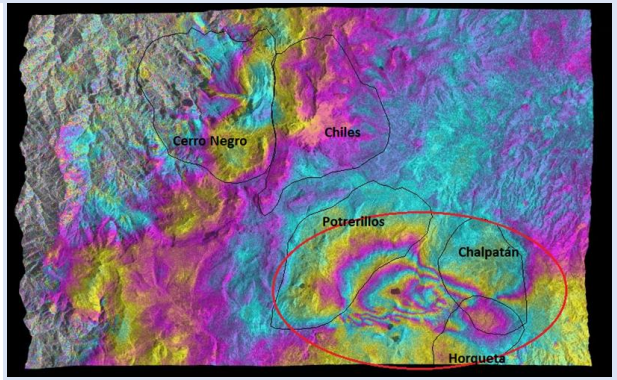
Mw 5.6 San Gabriel, Ecuador (2022.07.25)



Ascending



Descending



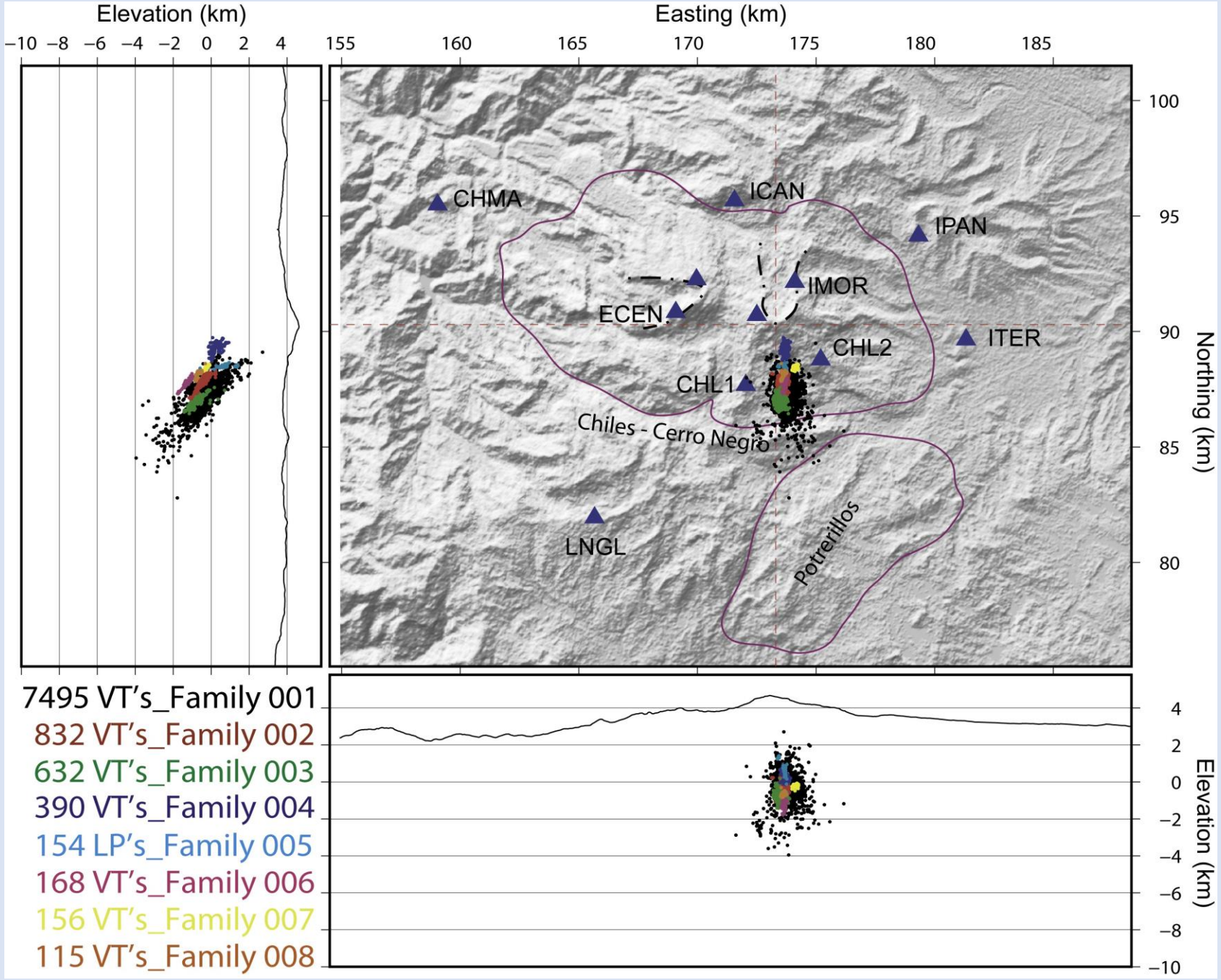
COMET web page

gCent@gCentBulletin, 28 jul. 2022

https://earthquake.usgs.gov/earthquakes/eventpage/us7000htbb/executive

Sentinel p125 2022.07.15-2022.07.27
Centroid lon/lat: -77.859/0.703
Centroid depth (km): 3.46 Depth range (km): 0.92-6.00
Geodetic Mag: Mw 5.65 Slip mag (m): 0.306
Str/Dip/Rake: 262/89/199
Len/Wid (km): 7.35/5.08

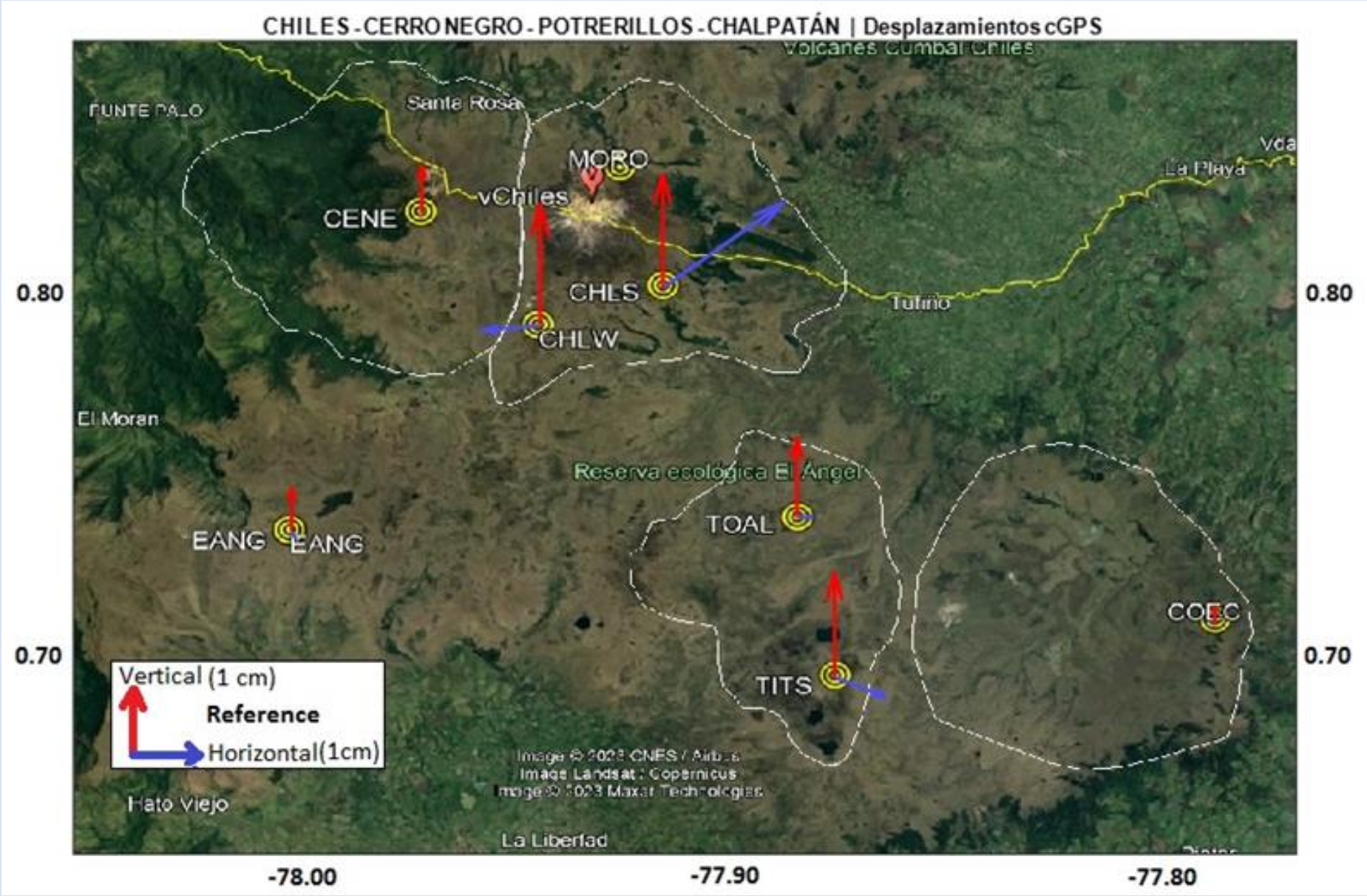
Strike-slip; left-lateral n an E-W blind fault, Unidentified..



