



Experience with tsunami risk management in Chile

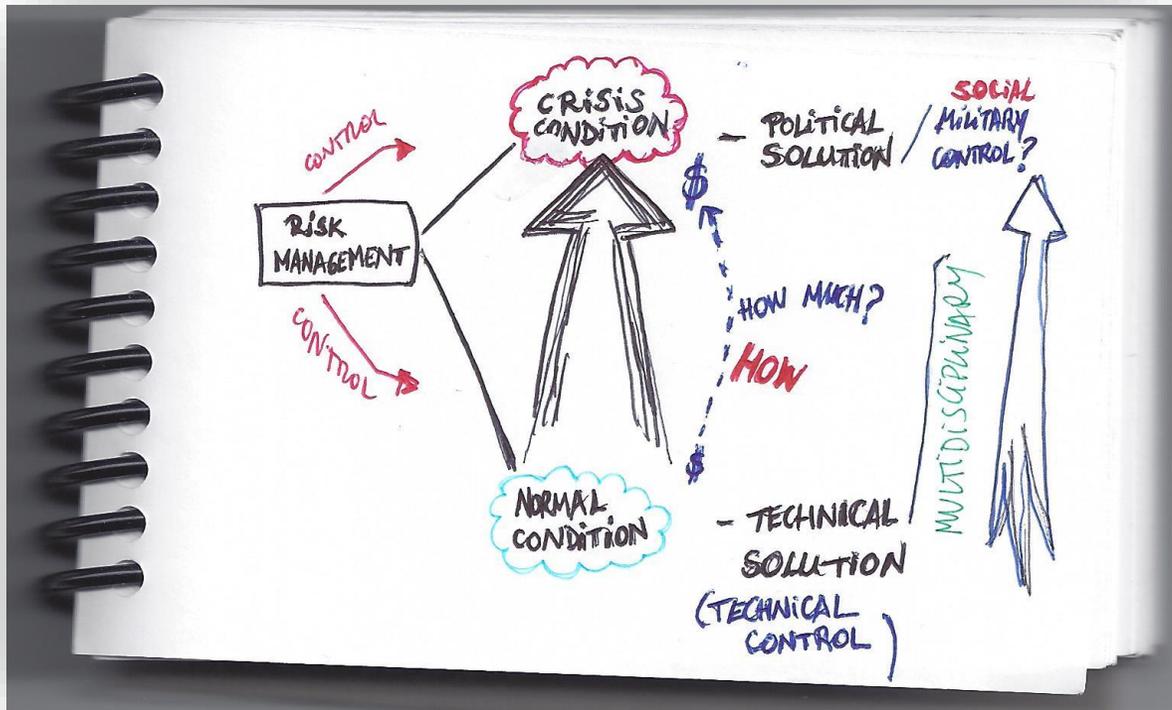


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Master of Disaster Management – BRI/GRIPS - JAPAN
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Experience with tsunami risk management in Chile



OBJECTIVES:

- To generate reflections about Disaster Risk Management in Chile and other countries.
- Learn about Chile, its context, prehistory and history.
- To know the main disasters in this geographical area, especially earthquakes and tsunamis.
- Have an approach to the measures that Chile has taken to reduce Tsunami Disaster Risk (and other disasters risk).
- Assimilate and share experiences.



Contents:

- Disaster Risk Management
- Chile: A multihazard country
- Earthquakes
- Tsunami
- Our vulnerabilities
- Our capacities
- Our latest experiences
- Strategic analysis and a sort of conclusions.





Disaster Risk Management

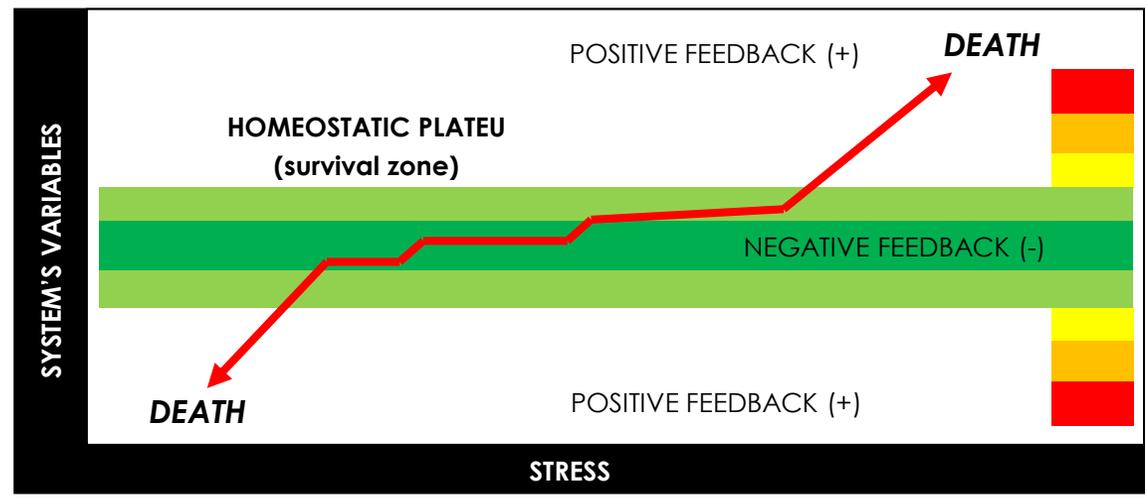
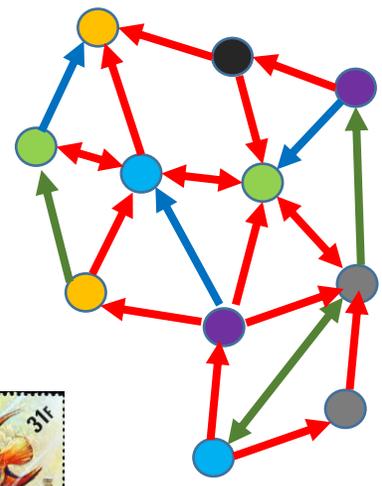
**To talk about DRM is to talk about
life and death.**



