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# *AndesNet and Monitoring Systems in Chile*

- ***AndesNet** (Chilean Coordination Network of Subduction Zone Scientists)*
- *Brief description of the Civil Protection System and monitoring systems regarding*
  - *Earthquakes*
  - *Tsunamis*
  - *Volcanoes*

*Sergio Barrientos, National Seismological Center, University of Chile,  
with the collaboration of  
Álvaro Amigo (SERNAGEOMIN) and Carlos Zúñiga (SHOA)*

## **AndesNet** (Chilean Coordination Network of Subduction Zone Scientists)

### **Invitation (AndesNet@gmail.com)**

Email inviting all participants of the Termas El Corazón Workshop (except ANID and Onemi reps.) on Sept. 22. 2022

- Information contact of all participants
- 71 participants filled a form showing interest in networking, voted for AndesNet
- Support letter for AccelNet application
- Meeting announcement (held on November 9, 2022)
- 9 post-docs, 9 Ph.D. and 3 M.Sc. students, 1 consultant, 1 Municipality, 7 SERNAGEOMIN
- 23 young researchers, 24 senior researchers
- Institutional affiliation: 14 University of Chile (3 CSN, 1 AMTC), 3 CKELAR, 2 CIGIDEN, 1 Univ. Mayor, 1 Cyclo

### **Meeting November 9 at 6 pm, one hour, 14 people attended**

- Welcome and presentation of the Executive Committee (until mid-next year) (Laura Bono, Alvaro Amigo, Andrés Tassara, and Sergio Barrientos)
- Presentation of AndesNet and SZNet proposal to AccelNet (AT)
- SZ4D implementation plan (SB)
- Chilean participation in SZ4D Working Groups and Committees
- Houston meeting (AA)
- Open discussion on objectives and tasks of AndesNet



# Monitoring Systems (SINAPRED)



The new law 21.364 recognizes “Technical Bodies” which monitor different threats

Earthquakes

- National Seismological Center, Univ. of Chile

Tsunamis

- National Warning System - Hydrographic and Oceanographic Service of the Navy

Volcanoes

- National Geology and Mining Service (Sernageomin)

Floods

- Water Resources Management Agency (DGA)

- Water Works Agency (DOH)

Forest Fires

- National Forest Corporation (CONAF)

Meteorology

- Chilean Meteorological Agency (DMC)

Nuclear Radiation

- Chilean Nuclear Energy Commission



CATs Regionales



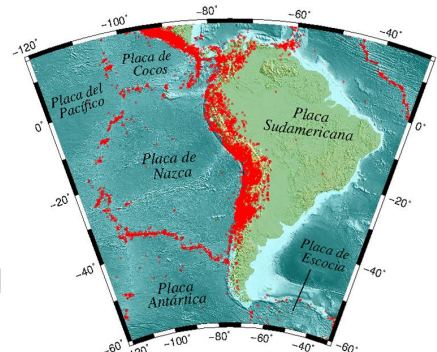
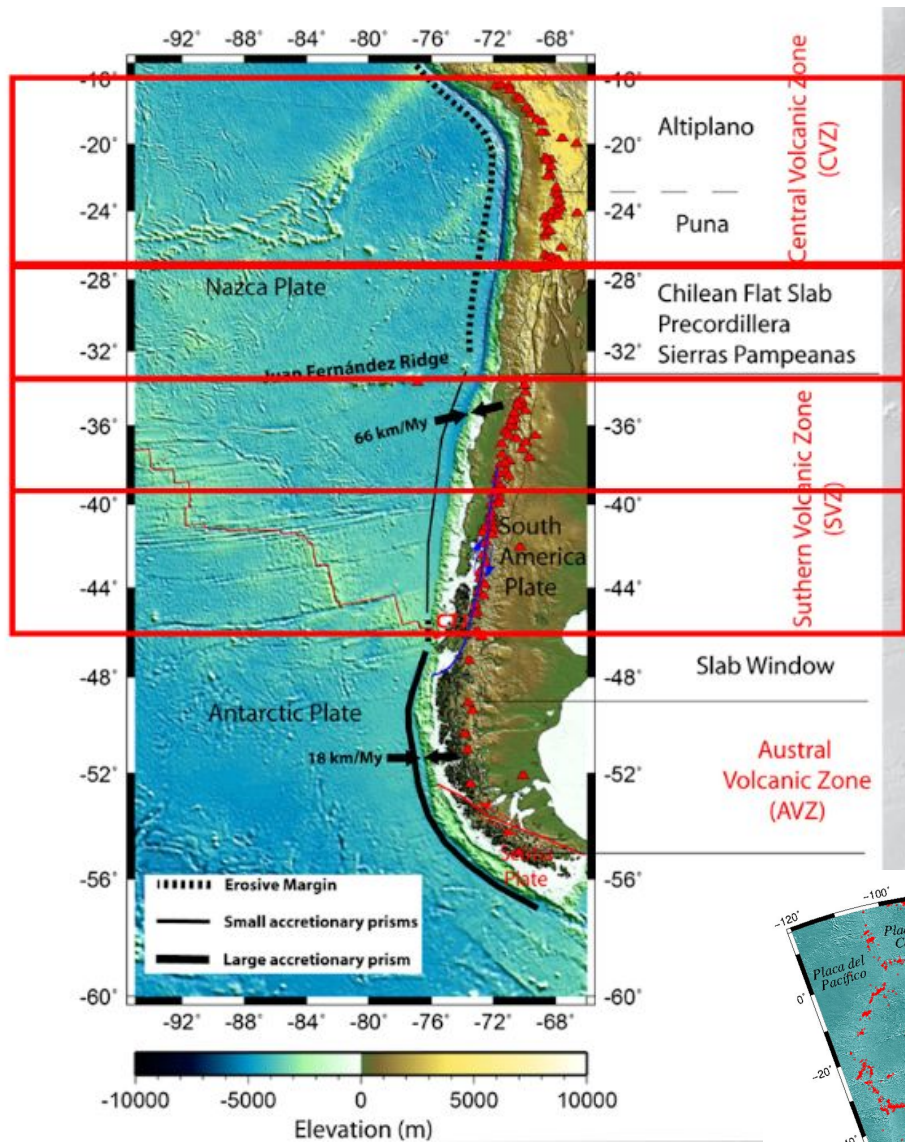
COEs Regionales





# Chilean seismicity

Since 1900.- in terms of disasters of natural origin in Chile, earthquakes, and tsunamis are responsible for 99% of fatalities and 98% of economic loss

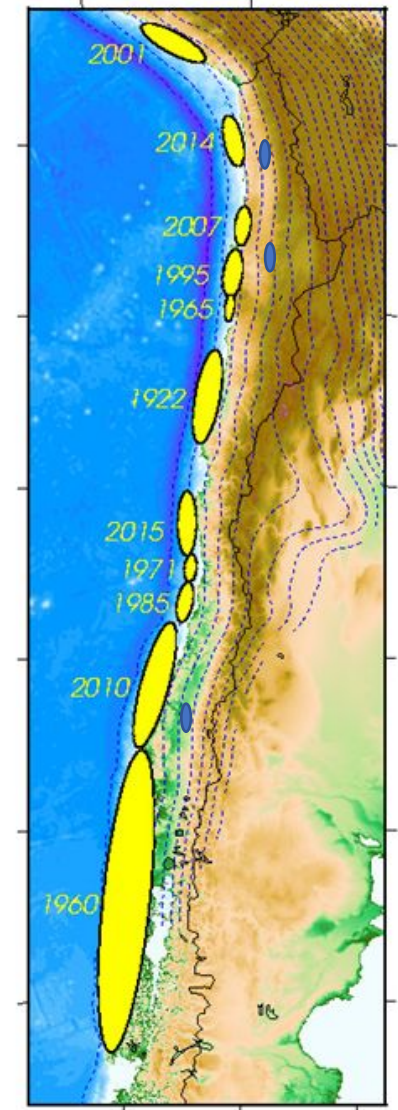


- High seismic productivity rates
  - Number of earthquakes per unit time
  - Giant earthquakes
- Average during the last 450 years:
  - One earthquake  $M > 8$  every 12 years

**Tsunamis 4 m or more**  
 1570, 1575, 1604, 1657, 1730, 1751, 1819, 1835, 1849, 1859, 1868, 1877, 1918, 1922, 1960, 2010  
 Intervals 5,29,53,73,21,68,16,2,12,10,9,9,41,4,38, 50;  
**Average = 27.5 years**

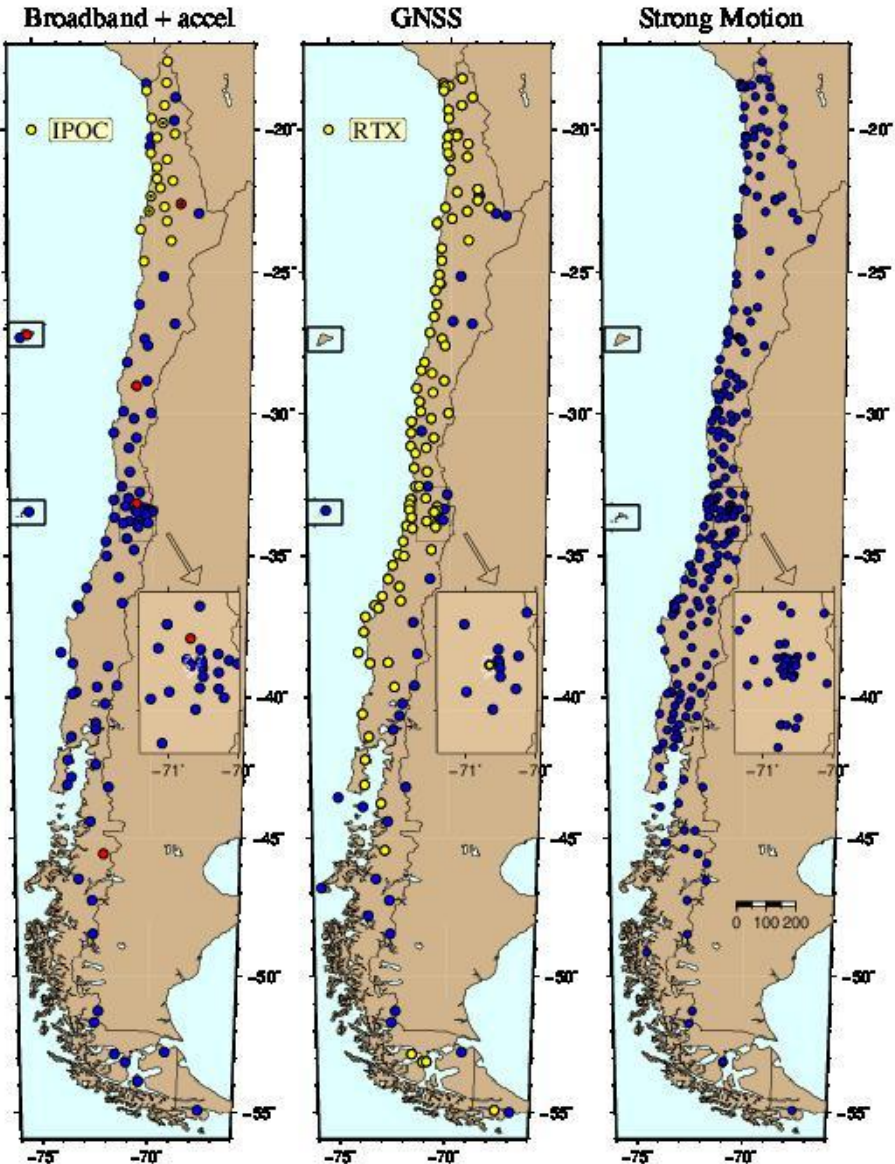


**Tsunamis 10 m or more:**  
 1604, 1730, 1835, 1868, 1877, 1922, 1960, 2010  
 Intervals 126, 105, 33, 9, 45, 38, 50;  
**Average = 58 years**