2023 EQ Swarm
March to August

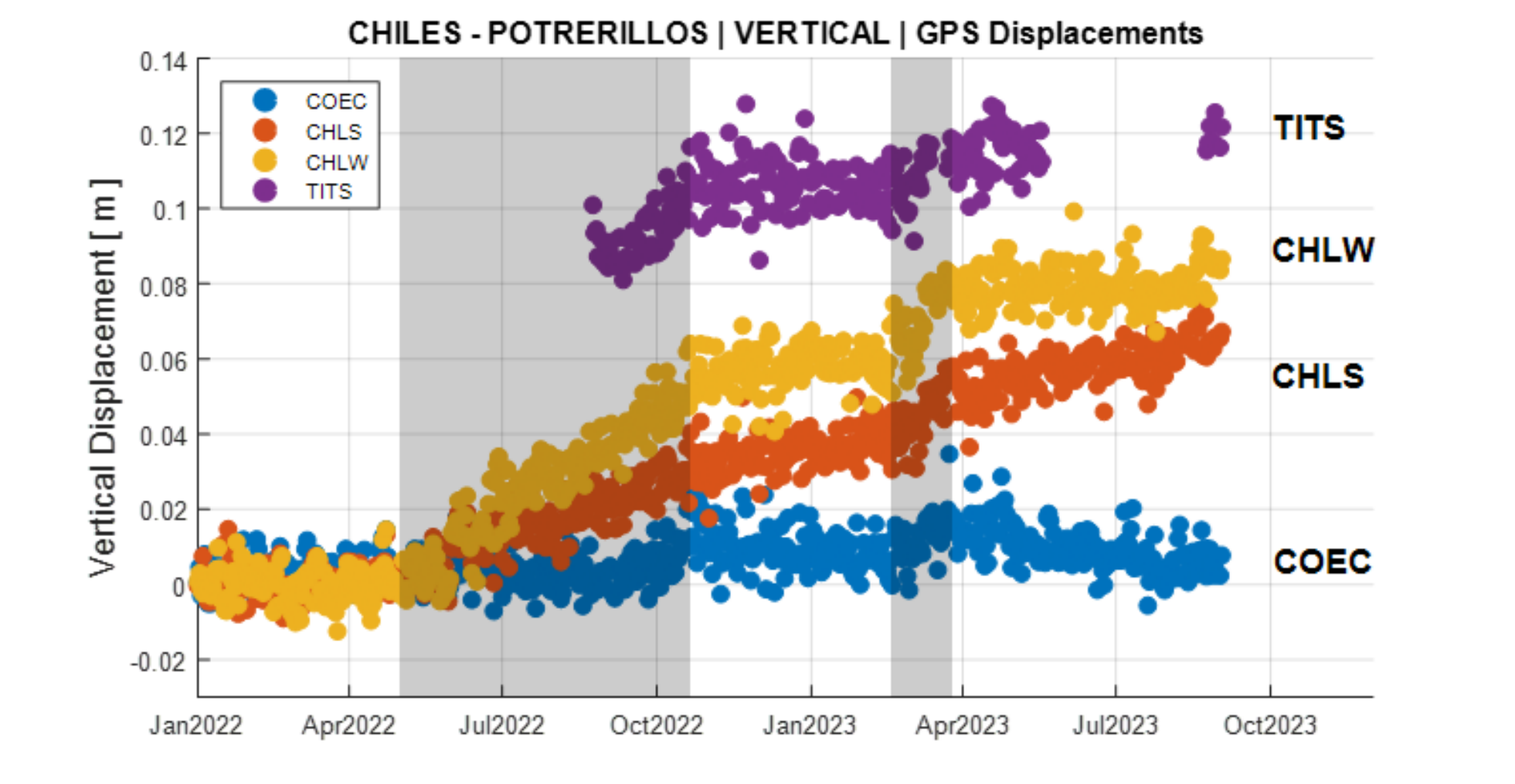
The swarm began on March 9, 2023.
Episode was the second most intense following 2014-2015 episode.

This period draws our attention since a greater number of LPs (Family 5) (shallower) was observed in comparison to previous periods

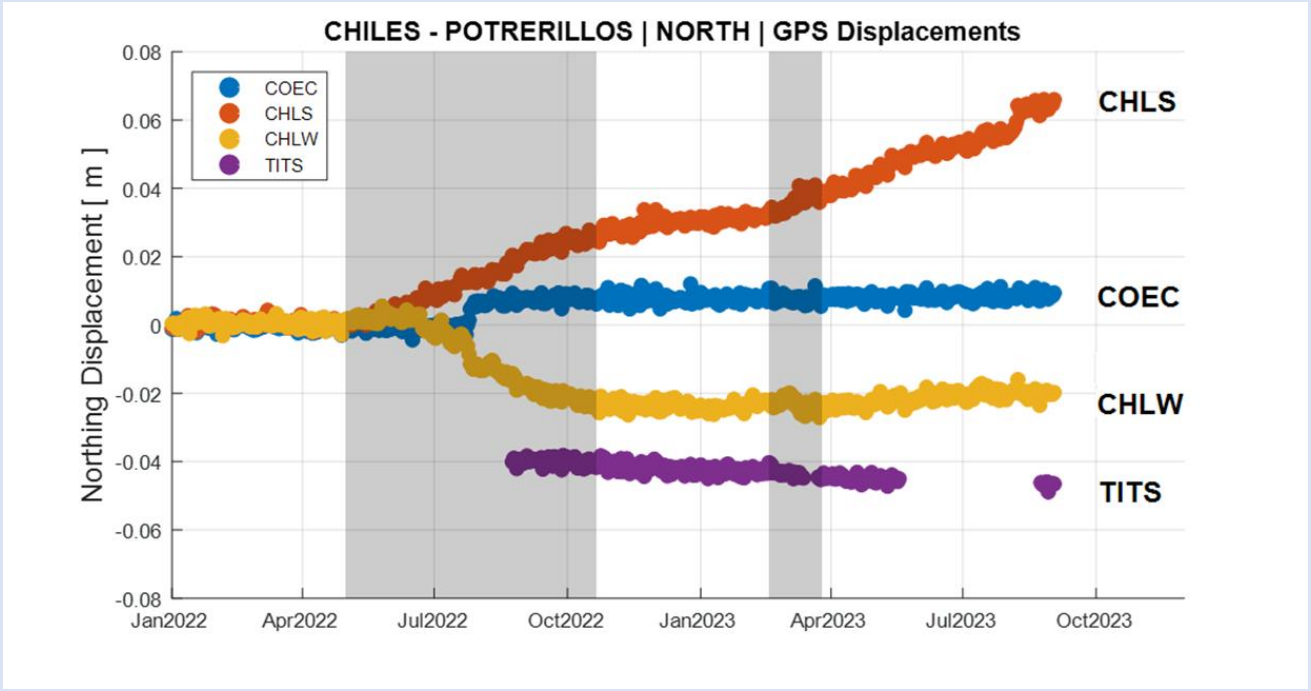


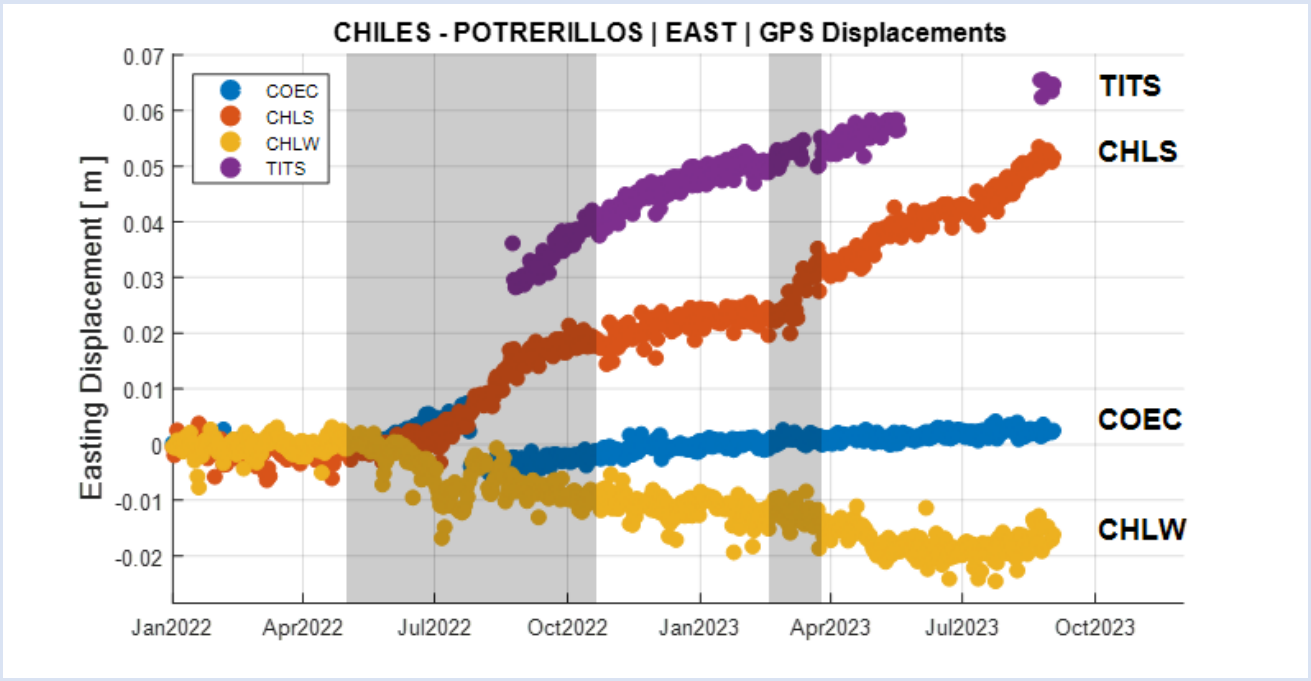
The GPS Registry:

Map of GPS velocities, covering 60 días, between March and May 2023. Vectors are representative of 2022-2023 trends.



Beginning in May 2022_vertical displacements at CHLW-GPS were approx. 90 mm/yr (3 y 4 times greater than the rate in 2014 to 2021).