Disaster Risk Management

じんせい 人生 生ビール 生 VIDA LIFE ♀

<https://www.espaiwabisabi.com/la-palabra-vida-japones/>

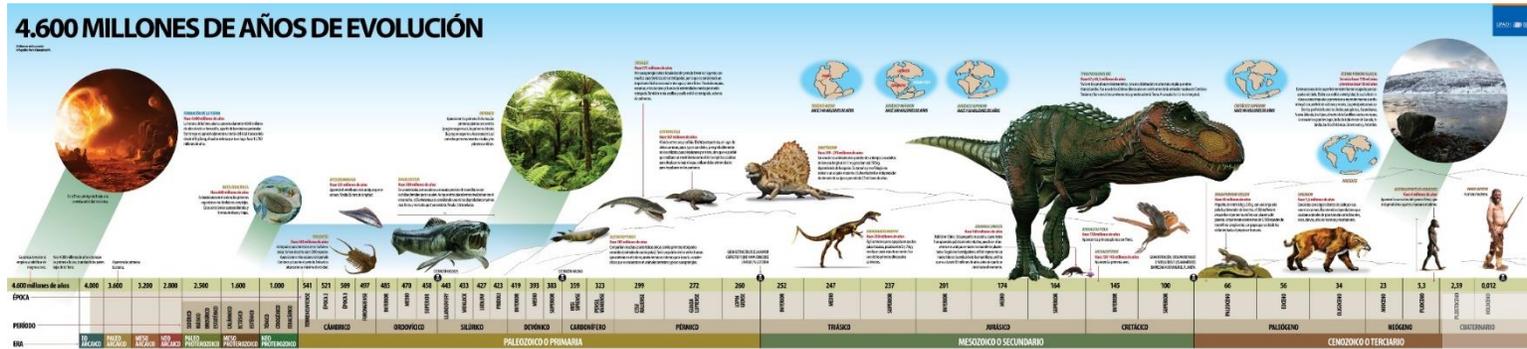


UNCERTAINTY UNDER STRONG LAWS!!!