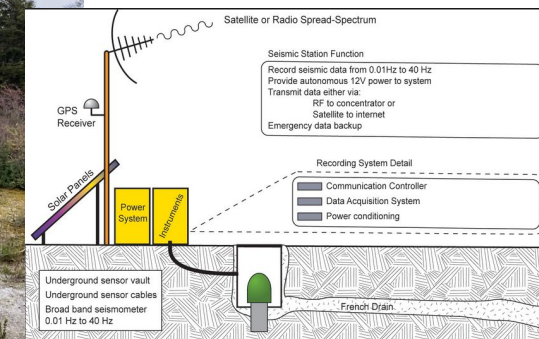
# Observation System



*110 6-component stations  
BB + accelerometers  
25 academic partners  
128 GNSS (100 RTX)  
295 accelerometer Civil engineering  
purposes. (Installed by Minvu Onemi)*

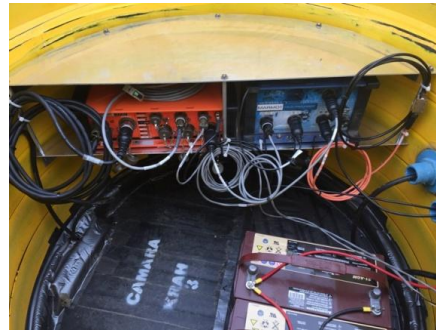
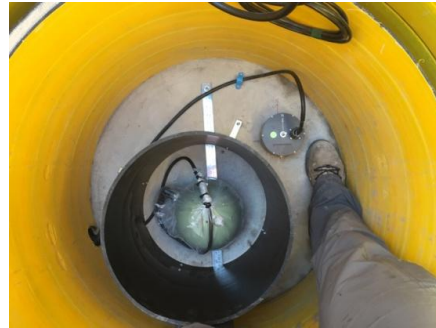


*Foreign stations  
7 Argentina  
5 Peru*





# Installation (VA06 Catapilco)



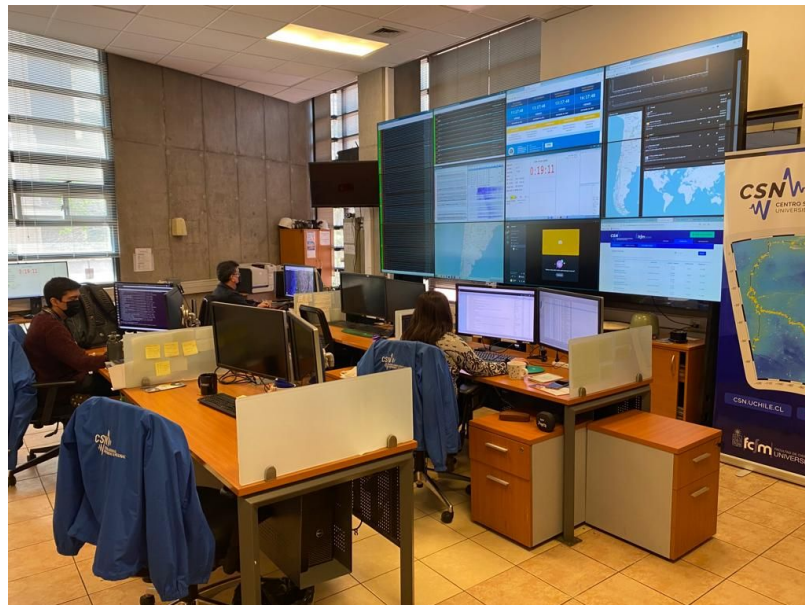


# Seismic Analysis Office (OPA)

Data Center



Early Bird and SeisComP automatic solutions, Seisan final solution

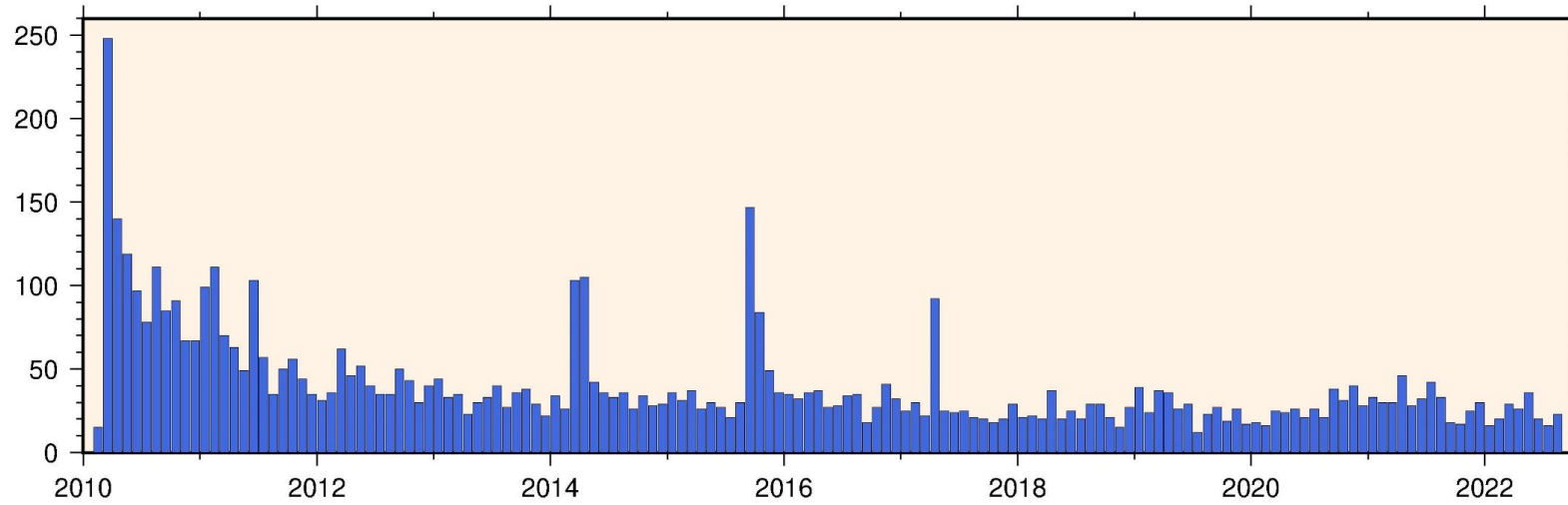


CPTR, installed at Ovdas, Temuco

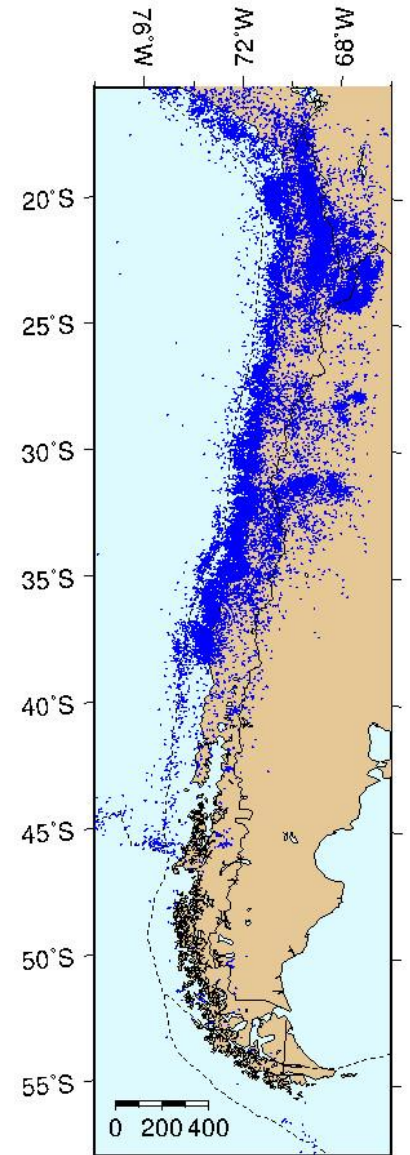
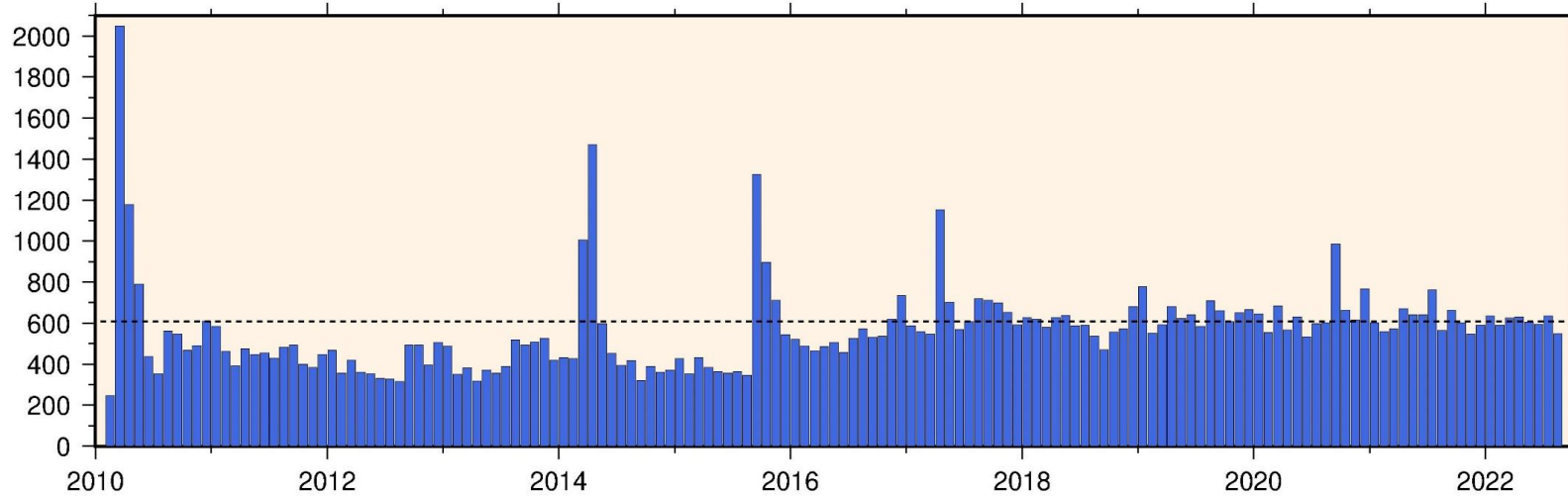