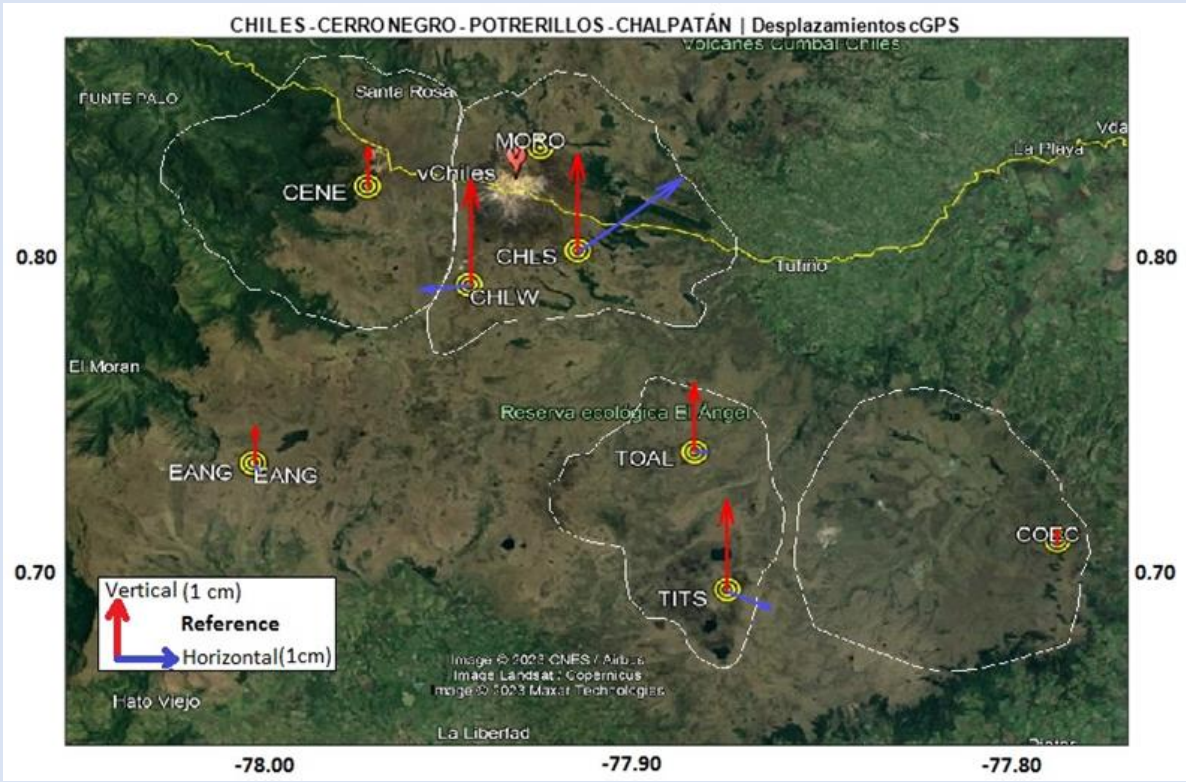


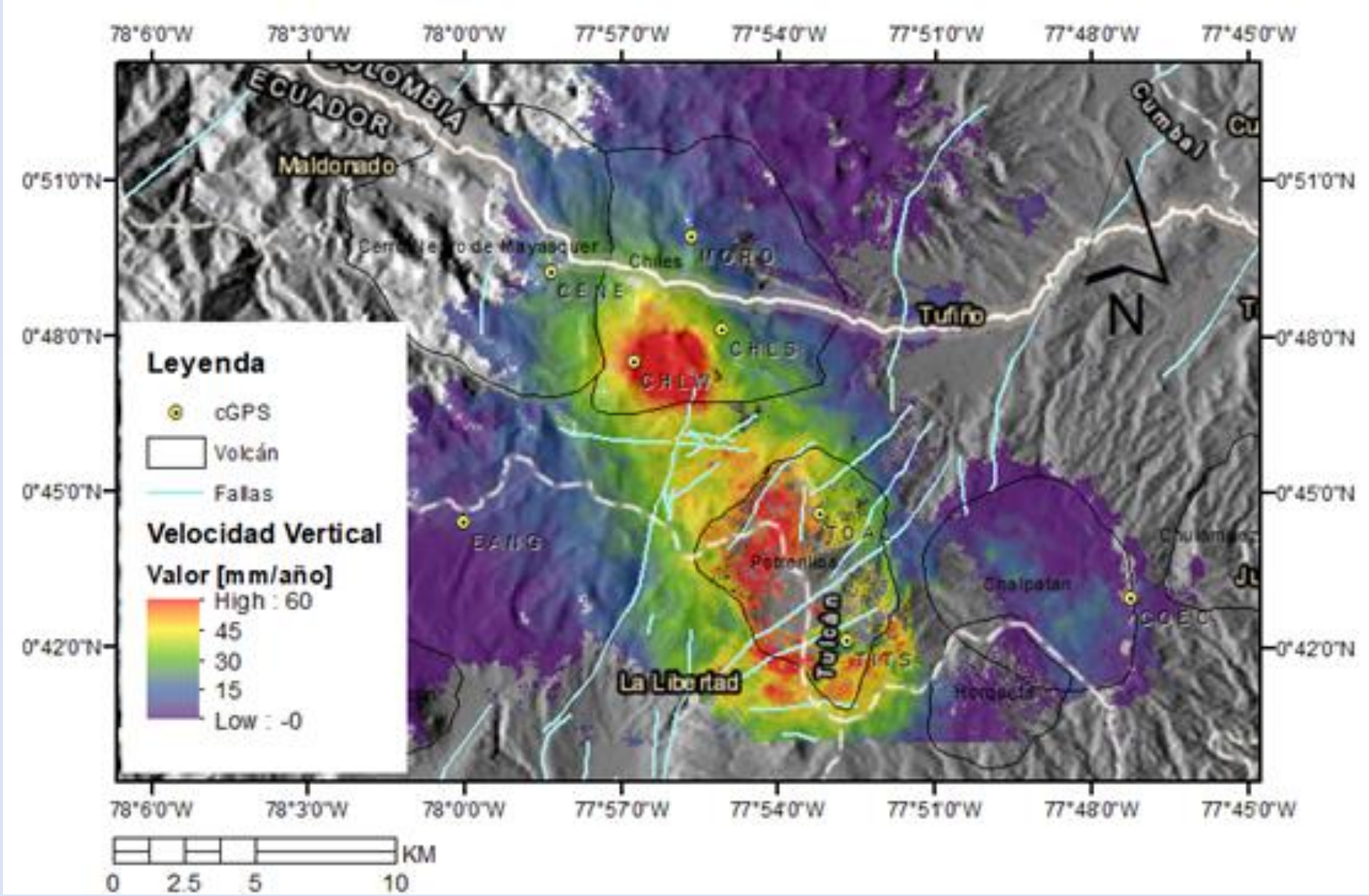


11 - 15 SEPTEMBER 2023 UNIVERSITY OF LEEDS

FRINGE 2023

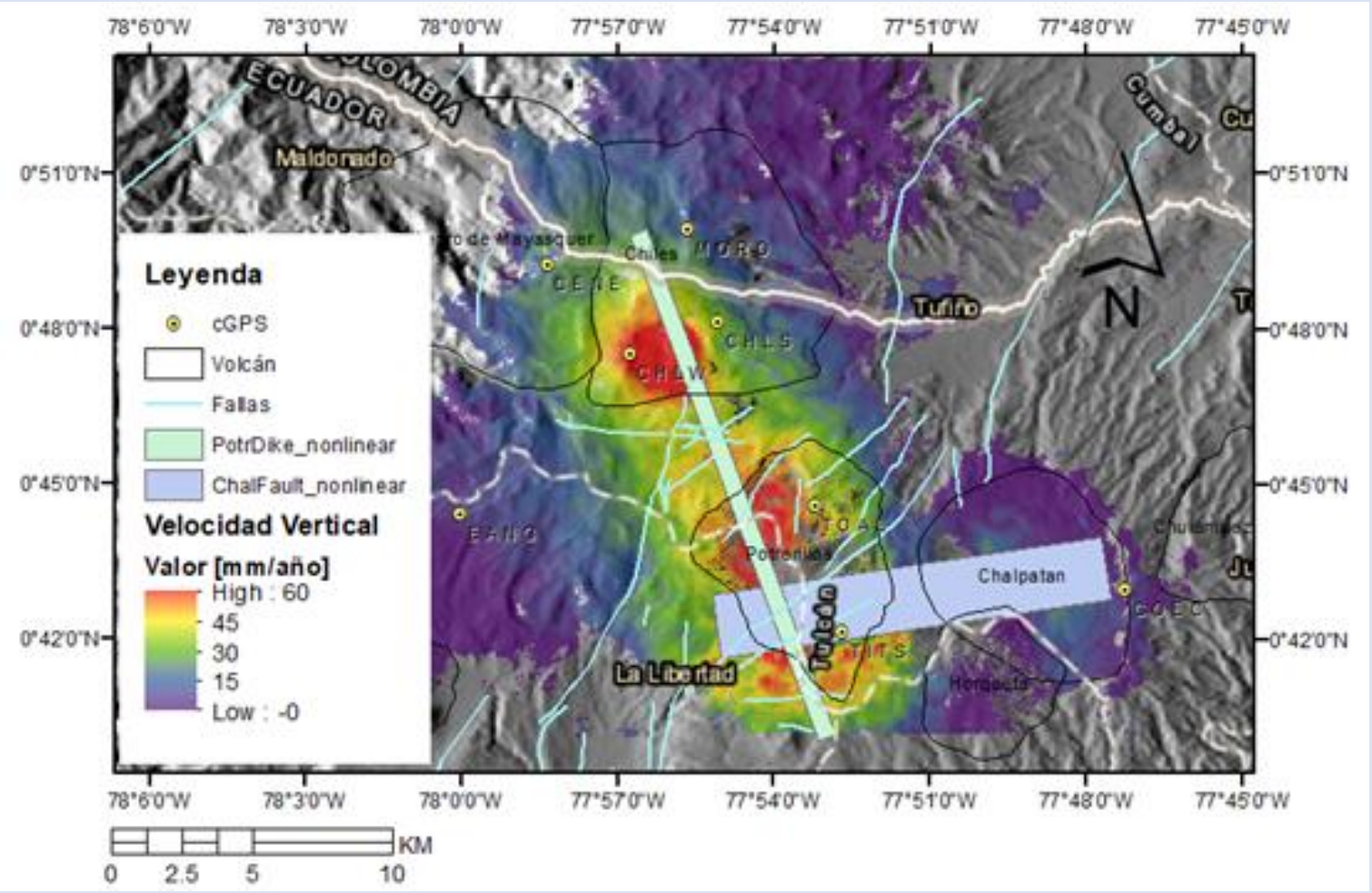
The GPS Response:





InSAR Results

Sentinel-1 InSAR velocity map created by decomposing ascending and descending orbits. Ascending orbits from April 2022–February 2023, and Descending orbits from January 2022 to March 2023. Shown here is the vertical component´s average velocity.



Prelinimary Modeling

Best fit is obtained with two sources :

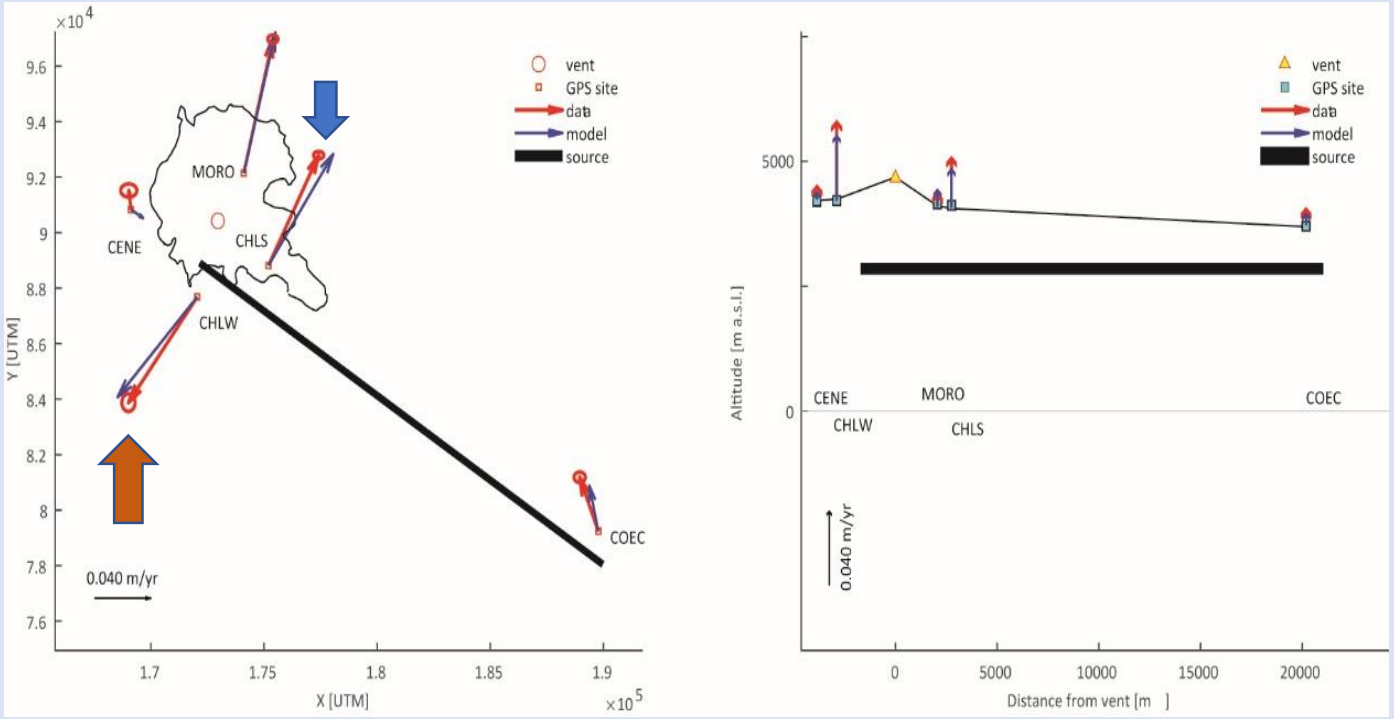
1) Chiles – Potrerillos (Volcanic Source) - Dike

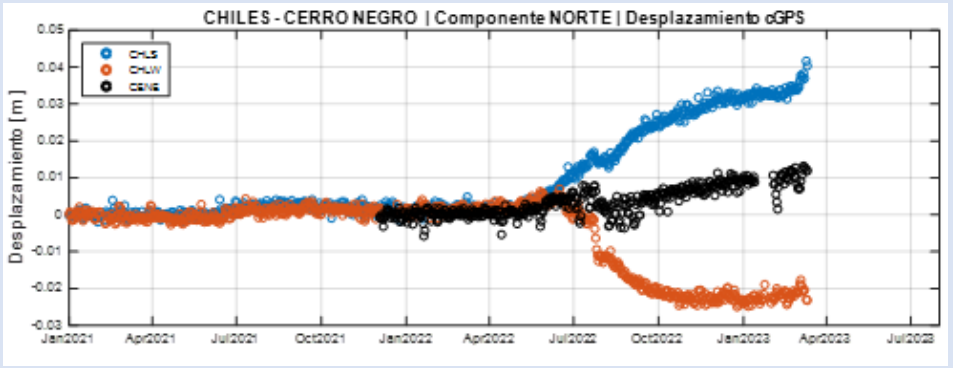
Length: 19248.2 m
Width: 801.5 m
Depth: 3449.4 m (bajo nivel del mar)
–> **8.15** Km Chiles summit
Dip: 35.63 deg
Opening: 0.2471 m
Volumen change: 3.81 millones de m^3

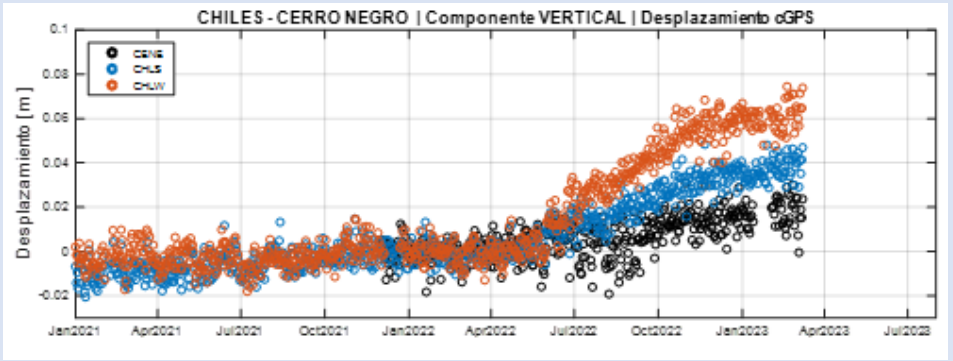
2) Chalpatán (Tectonic EQ_25-julio-2022)

Length: 14077.6 m
Width: 4652.8 m
Depth: -3097.4 m below sea level
Dip: 60.87 deg; Strike: 261.58 deg; Rake: 180.00 deg; Slip: 0.1841 m]
Geodetic Moment: 3.62E+17 N*m