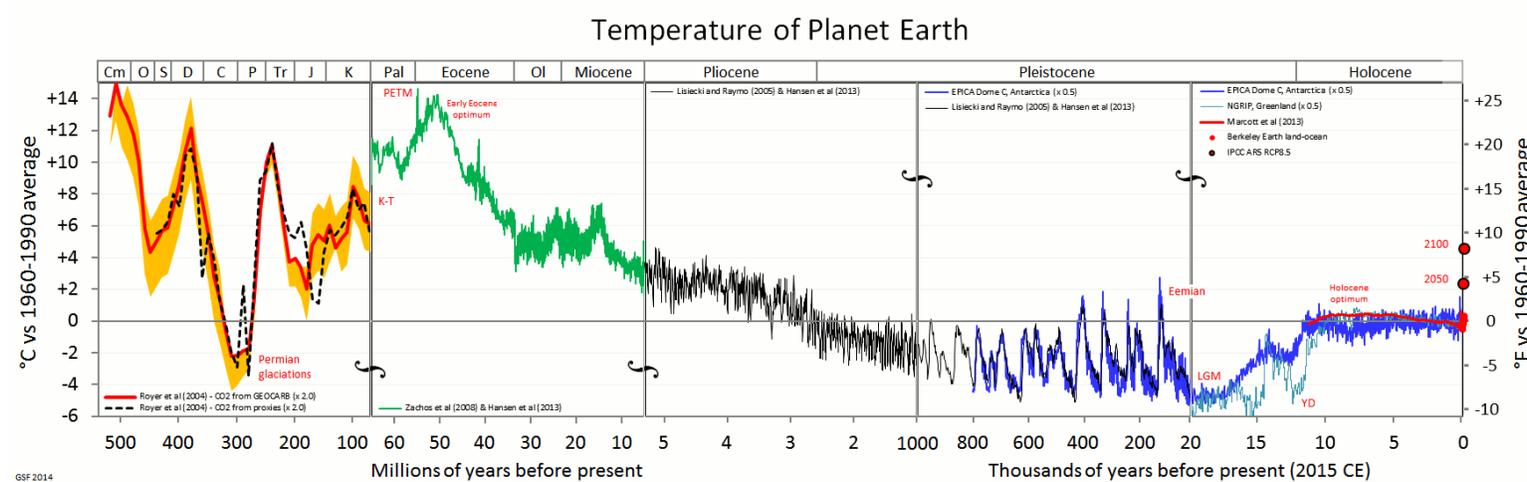


Disaster Risk Management

**Let's analyze things regarding to
Time, People and Place... and **Law**.**



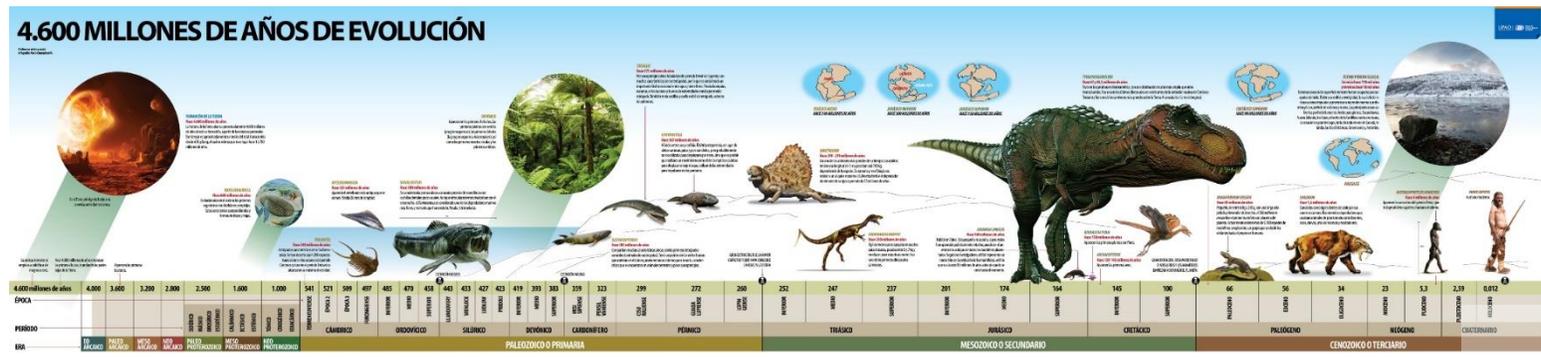
TIME



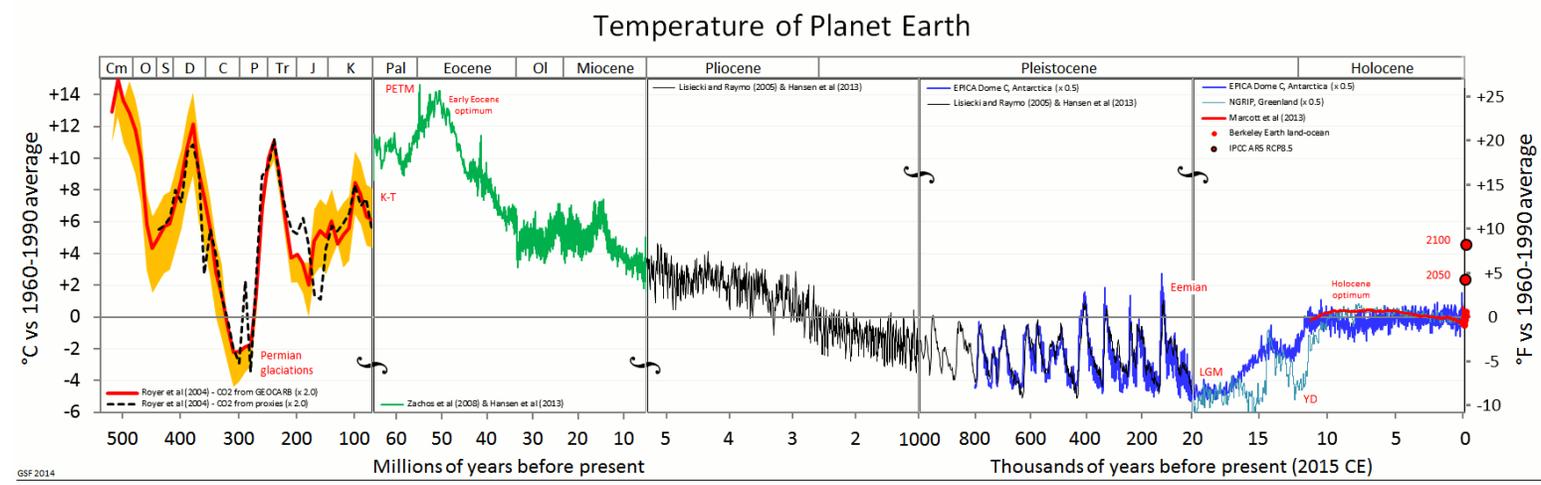
**TO BE AWARE OF TIME SCALES,
TO FACE THE COMPLEXITY OF THIS CHALLENGE.**



Disaster Risk Management



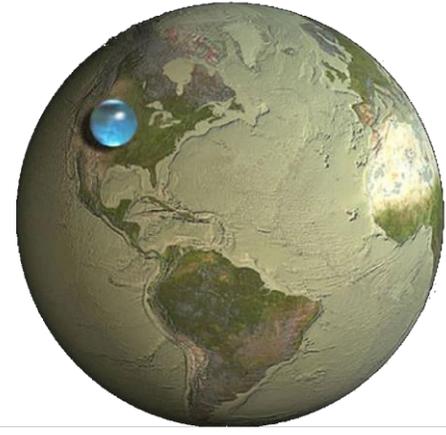
PEOPLE



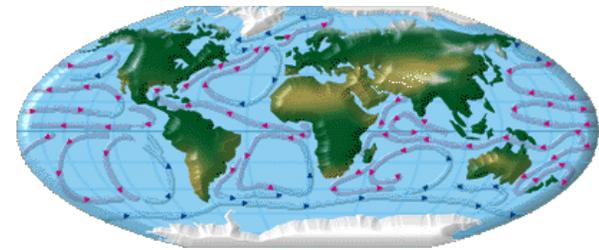
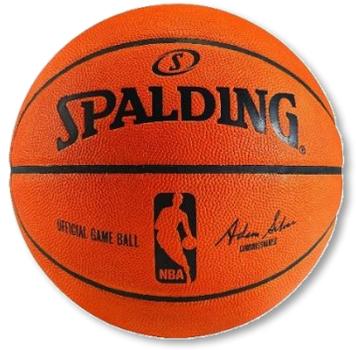
TO BE AWARE OF PEOPLE'S THINGS, TO FACE THE COMPLEXITY OF THIS CHALLENGE.