# Seismicity of Chile

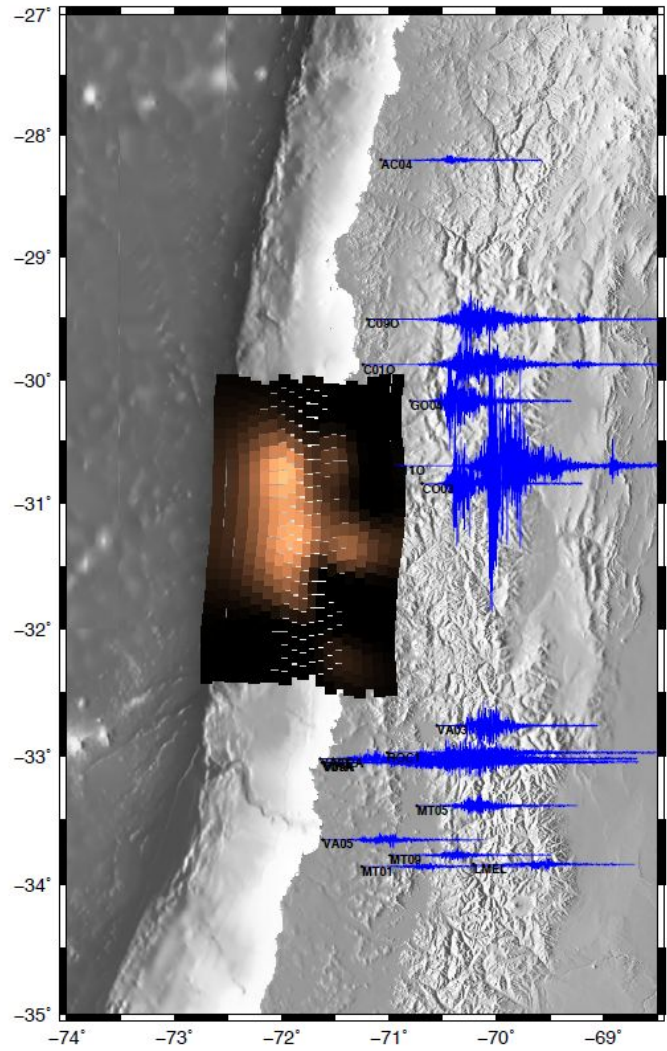
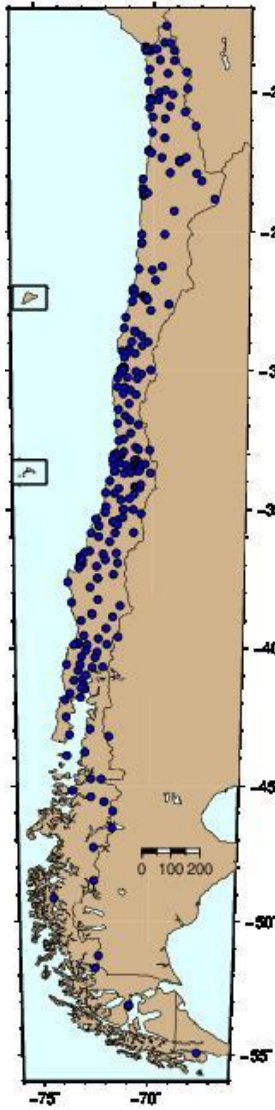
Number of felt earthquakes/month



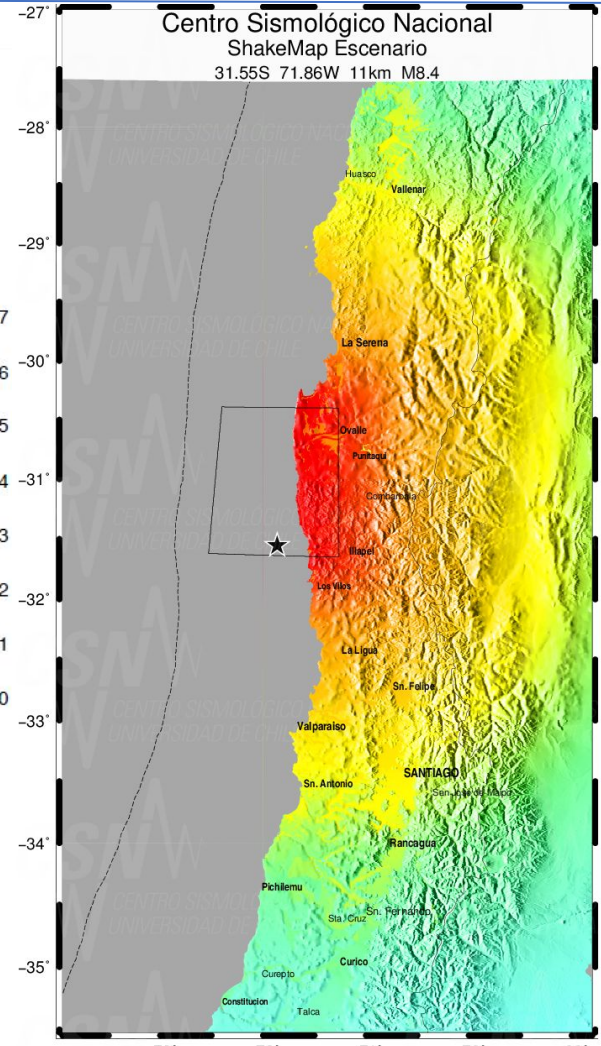
Total number of events/month ( $M \geq 3$ )



# Accelerographic Network

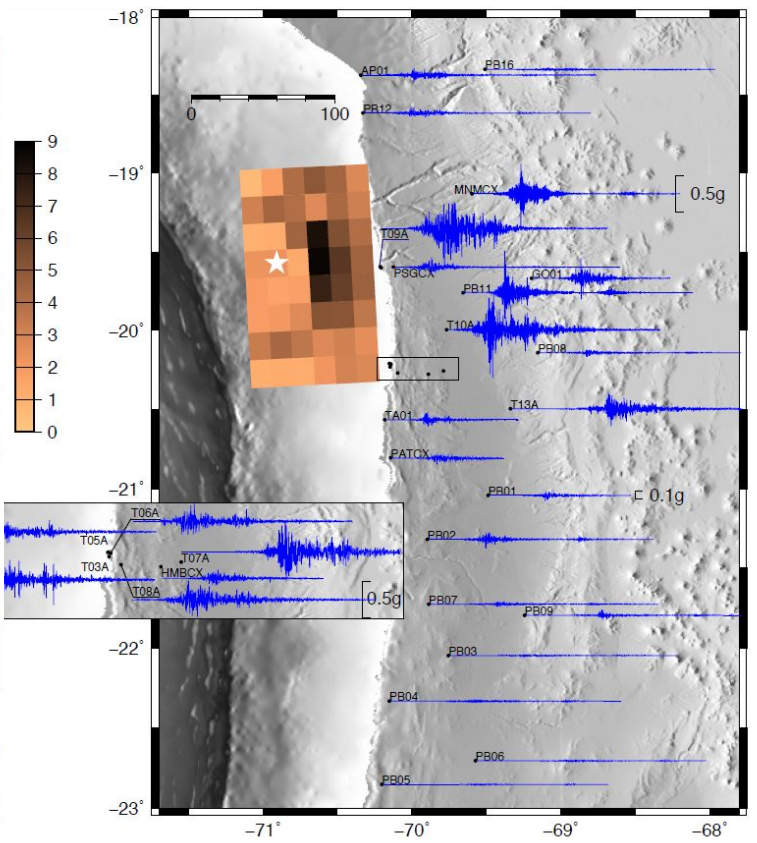


Leyton, 2015



| Percepción              | No sensible | Débil   | Suave    | Moderado | Fuerte   | Muy Fuerte | Severo   | Violento | Extremo |
|-------------------------|-------------|---------|----------|----------|----------|------------|----------|----------|---------|
| Daño Potencial          | Ninguno     | Ninguno | Muy poco | Poco     | Moderado | Alto       | Muy Alto |          |         |
| Acel Max (%g)           | <0.19       | 1.9     | 4.4      | 13       | 24       | 44         | 83       | 156      | >290    |
| Vel Max (cm/s)          | <0.02       | 0.1     | 1.4      | 4.7      | 9.6      | 20         | 41       | 86       | >178    |
| Intensidad Instrumental | I           | II-III  | IV       | V        | VI       | VII        | VIII     | IX       | X+      |

Escala basada en Worden et al. (2011)



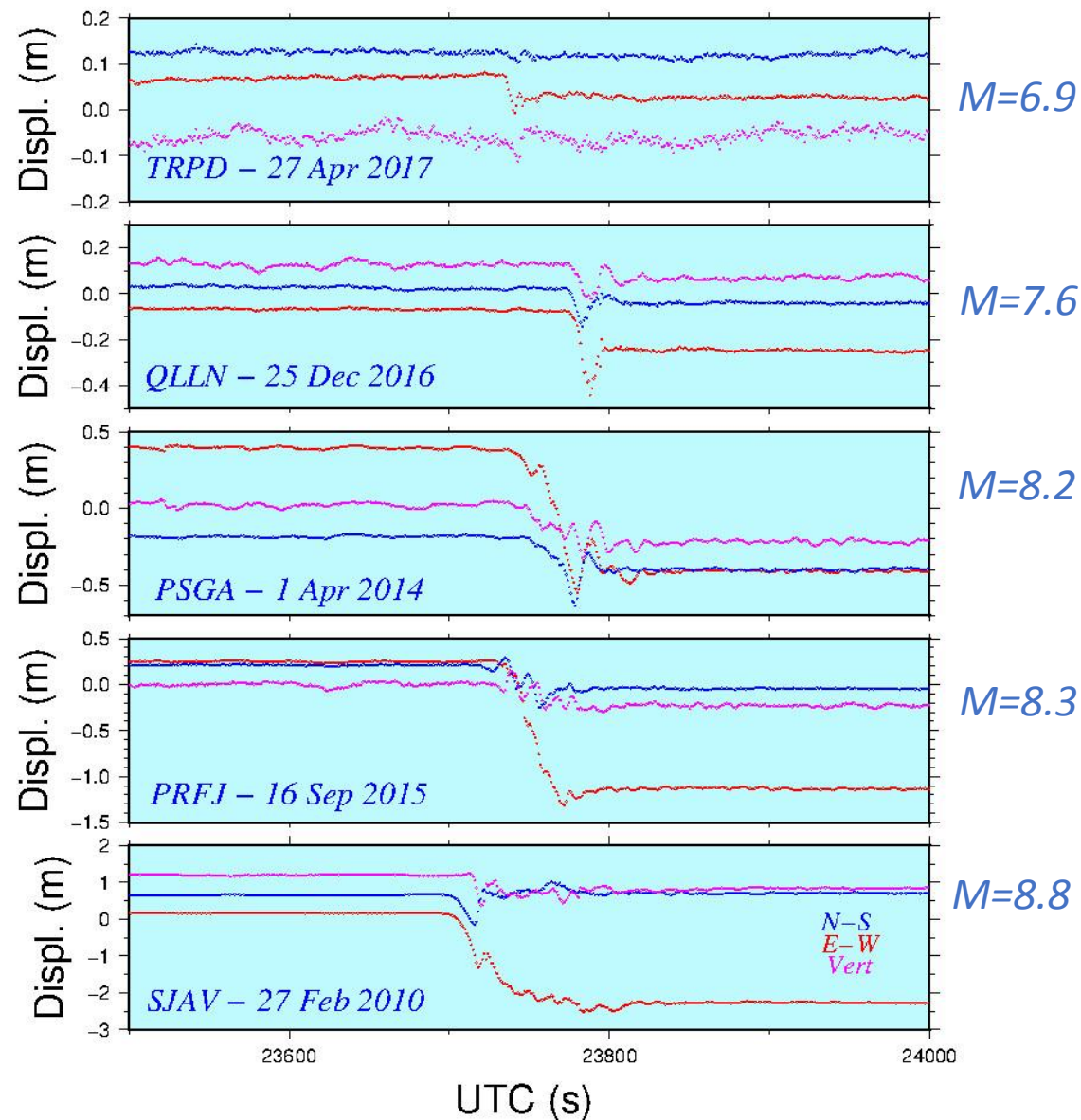
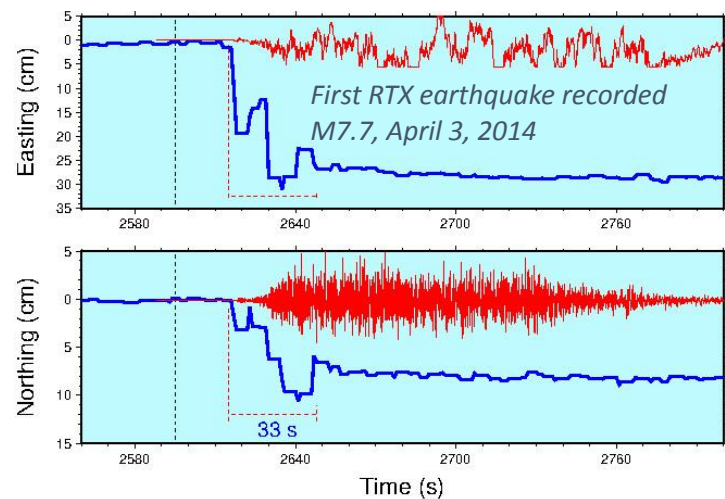
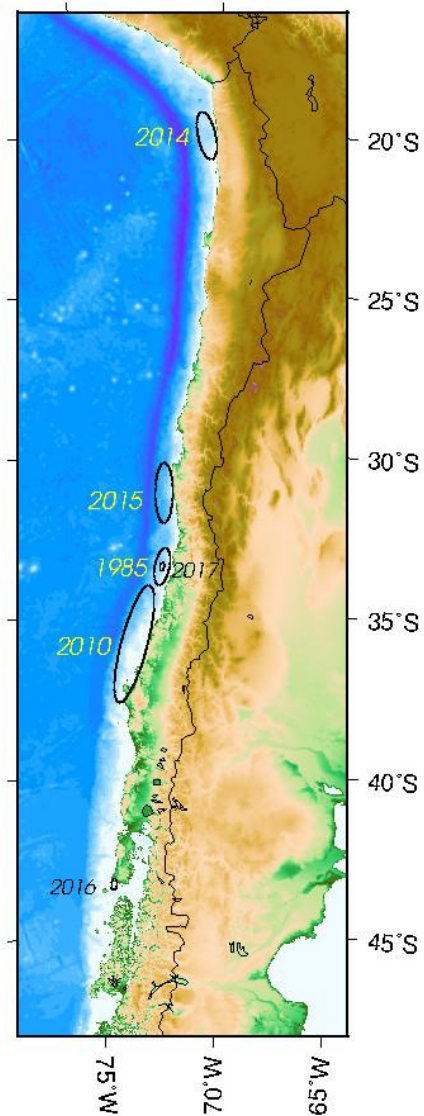
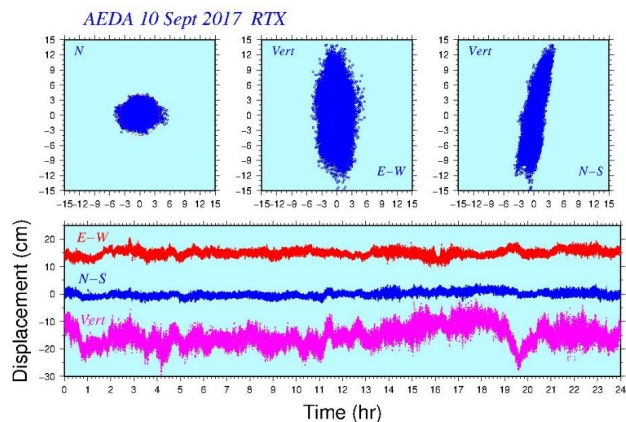
12 698 records of  
2 760 events since  
March, 2012