Dike solution from modeling GNSS deformation velocities



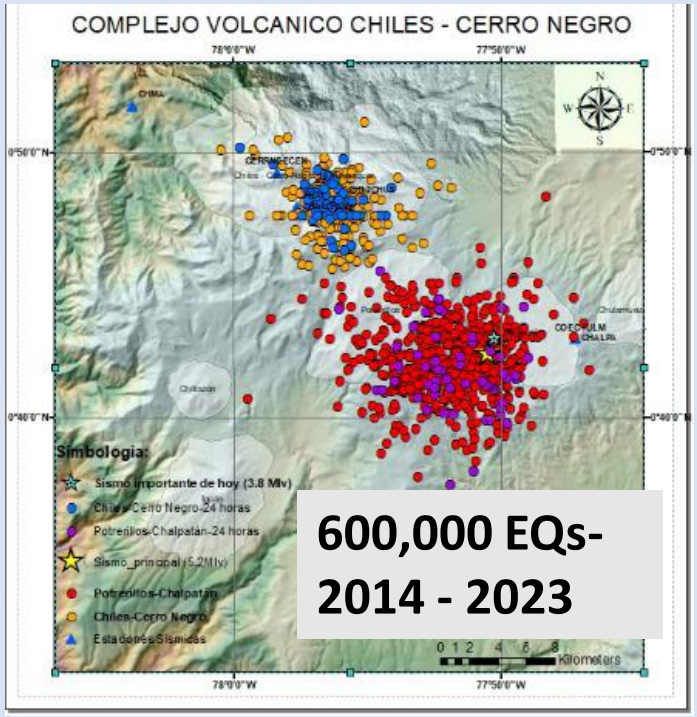


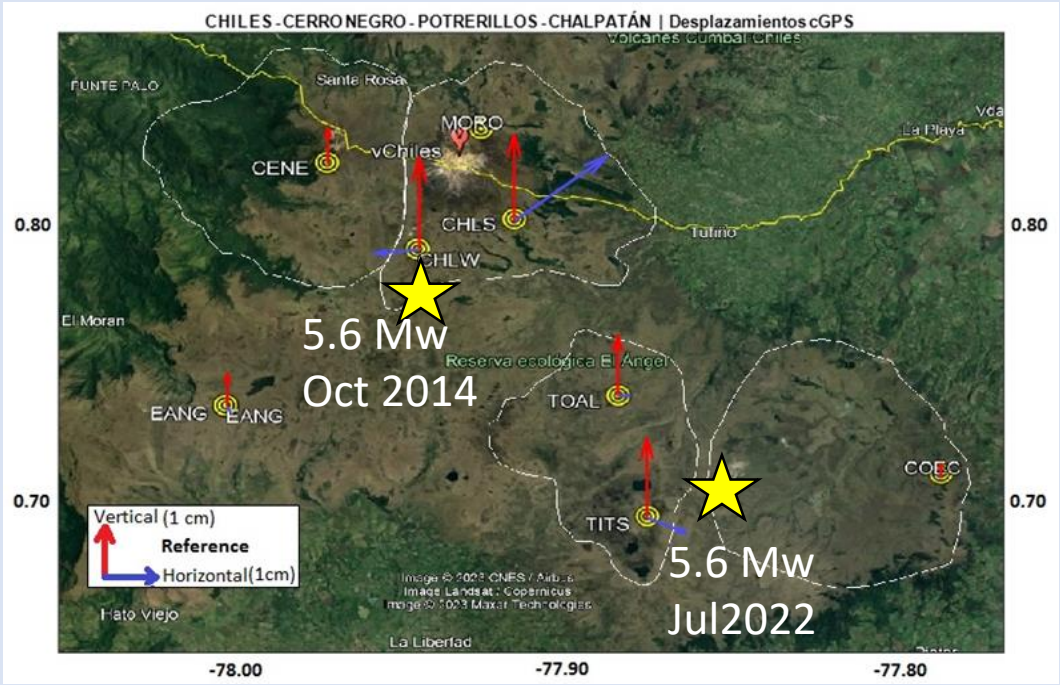


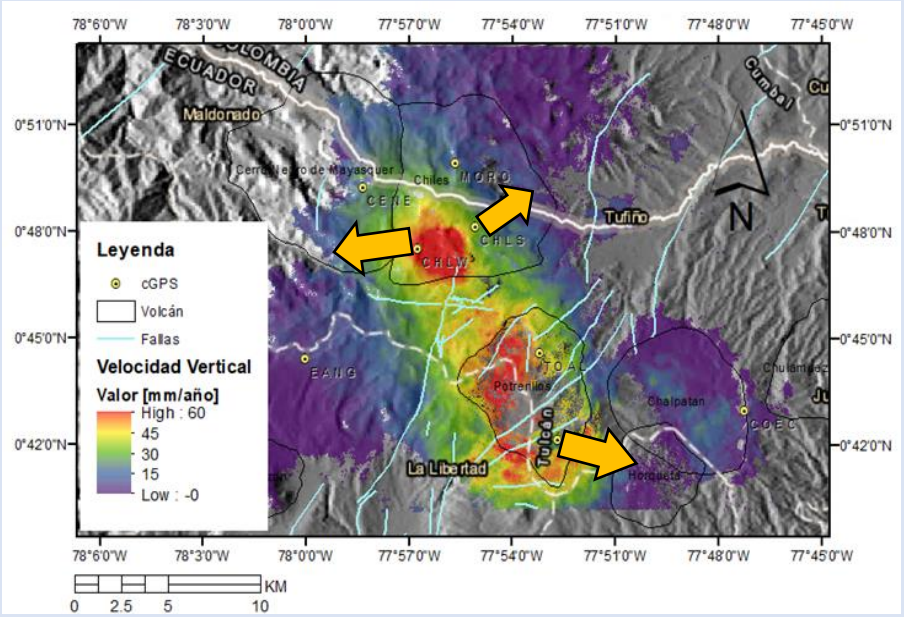
Modelling of GNSS deformation velocities from 2022 using an opening dislocation (dike). Depth and location are relative to the Chiles summit (172963 N 90423 E, UTM 18N, 4650 m. a.s.l.)

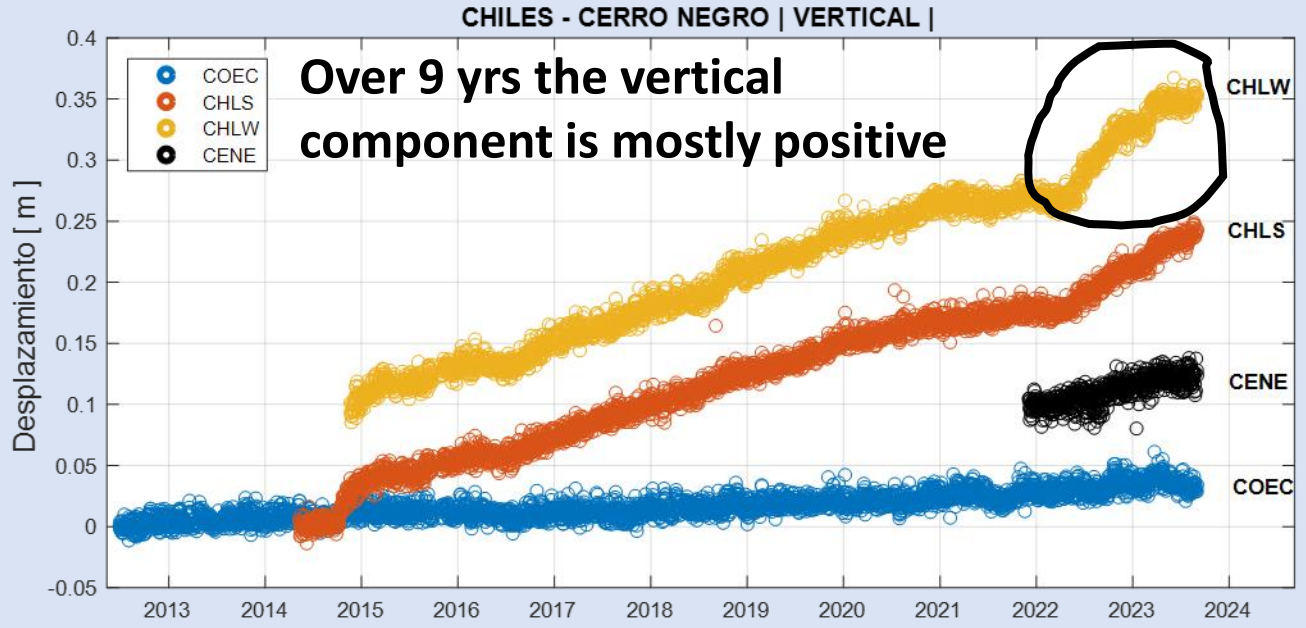
Data set				Location				Depth		Dip angle	Opening	Volume change
								Top	Bottom			
	X2v	N	p	Xi	Yi	Xf	Yf	Zt	Zb	dip	U	dV
				km	km	km	km	km	km	dd	m	km^3
GNSS	11.5	15	8	-0.8 ± 1.1	-1.5 ± 2.4	17.0 ± 5.4	-12.4 ± 3.4	1.5 ± 1.3	2.0 ± 0.8	81 ± 20	5 ± 1	0.024 ± 0.008
InSAR	0.3	3692	8	7.1	-3.8	6.2	-7.6	5.8	7.3	13	0.23	0.006

Putting it all together- graphic summary:





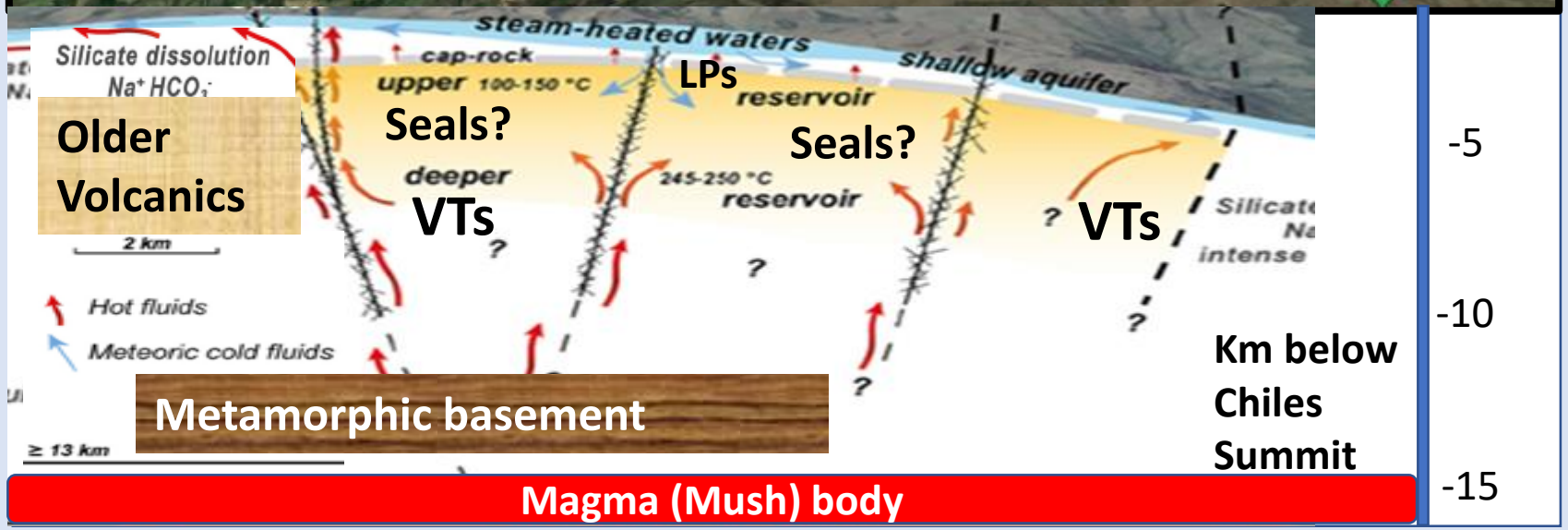




W


Santa Rosa
Chiles
Nest
Volcanes Cumbal-Chiles
Guan
Cumbal
La Union
Reserva ecológica El Ángel
Tufiño
20 km
Portrerillos-Voladero Nest
Laguna El Voladero