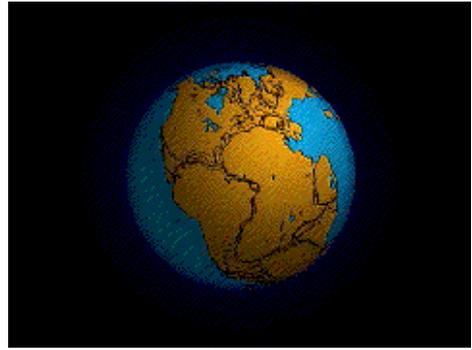
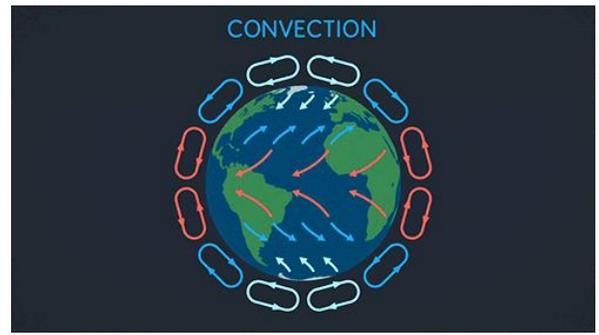
EARTH DIAMETER = 12,742 [km]
 AVG. OCEAN DEPTH = 4 [km]
 MAX. OCEAN DEPTH = 11 [km]
 HIGHEST BREATHABLE AIR = 8 [km]



Disaster Risk Management



PLACE

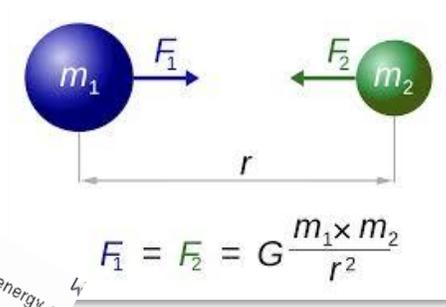


**TO BE AWARE OF OUR POSITION IN THE UNIVERSE,
 TO FACE THE COMPLEXITY OF THIS CHALLENGE.**



Disaster Risk Management

Energy can neither be created nor destroyed - only converted from one form of energy to another



LAW

If there is not work, Energy will disperse...



- The law of conservation of energy. This states that energy can be neither created nor destroyed. However, energy can change forms, and energy can be converted from one form to another.
- The concept of internal energy and its relationship to temperature. If a system has a definite temperature, then its total energy has three distinguishable components. If the system is in a state of thermal equilibrium with its surroundings, it has potential energy relative to some reference point. Finally, it has kinetic energy relative to the same reference point. The total energy of a system is the sum of its potential energy and its kinetic energy.
- The flow of heat through a system. Heat is a natural process of energy transfer between two systems. It is the characteristic distinguishing feature of the first law of thermodynamics.

The first law of thermodynamics may be stated in several ways:

The increase in internal energy of a closed system is equal to the heat supplied to the system minus the work done by the system.

$$\Delta U_{system} = Q - W$$

For a thermodynamic cycle of a closed system, which returns to its original state, the net work done by the system, equals the net heat supplied to the system.

$$\Delta U_{system} (full\ cycle) = 0, \text{ and, consequently } Q = Q_{in} - Q_{out} = W$$

The increase in internal energy of a closed adiabatic system can only be the result of the net work performed on the system.

$$\Delta U_{system} = U_{final} - U_{initial} = -W$$

More specifically, the First Law encompasses several principles:

Let's put the ball on the ground.





CONCEPT

The potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems (IPCC 2014).

- **Uncertainty.**
- **Damages.**
- **Losses.**
- **Death.**

FORMULATION

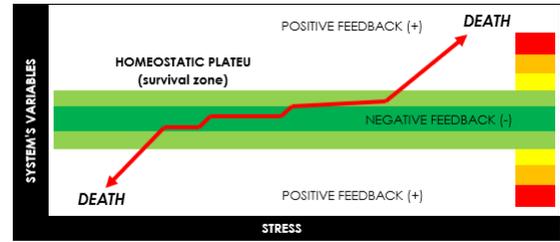
$$R = P \times I$$

R: Risk
 P: Probability of occurrence of a Hazard's scenario
 I: Impact level (dependent of vulnerability and exposure)