<http://evtdb.csn.uchile.cl/>



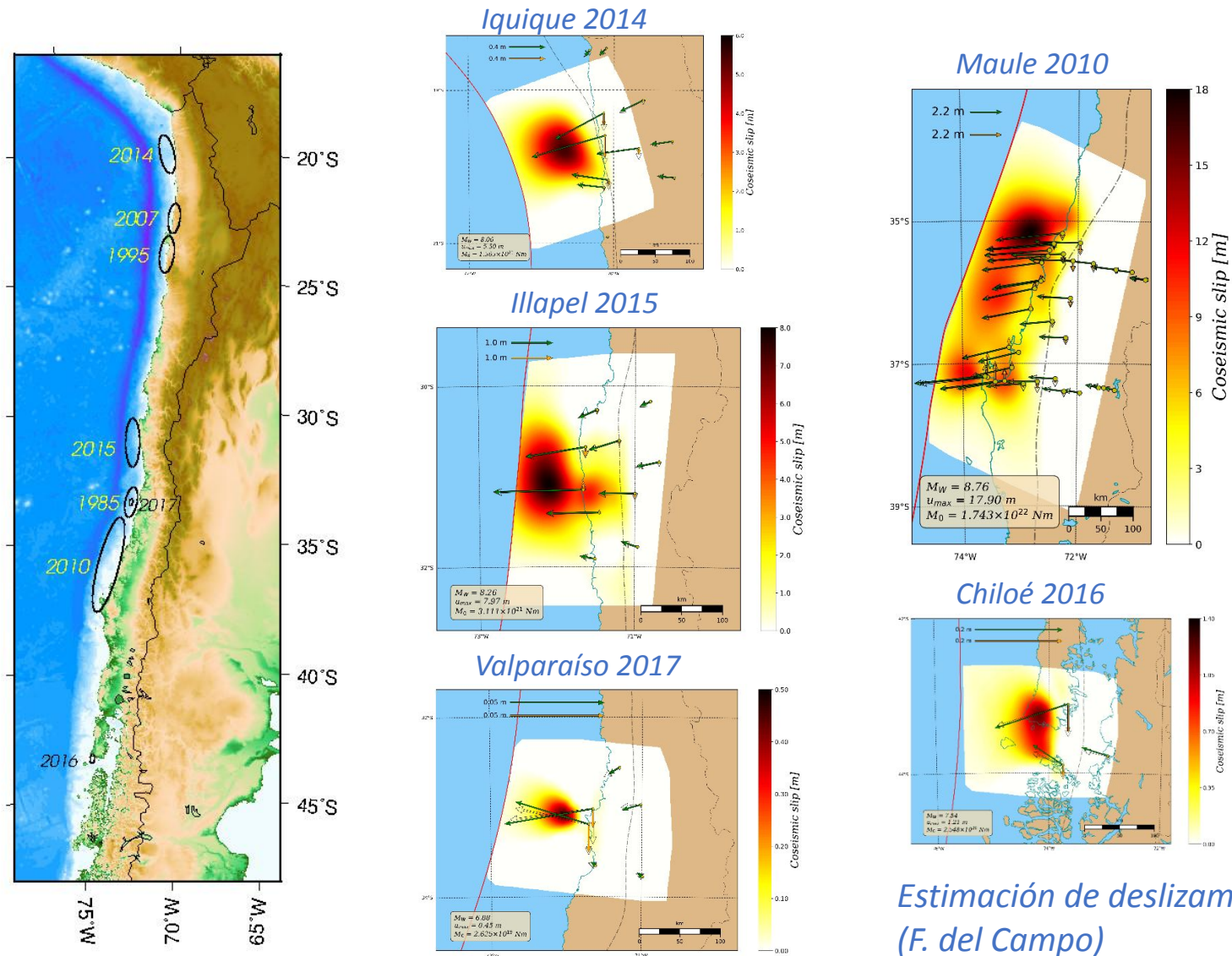
# GNSS records

**RTX** (comercial solution) t, x, y, z: 1 s/s  
 Orbit and clock corrections through a different satellite (error horizontal: 4-cm)





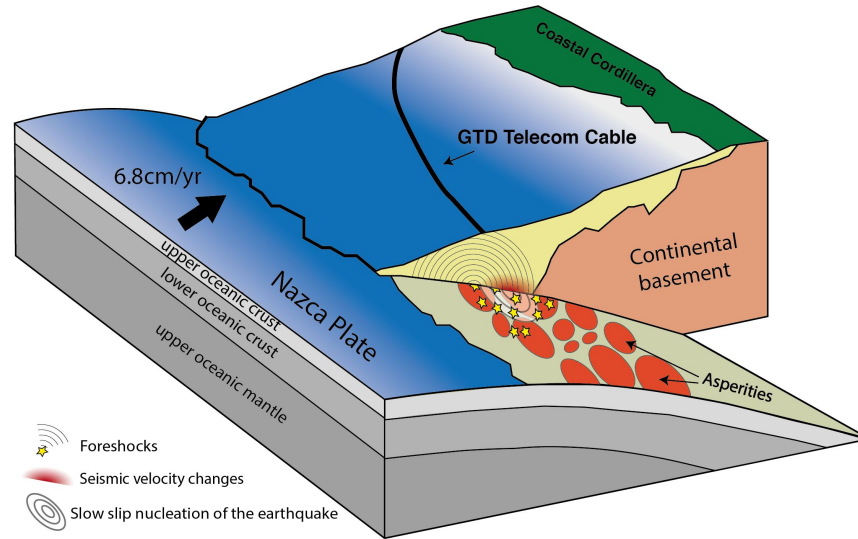
# Recent Large Earthquakes in Chile



Estimación de deslizamiento  
(F. del Campo)

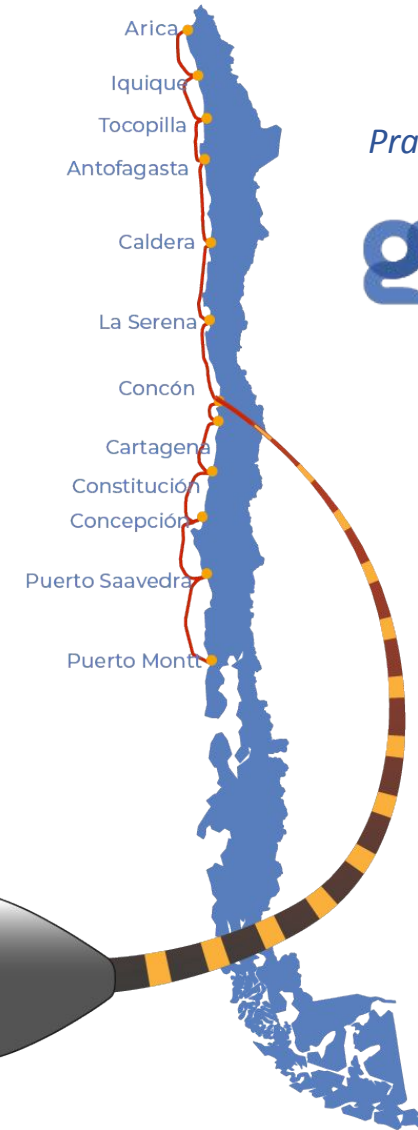
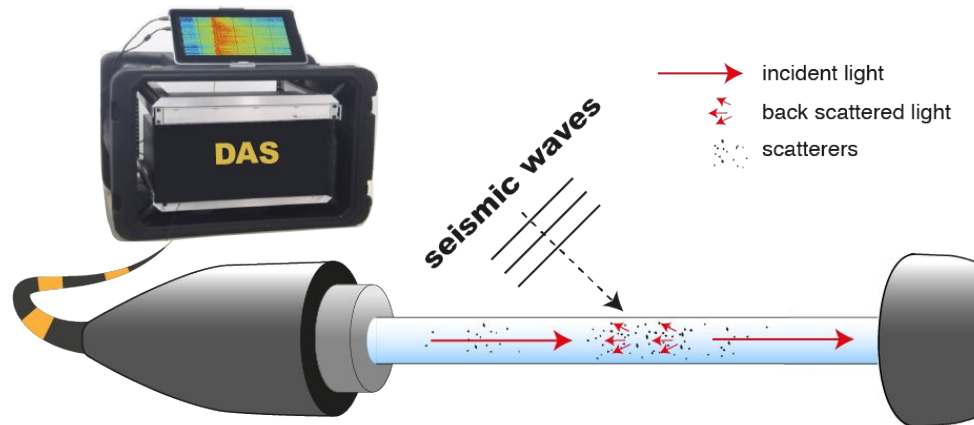
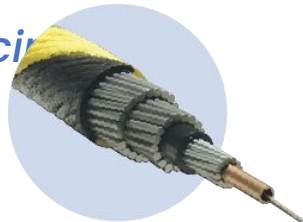
# Looking to the future: Distributed Acoustic Sensing