E


Silicate dissolution
Na+ HCO3-
Older
Volcanics
steam-heated waters
cap-rock
upper 100-150 °C
reservoir
LPs
Seals?
deeper
245-250 °C
reservoir
VTs
Seals?
VTs
shallow aquifer
intense
2 km
Hot fluids
Meteoric cold fluids
Metamorphic basement
≥ 13 km
Km below
Chiles
Summit
-5
-10
-15
Magma (Mush) body

Conclusions:

Incipient deformation is precursor and synchronous to seismic swarm reactivation. Deformation continues at CHLS GPS station after swarm activity ceases.

Seismic nest activity occupies areas at/next to old dormant volcanoes.

VT events are concentrated at 4-8 km below Chiles summit (4600 m) in the metamorphic basement, where magma may be concentrating at contacts. Magma bodies are pushing upward and creating notable deformation, detected by InSAR and GPS resulting in ~30 cm uplift in 9 yrs, with only two short episodes of deflation.

Lateral expansion of the seismic nests and deformation fields may be due to redistribution of stresses on regional SW-NE trending faults

In the future if magma ascends closer to the surface, breaking seals and disrupting the hyrothermal system, then deformation may accentuate, spawning hotsprings and geysers in new áreas. So far no significant changes have been observed in frequently sampled warm springs at the base of Chiles or Potrerillos-Voladero Caldera.

The two 5.6 Mw EQs in 2014 y 2022, both on the perimeter of seismic nests and deformation halos, are likely the result of the disruption by magmatic pressures of the stress fields of local faults, leading to rupture of these faults.

Preliminary modeling of GPS and InSAR data suggests that a dike is being emplaced NW-SE, a hypothesis coherent with the vectors of the main GPS stations near the Chiles nest and the expansion of InSAR halos.

Pyroclastic deposits of past eruptions were H2O-rich, of high silica content (~70 wt% SiO2), were explosive, and occurred 15-20 kyBP.

Thank you!

pmothes@igepn.edu.ec

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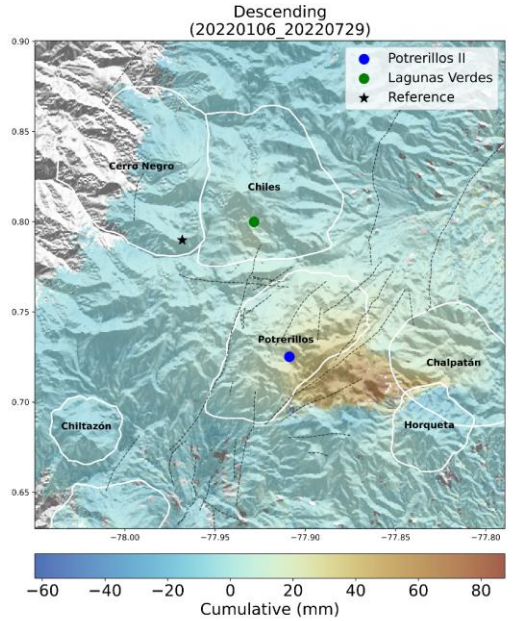
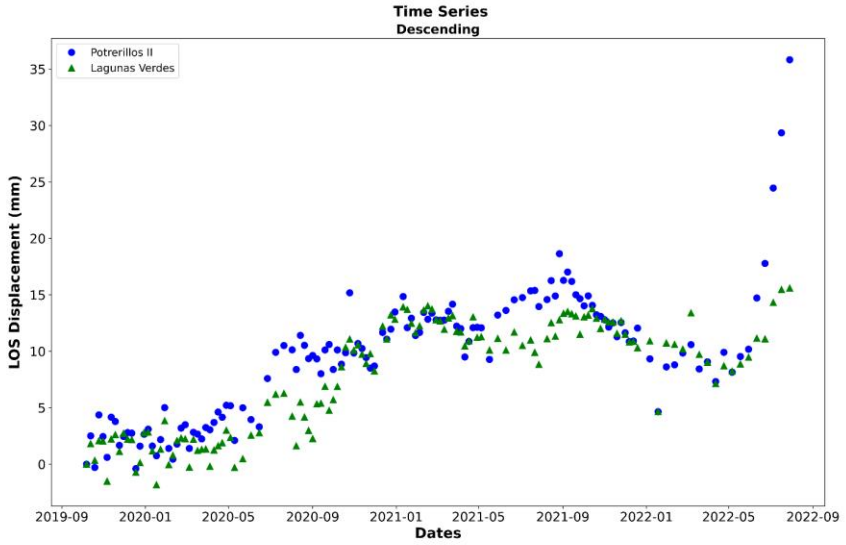
EQ 25 July 2022