RISK MATRIX		IMPACT LEVELS				
PROBABILITY OF OCCURRENCE (FACTOR)		NEGLECTIBLE	MINOR	MODERATE	SERIOUS	SEVERE
		1	2	3	4	5
VERY LOW	1	LOW - ACCEPTABLE	LOW - ACCEPTABLE	LOW - TOLERABLE	LOW - TOLERABLE	MEDIUM - TOLERABLE (UNDER CONDITIONS)
LOW	2	LOW - ACCEPTABLE	LOW - TOLERABLE	MEDIUM - TOLERABLE (UNDER CONDITIONS)	MEDIUM - TOLERABLE (UNDER CONDITIONS)	HIGH - INTOLERABLE (UNSTABLE)
MEDIUM	3	LOW - TOLERABLE	MEDIUM - TOLERABLE (UNDER CONDITIONS)	MEDIUM - TOLERABLE (UNDER CONDITIONS)	HIGH - INTOLERABLE (UNSTABLE)	HIGH - INTOLERABLE (CRITICAL)
HIGH	4	LOW - TOLERABLE	MEDIUM - TOLERABLE (UNDER CONDITIONS)	HIGH - INTOLERABLE (UNSTABLE)	HIGH - INTOLERABLE (CRITICAL)	HIGH - INTOLERABLE (CRITICAL)
VERY HIGH	5	MEDIUM - TOLERABLE (UNDER CONDITIONS)	HIGH - INTOLERABLE (UNSTABLE)	HIGH - INTOLERABLE (CRITICAL)	HIGH - INTOLERABLE (CRITICAL)	HIGH - INTOLERABLE (CRITICAL)

RISK

Multihazard (Impossible to separate from other hazards)
 Multidimensional impact
 Multidimensional vulnerability





Let's talk about Chile.

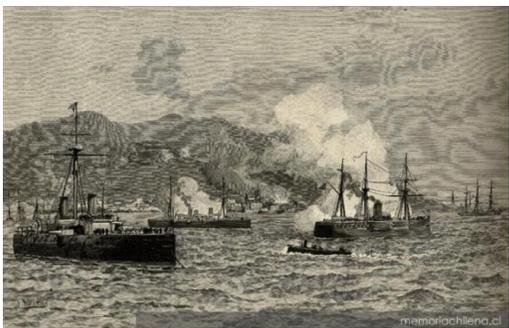


<https://wallpaperaccess.com/santiago-chile>





Chile: A multihazard country



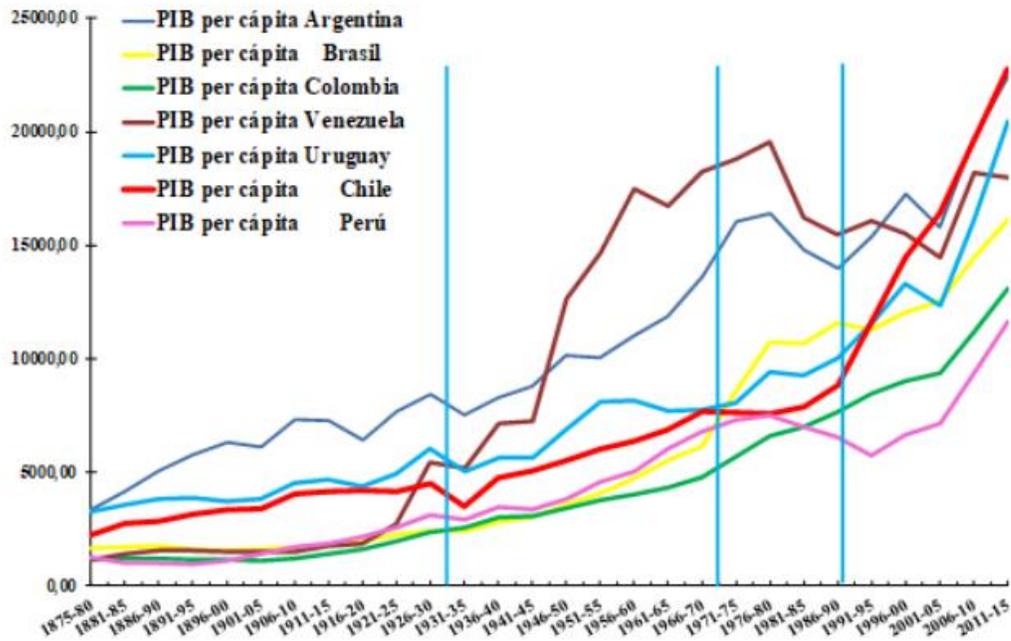
**Chile is a “young” country...
 ...historically and geologically
 (not more tan 550 [Myr])**