Unique Telecom Infrastructure  
Telecom cables transformed into "s"  
- 3500 km long  
- 12 landing points



Project with D. Rivet (GeoAzur)

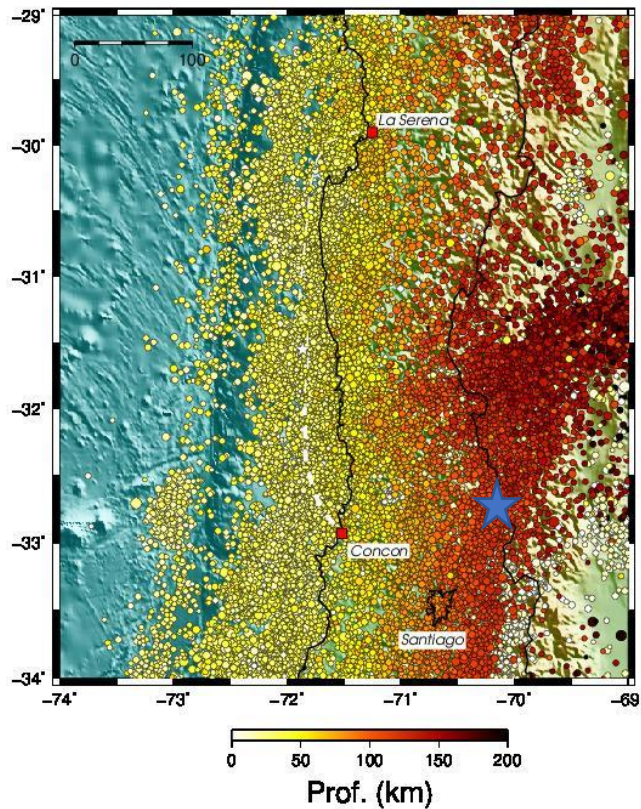
Optical Fiber  
Dense network of sensors  
150 km long  
50 000 sensors  
4 m sensor spacing



Prat Cable  
gtd



# DAS (P.I. Diane Rivet)



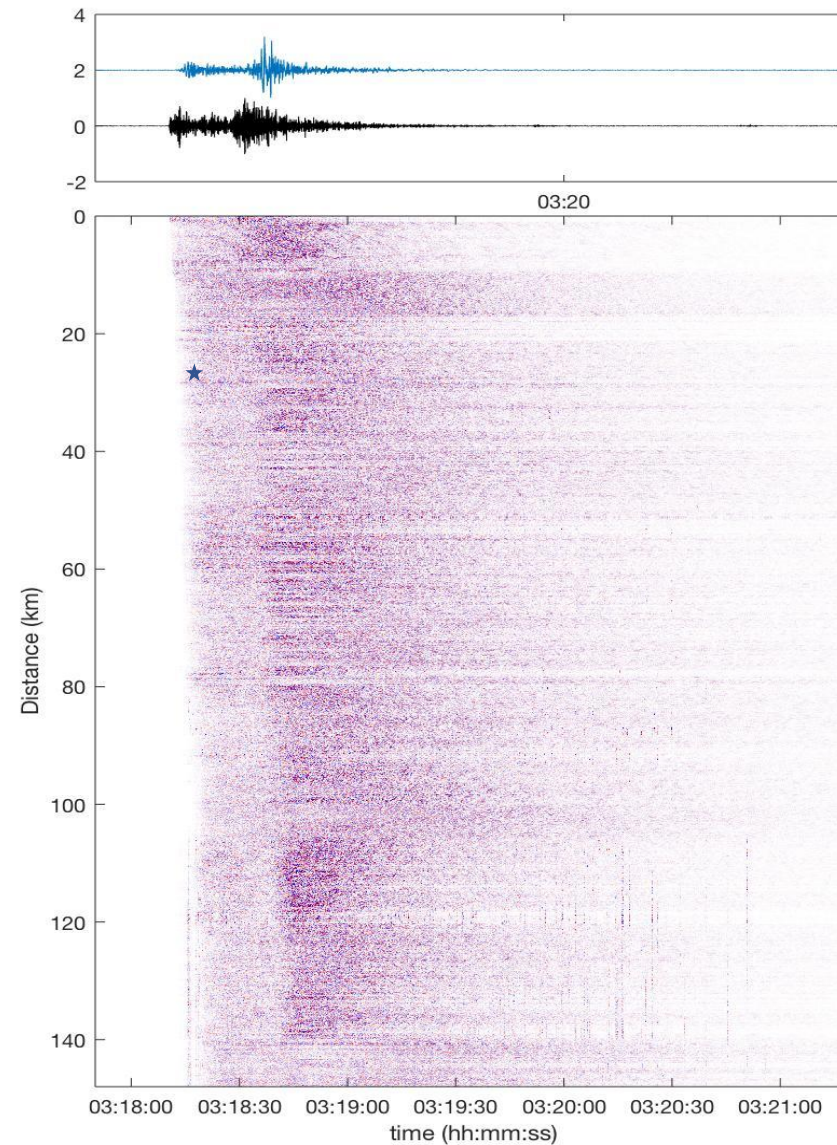
*DAS recording of a M5.7 about 100 km away  
4 m spacing between channels*

*150 km long arrays*

*37000 sensors*

*4 m spacing between sensors*

*125 Hz temporal sampling*





# Tsunami Warning System

*SNAM officially created in 1966*

*Under the Hydrographic Insitute of the Navy, now Hydrographic and Oceanographic Service of the Navy*



**SERVICIO HIDROGRÁFICO Y OCEANOGRÁFICO DE LA ARMADA**  
Sistema Nacional de Alarma de Maremotos

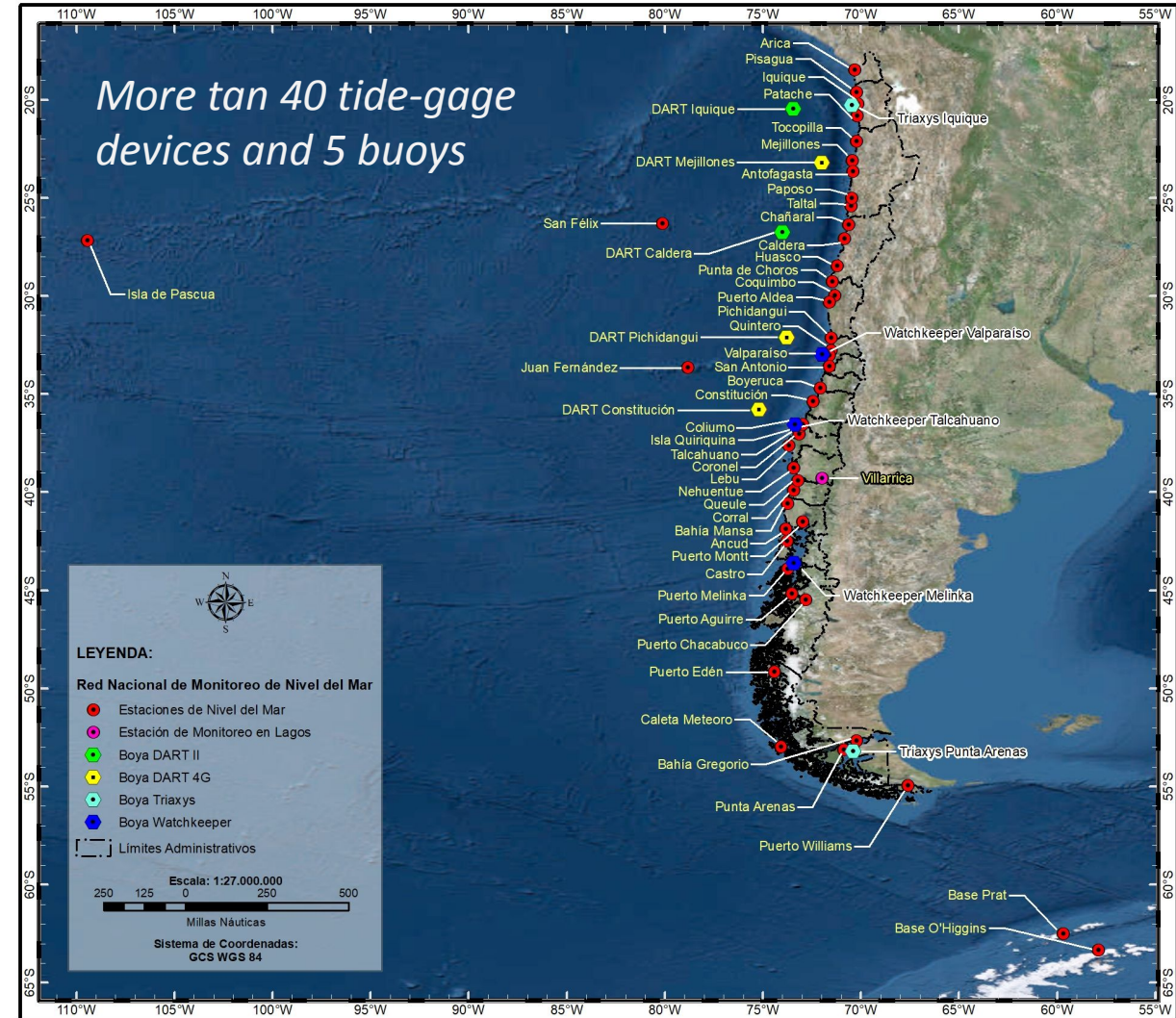
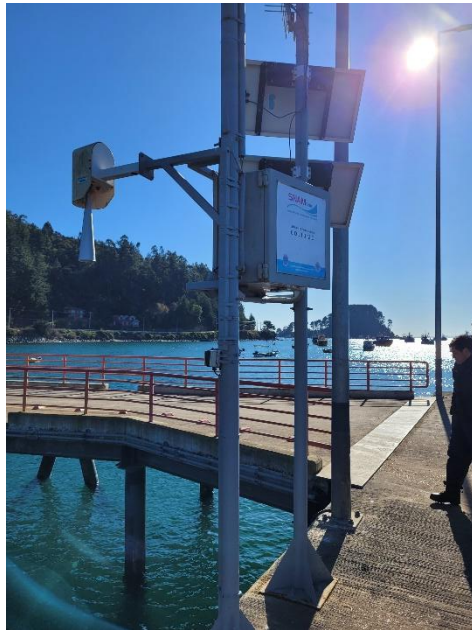