El Voladero-

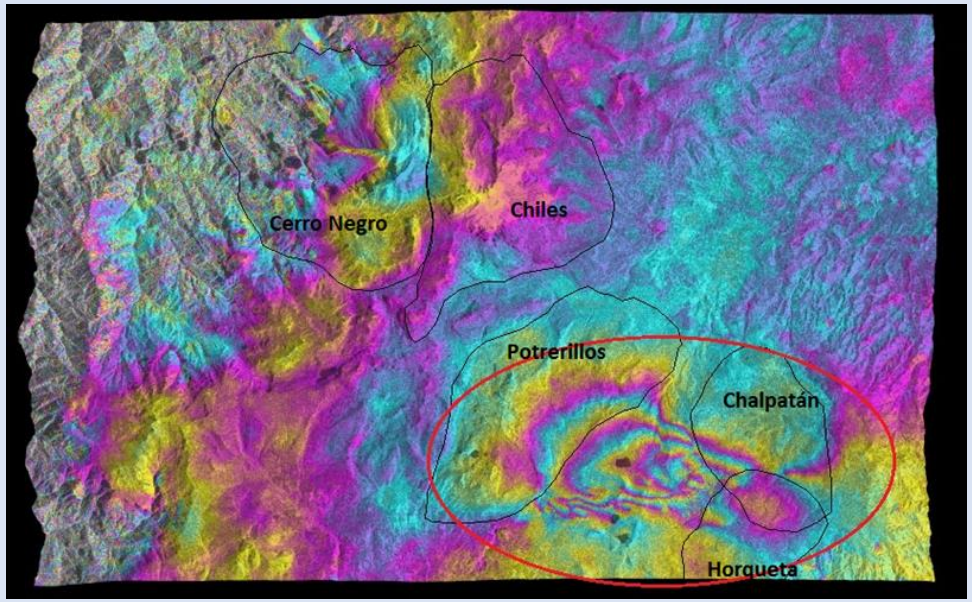
5 km Depth

5.6 Mw





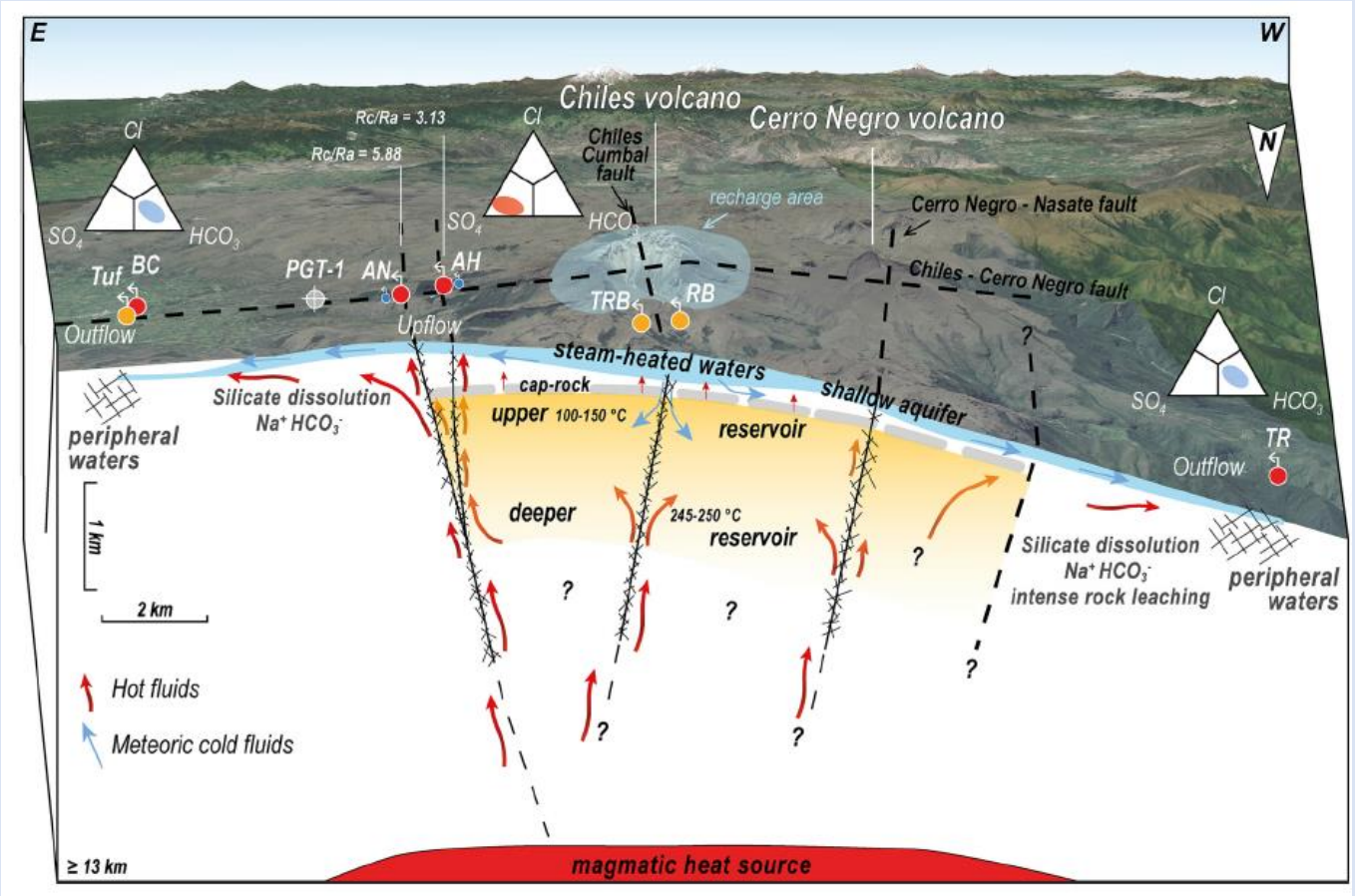
Descending

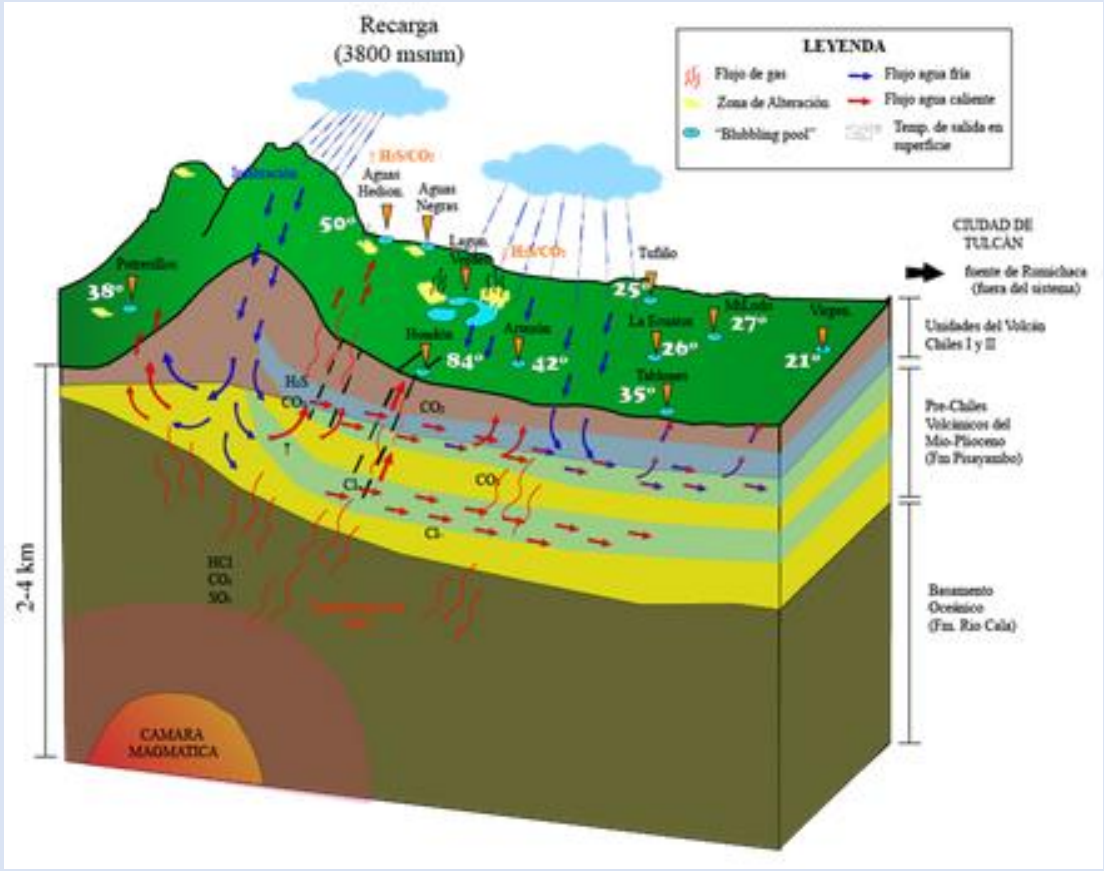


Pedro Espín, 31 July 2022

COMET web page

Graphic Conclusions:

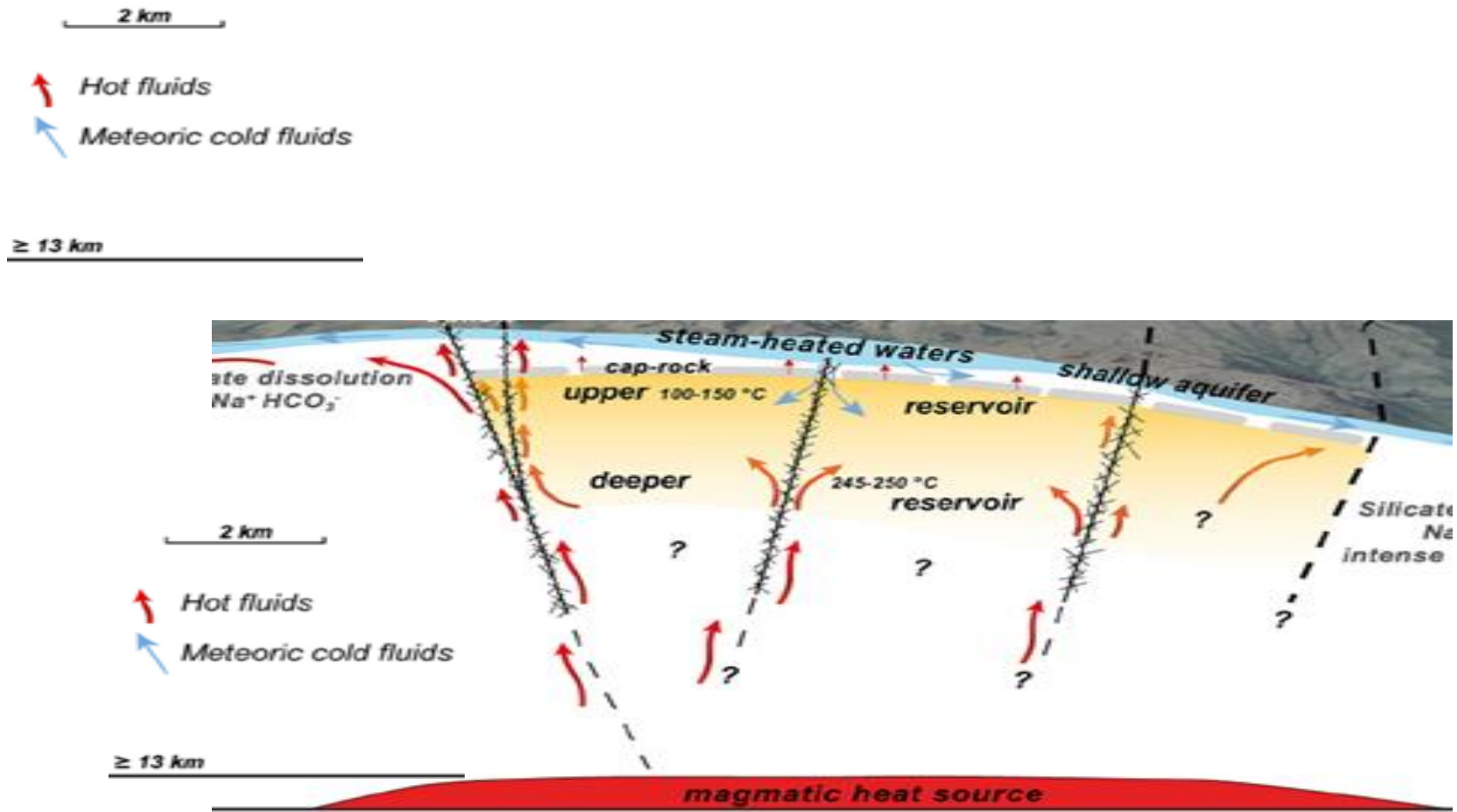




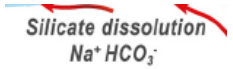
D. Sierra, 2022

Hacer un hibrido acá

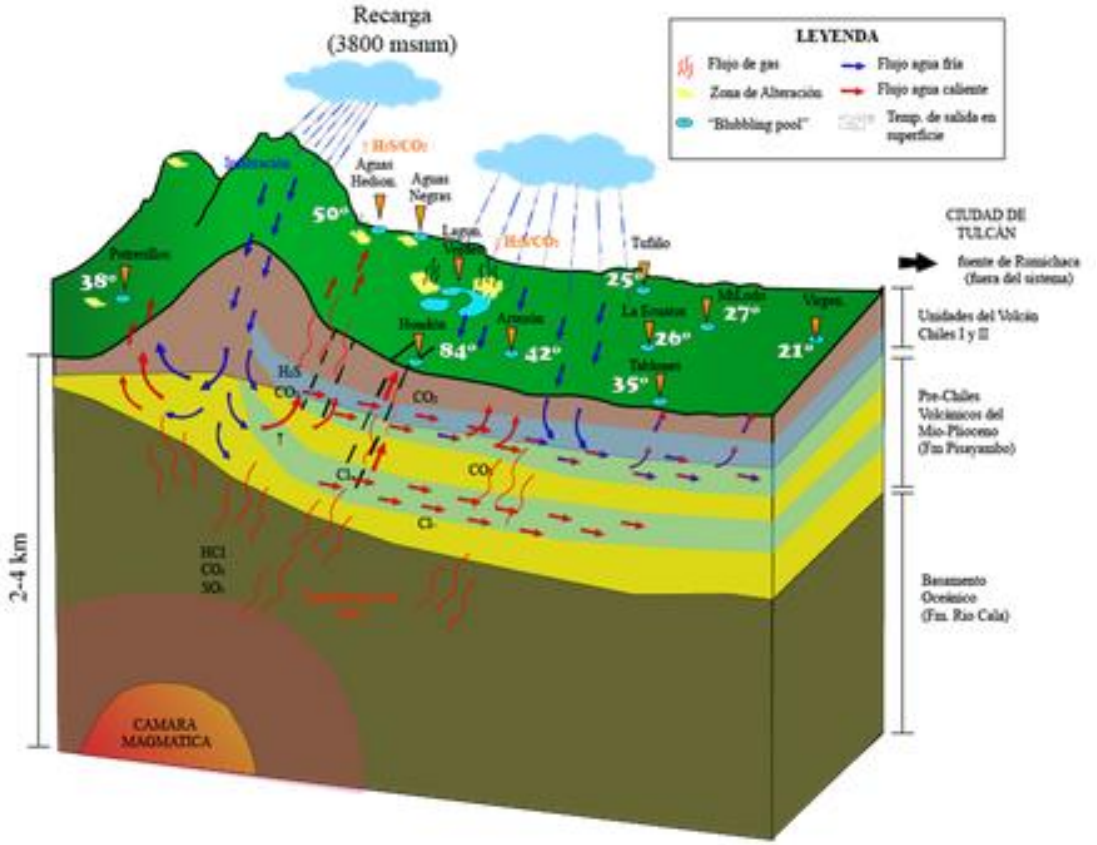
Taussi et al., 2022


2 km
Hot fluids
Meteoric cold fluids
≥ 13 km
steam-heated waters
cap-rock
shallow aquifer
upper 100-150 °C
reservoir
deeper
245-250 °C
reservoir
intense
magmatic heat source

Graphic Conclusions:



Taussi et al., 2022



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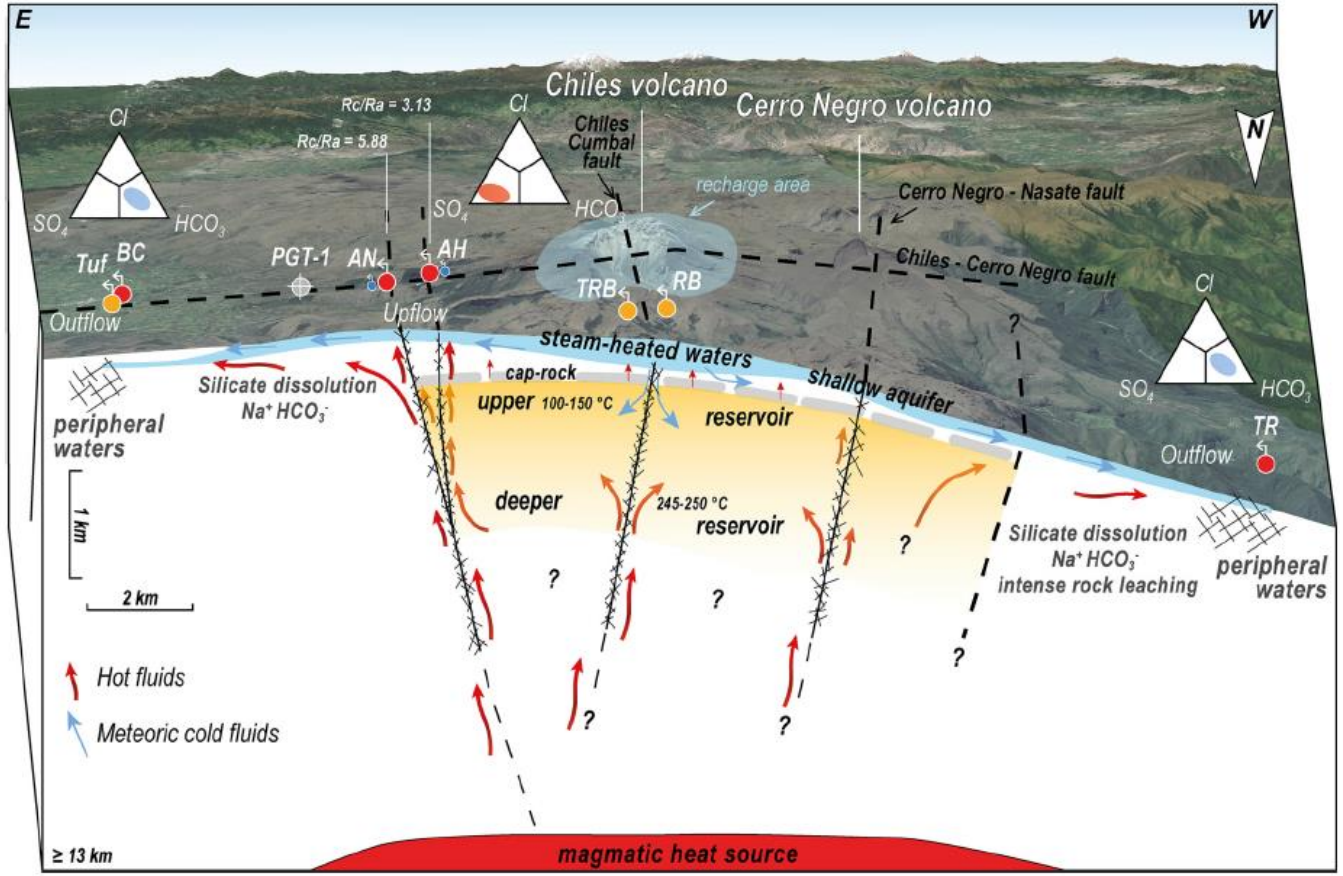
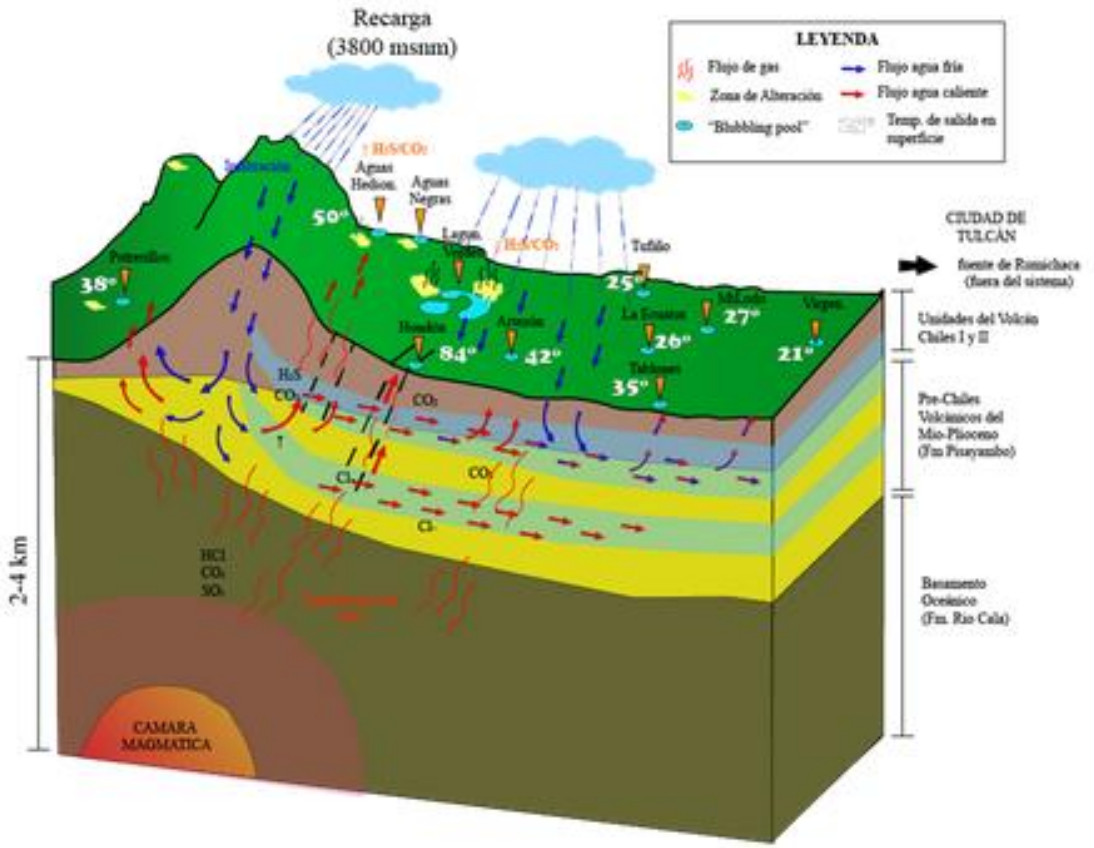
Graphic Conclusions:





D. Sierra, 2022

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