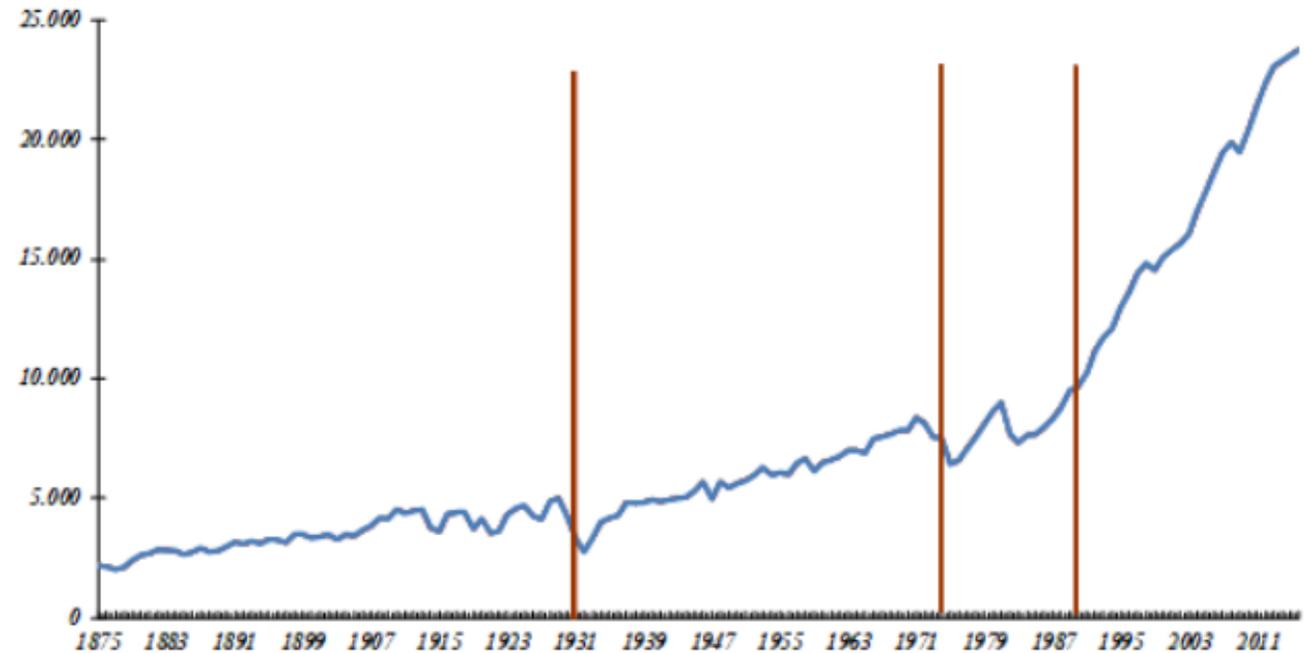
Chile: A multihazard country

First Spaniards
1536

Independence	Pacific War	Eastern Island Anex.	Civil War.	Military coup and gov.	Back to Democracy.
1810	1879	1888	1891	1973	1990



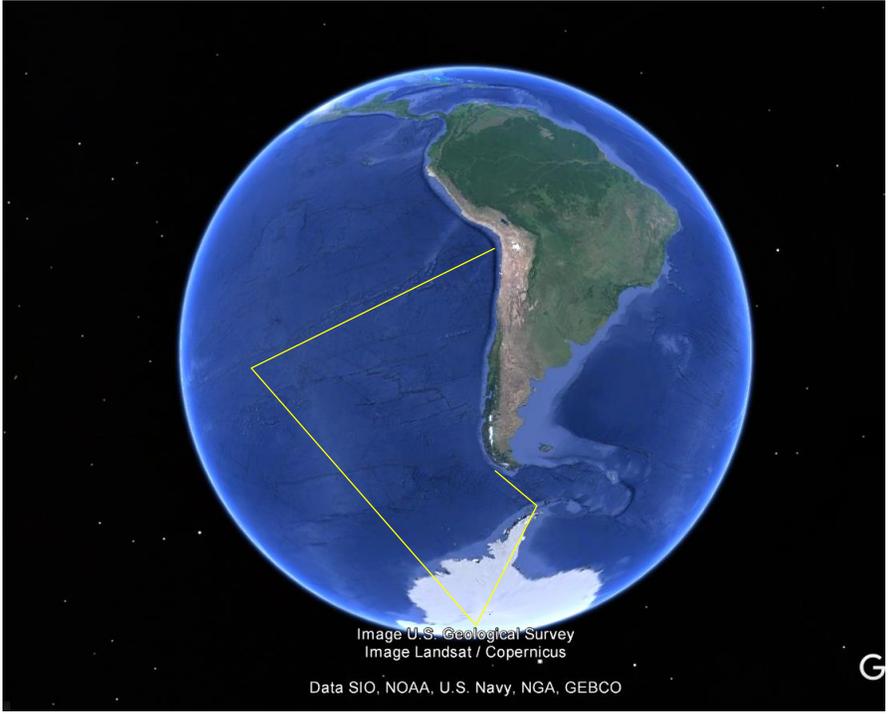
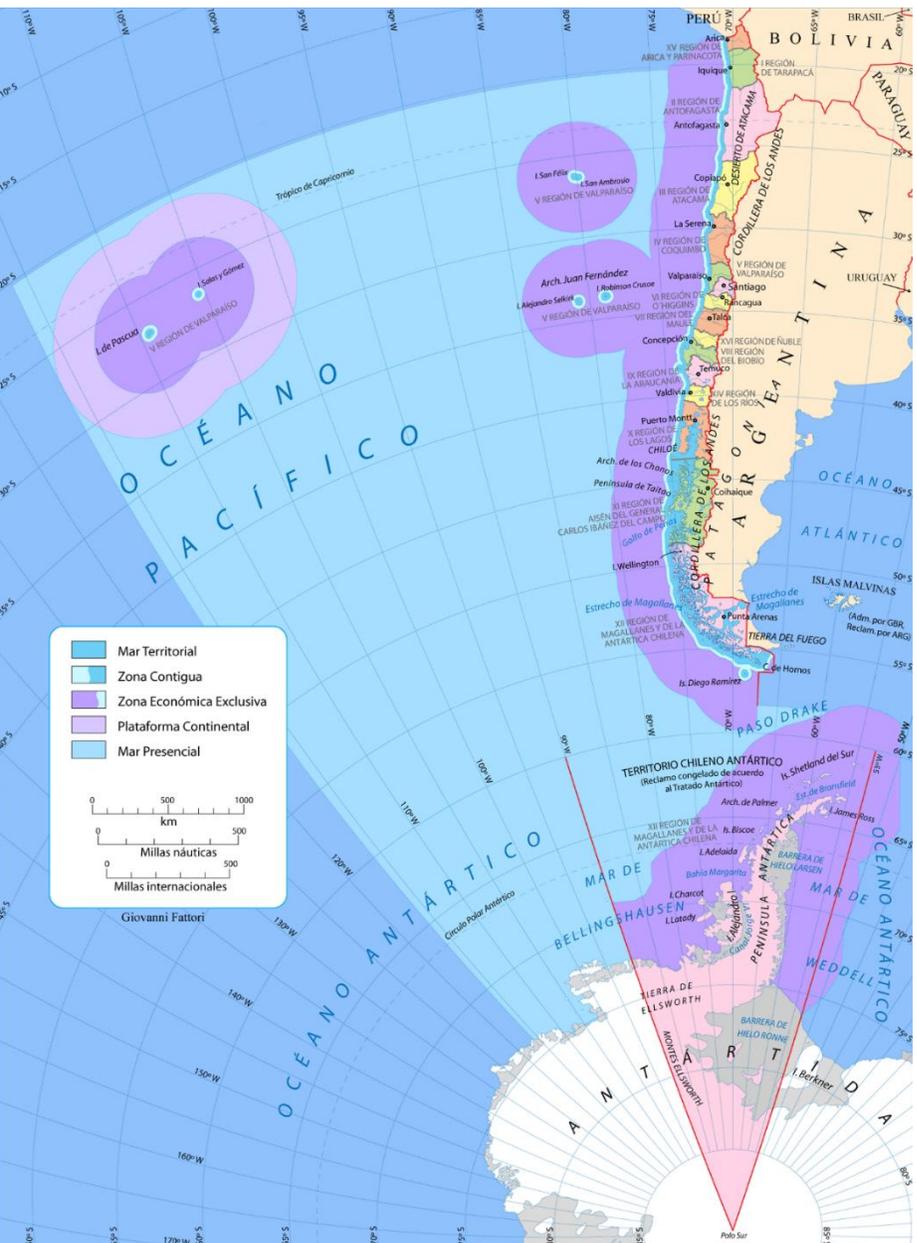
Chile: PIB per cápita en dólares de 2015 a Paridad del Poder de Compra