# Tsunami Warning System



Hydrographic and Oceanographic Service of the Navy

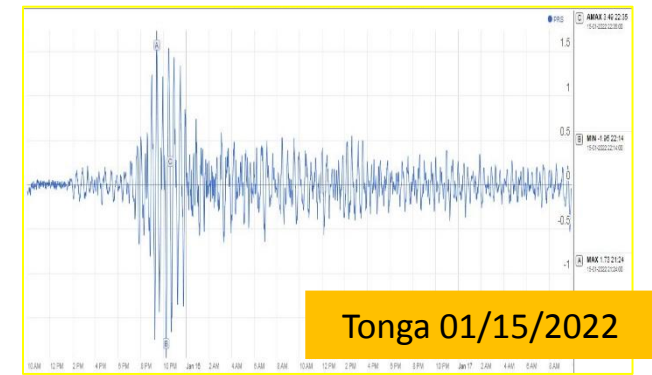
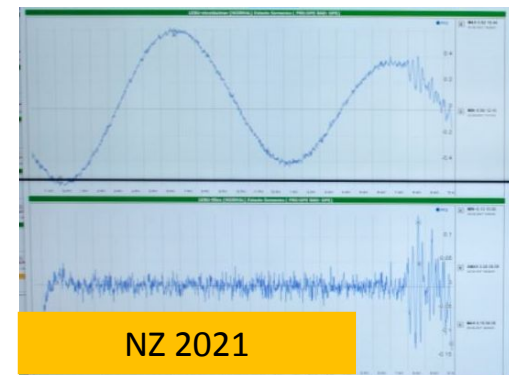
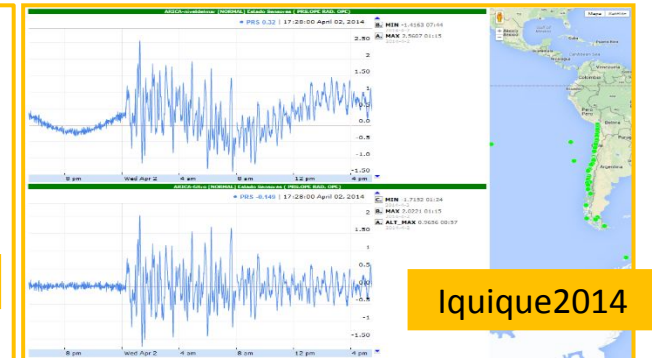
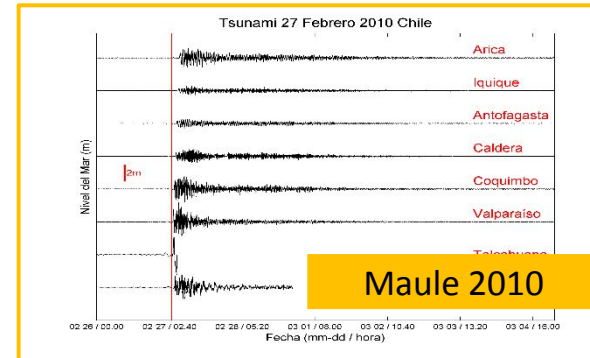
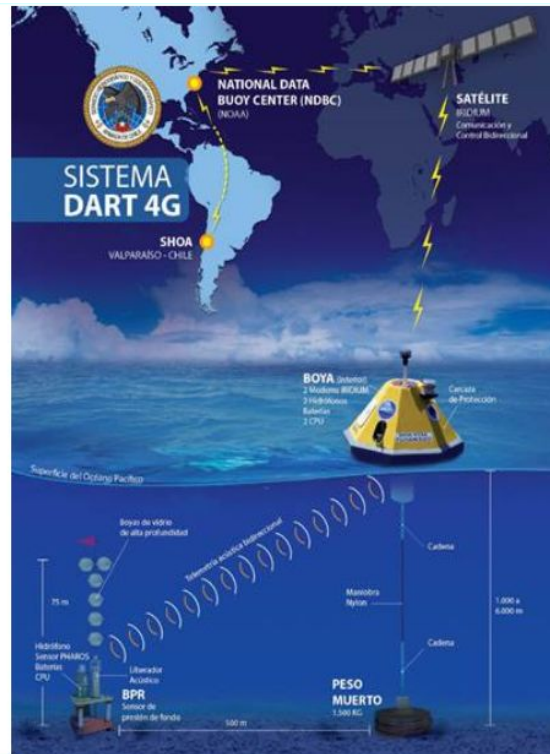
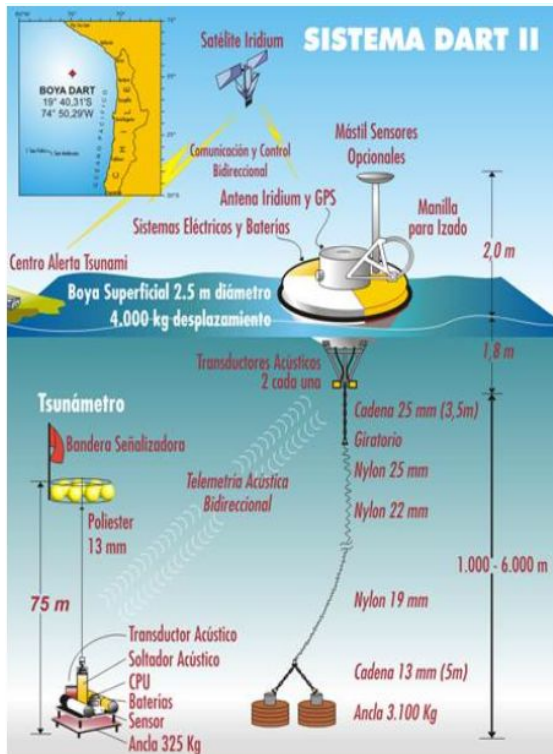




# Tsunami Warning System



Hydrographic and Oceanographic Service of the Navy

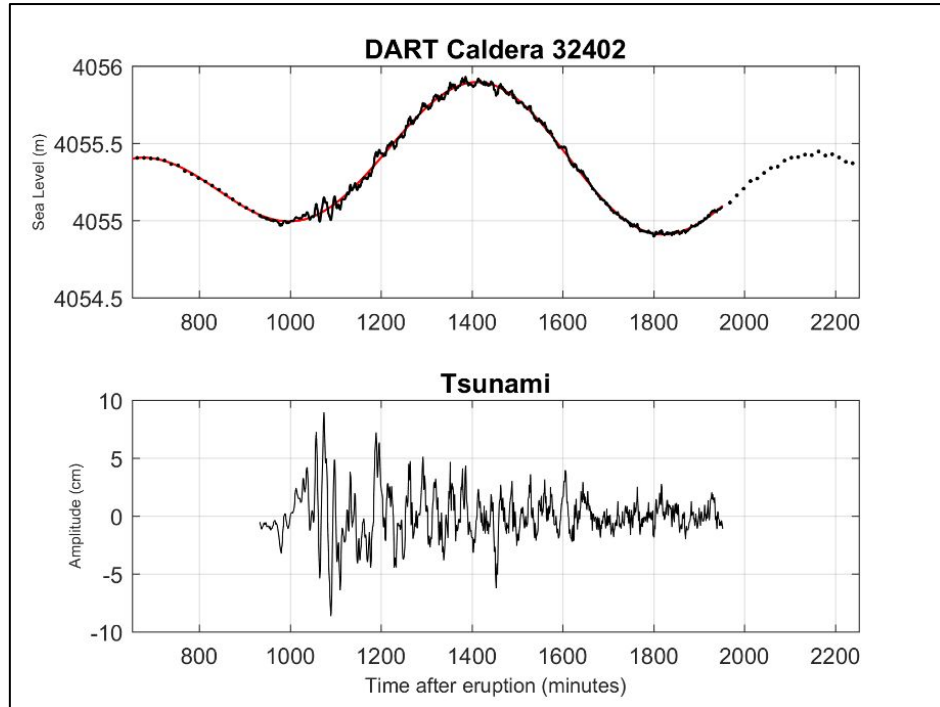




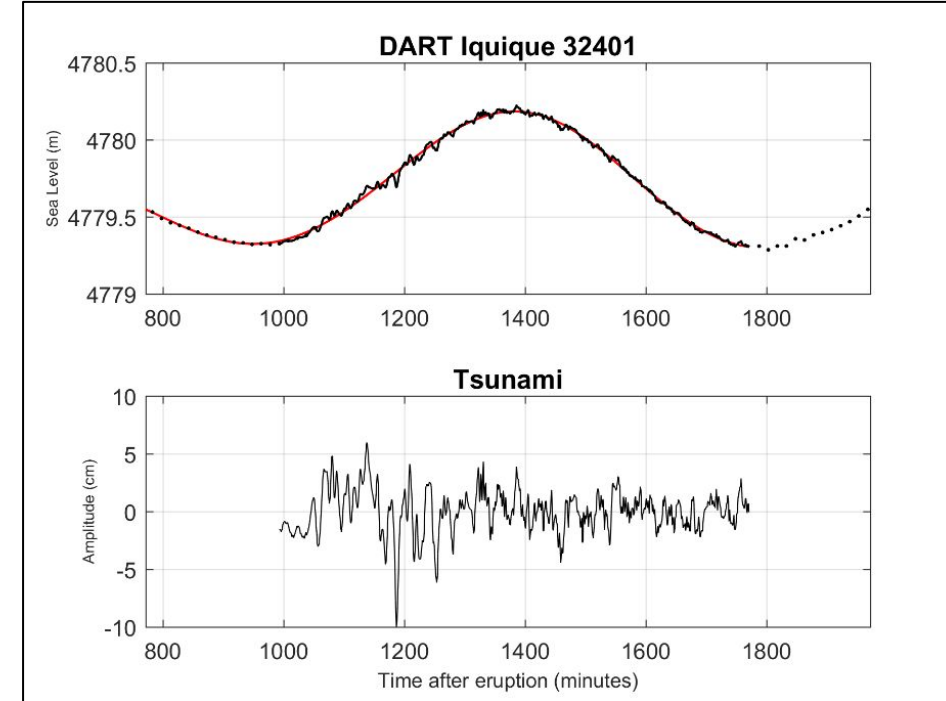
# Tsunami Warning System



Hydrographic and Oceanographic Service of the Navy



Tonga 2022



Tohoku, 2011

| Sea Level Station | Start of Tsunami Recording (UTC) | Max Height (m) | Time Max Height (UTC) |
|-------------------|----------------------------------|----------------|-----------------------|
| Chañaral          | 15-01-2022 14:07                 | 1.95           | 15-01-2022 22:14      |
| Caldera           | 15-01-2022 13:49                 | 0.90           | 15-01-2022 23:32      |

| Sea Level Station | Start of Tsunami Recording (UTC) | Max Height (m) | Time Max Height (UTC) |
|-------------------|----------------------------------|----------------|-----------------------|
| Arica             | 12-03-2011 03:28                 | 2.2            | 12-02-2011 08:09      |
| Pisagua           | 12-03-2011 03:13                 | 0.8            | 12-02-2011 04:44      |
| Iquique           | 12-03-2011 03:14                 | 1.0            | 12-02-2011 07:59      |