<https://www.democraciayprogreso.org/algunas-reflexiones-en-torno-al-desarrollo-economico-chileno-y-su-proyeccion-hacia-el-futuro/>

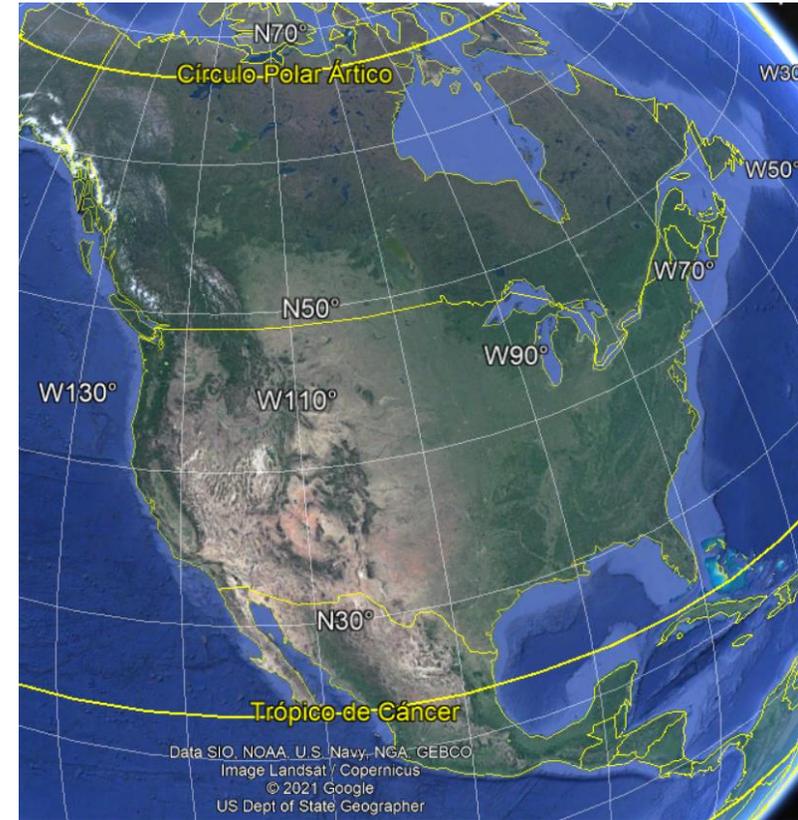
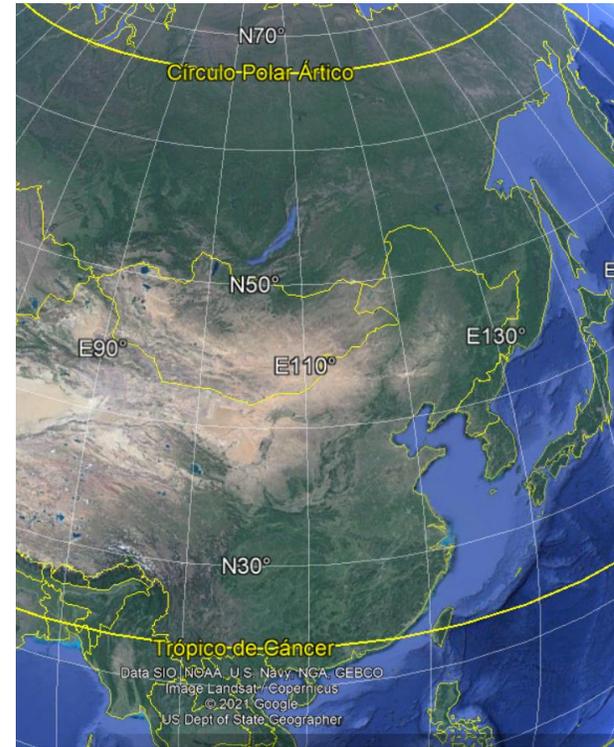