# RED NACIONAL DE VIGILANCIA VOLCÁNICA

Servicio Nacional de Geología y Minería

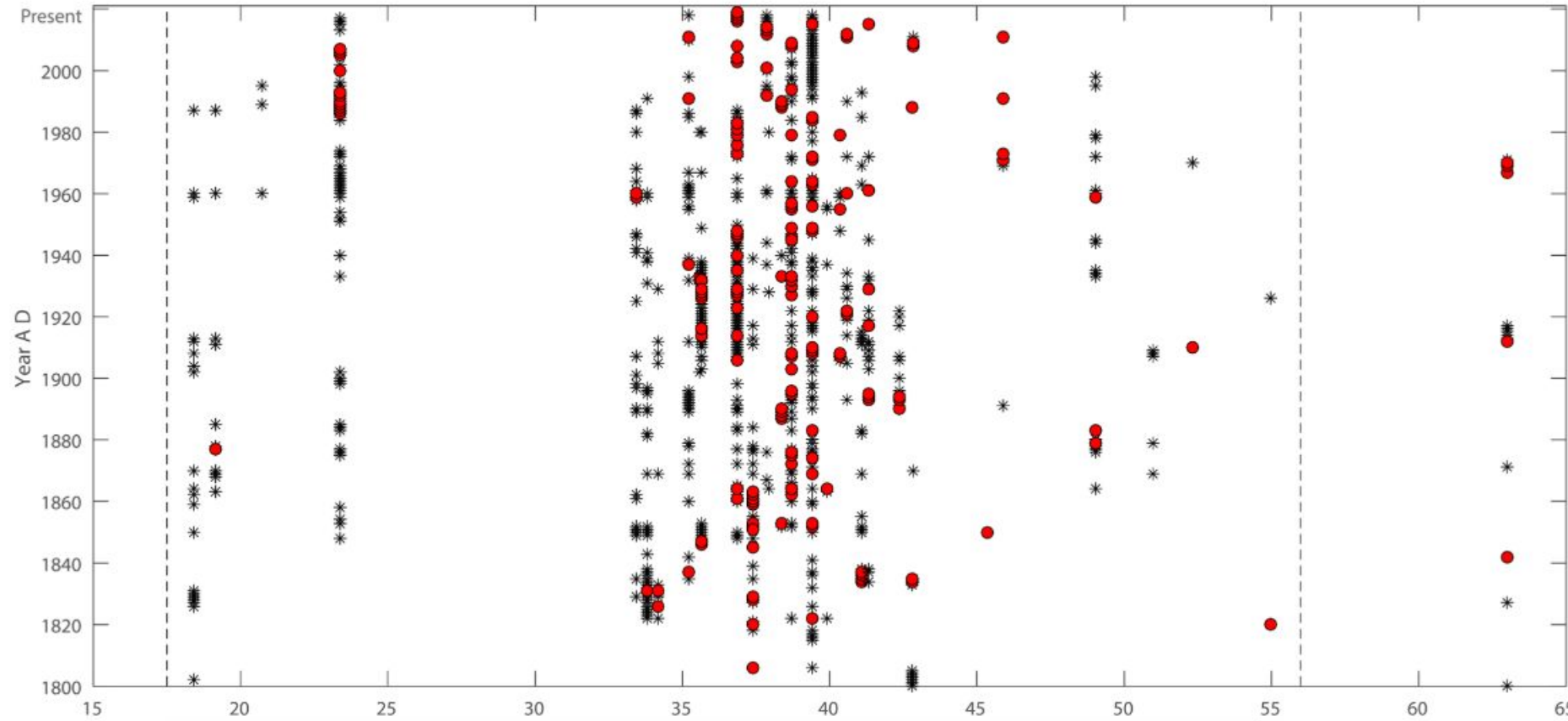
*After the Chaitén eruption in 2008, the Chilean Government decided to create a new, well-funded volcano-monitoring and hazard assessments program called “Red Nacional de Vigilancia Volcánica” (RNVV) which included **OVDAS** (that was therefore reinforced), potential additional VOs and a new program to conduct geological research and publish hazard maps.*



*A. Amigo (pers. comm.)*



# Volcanic events along latitude since 1800



A. Amigo  
(personal comm.)

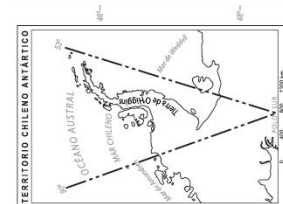


Central Volcanic Zone

Southern Volcanic Zone

Austral  
Volcanic Zone

Bransfield  
Rift



# NVEWS-like threat ranking

|    |                          |          |                   |         |         | i)   | ii)    | iii)    | iv) |
|----|--------------------------|----------|-------------------|---------|---------|------|--------|---------|-----|
| 1  | Villarrica               | IX y XIV | Estratovolcán     | -39,420 | -71,939 | 23,0 | 18,932 | 435,447 | I   |
| 2  | Llaima                   | IX       | Estratovolcán     | -38,694 | -71,733 | 22,0 | 17,285 | 380,279 | I   |
| 3  | Calbuco                  | X        | Estratovolcán     | -41,329 | -72,614 | 21,0 | 15,964 | 335,238 | I   |
| 4  | Nevados de Chillán       | XVI      | Complejo          | -36,871 | -71,368 | 19,0 | 16,099 | 305,877 | I   |
| 5  | Puyehue-Cordón Caulle    | XIV y X  | Complejo          | -40,585 | -72,112 | 21,0 | 14,118 | 296,482 | I   |
| 6  | Osorno                   | X        | Estratovolcán     | -41,102 | -72,499 | 20,5 | 14,401 | 295,213 | I   |
| 7  | Mocho-Choshuenco         | XIV      | Complejo          | -39,930 | -72,030 | 19,0 | 14,564 | 276,722 | I   |
| 8  | Antuco                   | VIII     | Estratovolcán     | -37,410 | -71,351 | 19,0 | 14,144 | 268,735 | I   |
| 9  | Carrán-Los Venados       | XIV      | Campo volcánico   | -40,366 | -72,073 | 16,5 | 16,085 | 265,411 | I   |
| 10 | Cerro Azul-Quizapu       | VII      | Complejo          | -35,654 | -70,759 | 21,0 | 12,500 | 262,507 | I   |
| 11 | Chaitén                  | X        | Complejo de domos | -42,837 | -72,650 | 20,0 | 12,792 | 255,833 | I   |
| 12 | Lonquimay                | IX       | Estratovolcán     | -38,379 | -71,589 | 16,0 | 14,919 | 238,709 | I   |
| 13 | Hudson                   | XI       | Caldera           | -45,900 | -72,970 | 21,0 | 10,235 | 214,944 | I   |
| 14 | Láscar                   | II       | Estratovolcán     | -23,363 | -67,731 | 16,5 | 10,053 | 165,867 | I   |
| 15 | Michinmahuida            | X        | Estratovolcán     | -42,798 | -72,445 | 17,0 | 11,930 | 202,811 | II  |
| 16 | Yate                     | X        | Estratovolcán     | -41,759 | -72,400 | 13,0 | 15,597 | 202,766 | II  |
| 17 | Sollipulli               | IX       | Caldera           | -38,977 | -71,519 | 14,0 | 14,413 | 201,777 | II  |
| 18 | Copahue                  | VIII     | Estratovolcán     | -37,850 | -71,170 | 17,0 | 11,711 | 199,093 | II  |
| 19 | Grupo Descabezado Grande | VII      | Complejo          | -35,586 | -70,751 | 20,5 | 9,051  | 185,546 | II  |
| 20 | Callaqui                 | VIII     | Complejo          | -37,926 | -71,446 | 16,0 | 10,901 | 174,420 | II  |
| 21 | Quetrupillán             | IX y XIV | Complejo          | -39,498 | -71,717 | 12,0 | 13,854 | 166,252 | II  |
| 22 | Parinacota               | XV       | Estratovolcán     | -18,164 | -69,143 | 14,0 | 11,474 | 160,635 | II  |
| 23 | Planchón - Peteroa       | VII      | Complejo          | -35,241 | -70,574 | 17,5 | 9,000  | 157,503 | II  |
| 24 | Hornopirén               | X        | Estratovolcán     | -41,876 | -72,431 | 10,0 | 15,567 | 155,669 | II  |
| 25 | Lanín                    | IX       | Estratovolcán     | -39,639 | -71,501 | 15,5 | 9,907  | 153,564 | II  |
| 26 | Complejo Antillanca      | X        | Complejo          | -40,776 | -72,155 | 11,5 | 12,062 | 138,713 | II  |
| 27 | Laguna del Maule         | VII      | Complejo          | -36,058 | -70,507 | 16,5 | 8,251  | 136,138 | II  |
| 28 | Melimoyu                 | XI       | Estratovolcán     | -44,072 | -72,868 | 13,0 | 10,413 | 135,366 | II  |
| 29 | Tupungatito              | RM       | Estratovolcán     | -33,401 | -69,802 | 13,0 | 9,390  | 122,067 | II  |
| 30 | Guallatiri               | XV       | Complejo          | -18,423 | -69,089 | 12,5 | 9,282  | 116,022 | II  |

i)

ii)

iii)

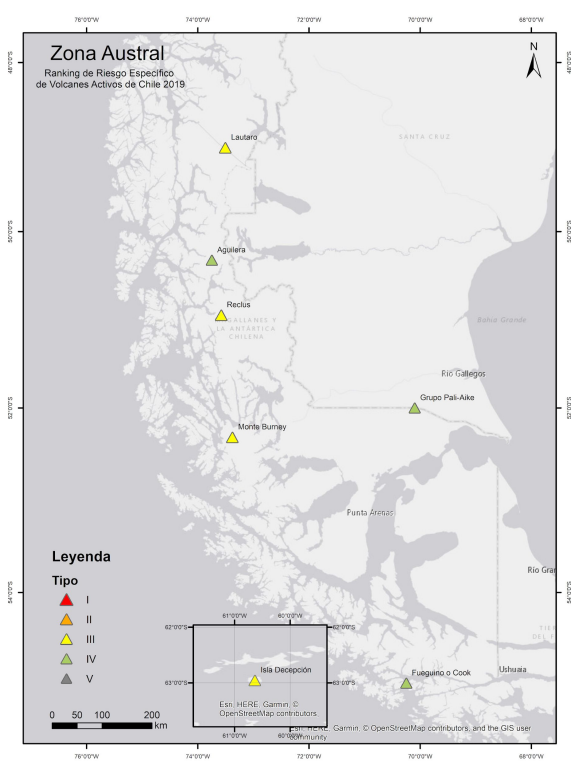
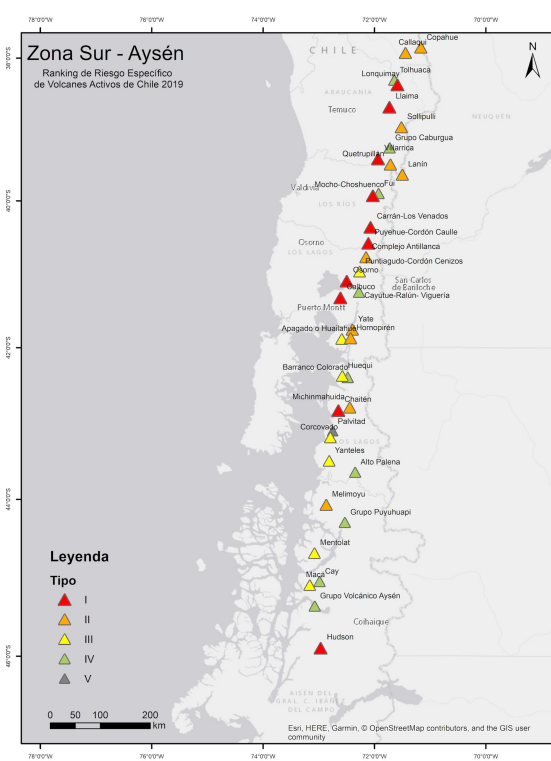
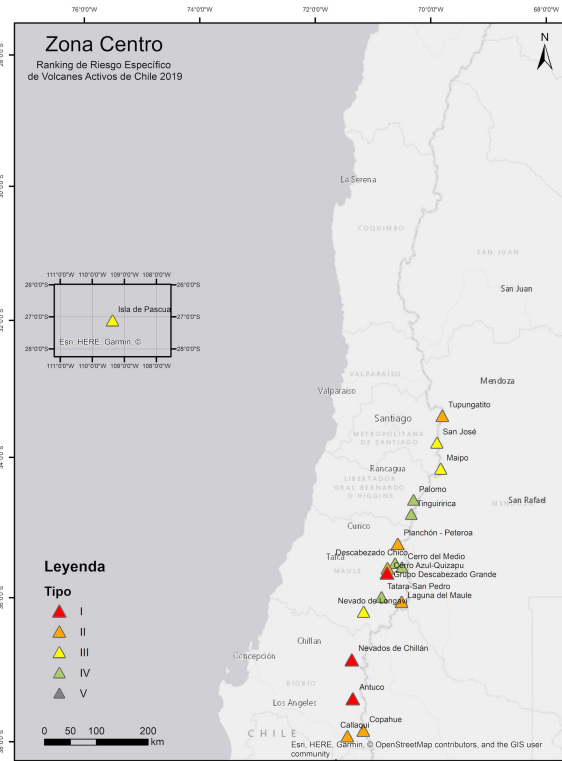
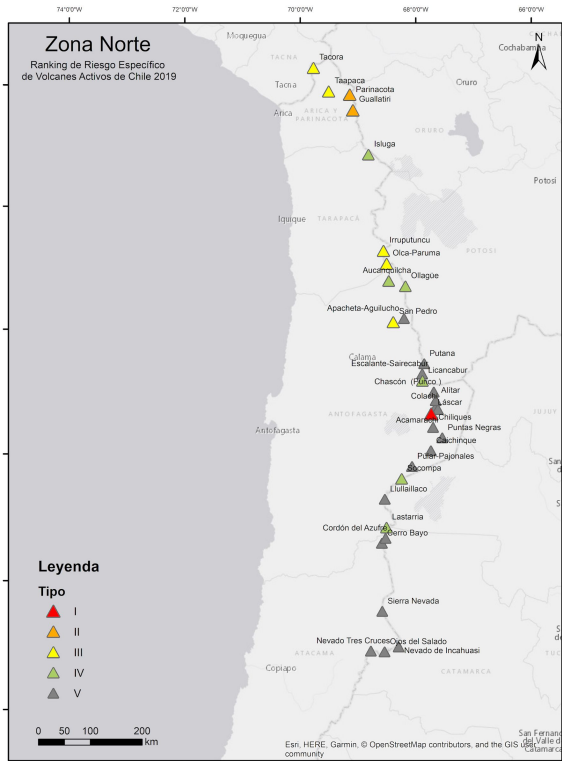
iv)



A. Amigo (personal comm.)

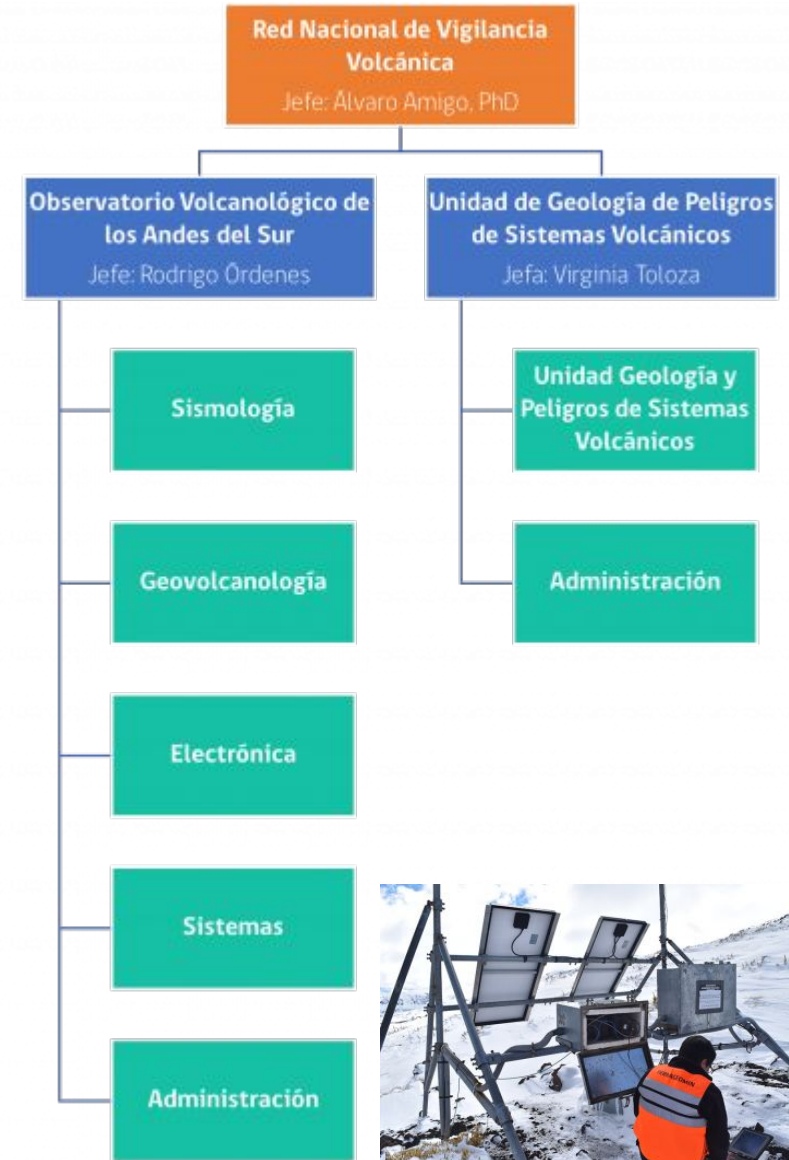
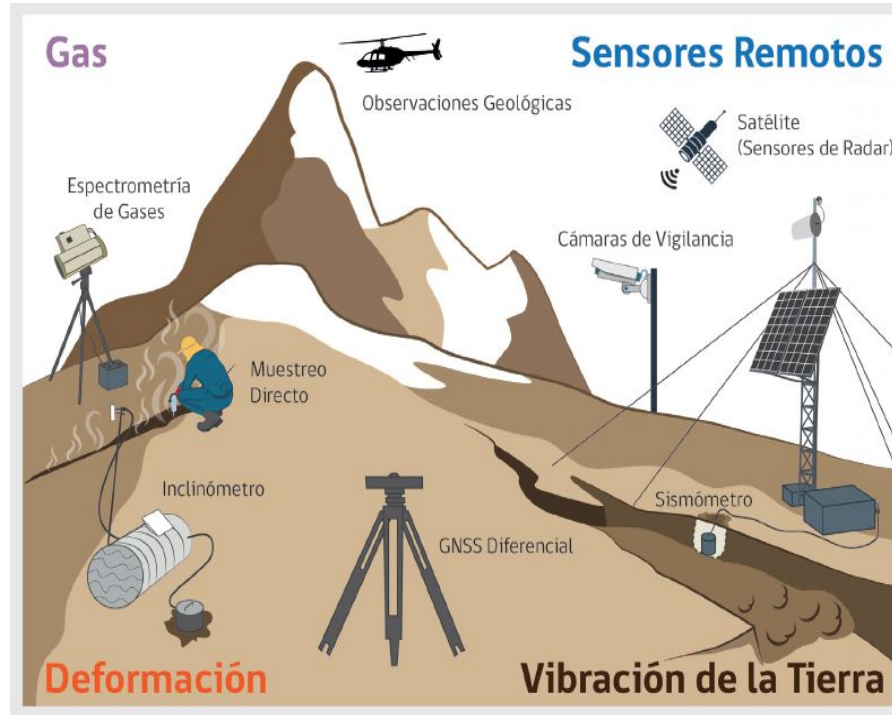


# Active volcanoes (4 categories)



A. Amigo (Sernageomin)

# Reinforced OVDAS



A. Amigo (personal comm.)

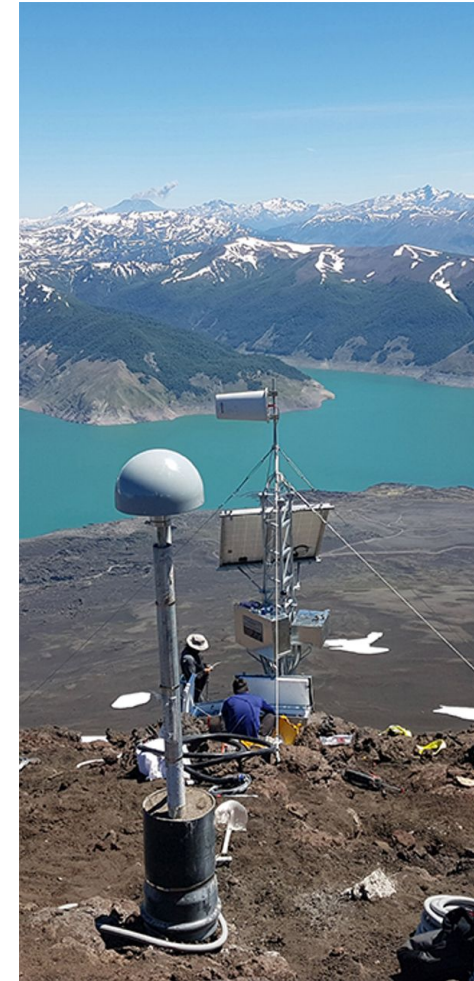




# Reinforced OVDAS

| Instruments                                 | Volcanoes |            |             |           | Total      |
|---|-----------|------------|-------------|-----------|------------|
|   | I<br>(13) | II<br>(16) | III<br>(10) | IV<br>(6) |            |
| <i>Ground vibration</i>                     |           |            |             |           |            |
| Seismic                                     | 77        | 64         | 19          | 15        | <b>175</b> |
| Accelerometers                              | 4         | -          | -           | -         | <b>4</b>   |
| <i>Deformation</i>                          |           |            |             |           |            |
| GNSS  | 33        | 16         | -           | -         | <b>49</b>  |
| Tiltmeters                                  | 9         | 7          | -           | -         | <b>16</b>  |
| Geodesic sites                              | 4         | 1          | -           | -         | <b>5</b>   |
| <i>Fluids detection and sampling</i>        |           |            |             |           |            |
| SO <sub>2</sub> (DOAS + IR camera)          | 7         | 4          | -           | 1         | <b>12</b>  |
| CO <sub>2</sub> /SO <sub>2</sub> (MultiGAS) | 1         | -          | -           | -         | <b>1</b>   |
| On-site surveys                             | 2         | 3          | -           | -         | <b>5</b>   |

| Instruments               | Volcanoes |            |             |           | Total     |
|---------------------------|-----------|------------|-------------|-----------|-----------|
|                           | I<br>(13) | II<br>(16) | III<br>(10) | IV<br>(6) |           |
| <i>Atmospheric waves</i>  |           |            |             |           |           |
| Infrasound                | 3         | 3          | -           | -         | <b>6</b>  |
| <i>Cameras</i>            |           |            |             |           |           |
| Webcams                   | 28        | 17         | 7           | 4         | <b>56</b> |
| Thermal                   | 2         | 1          | -           | -         | <b>3</b>  |
| <i>Ash collection</i>     |           |            |             |           |           |
| Ashmeters                 | 5         | 3          | -           | -         | <b>8</b>  |
| <i>Satellite coverage</i> |           |            |             |           |           |
| High-res imagery          | 14        | 14         | 10          | 14        | <b>52</b> |
| SAR analysis              | 9         | 1          | -           | -         | <b>10</b> |



**45 volcanoes monitored in the CVZ and SVZ**

# STAFF at RNVV



| Area                                      | Researchers        |            |         |              | Engineers and Technicians |            |                  | Administrative Officers |
|---|--------------------|------------|---------|--------------|---------------------------|------------|------------------|-------------------------|
|   | Geology/ Geography | Seismology | Geodesy | Geochemistry | Electronic/ Electrical    | Informatic | Field assistants |                         |
| Monitoring and early warning              | 4                  | 9          | 3       | 2            | 12                        | 8          |                  |                         |
| Geological mapping and hazard assessments | 8                  | -          | -       | -            | -                         | -          | 3                | 10                      |

## International Efforts

### Laguna del Maule & Lanín volcanoes



A. Amigo (personal comm.)



# Thank you