Chile: A multihazard country

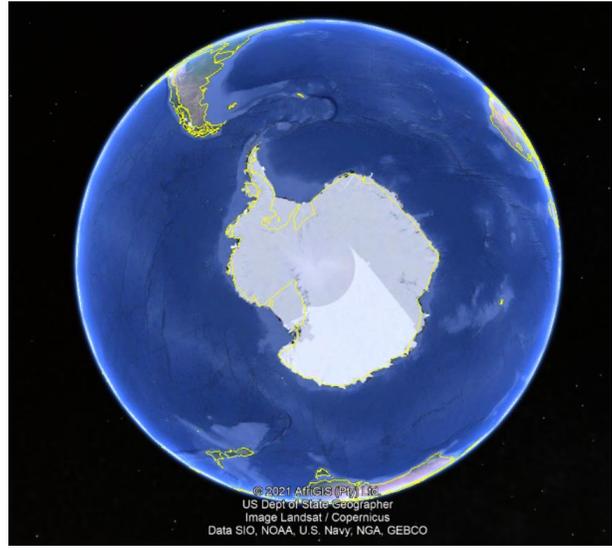
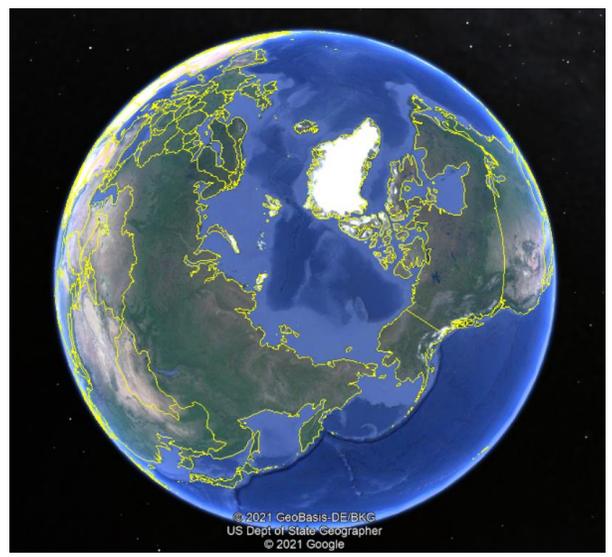
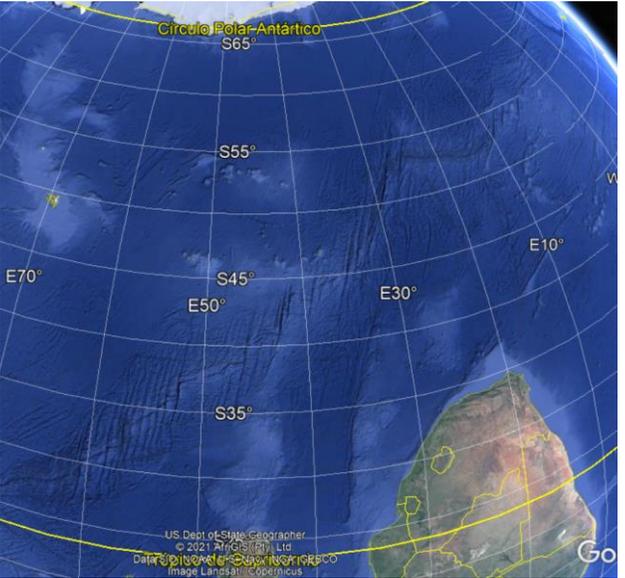
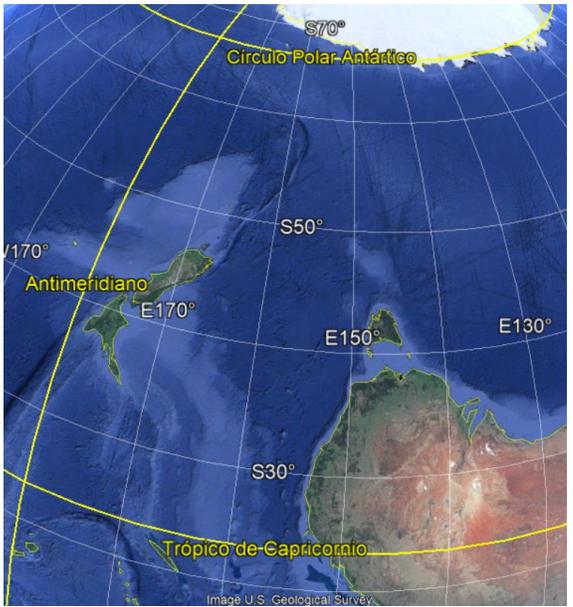


De Gi - Trabajo propio, Dominio público,
<https://commons.wikimedia.org/w/index.php?curid=5841884>

Chile: A multihazard country



Chile: A multihazard country

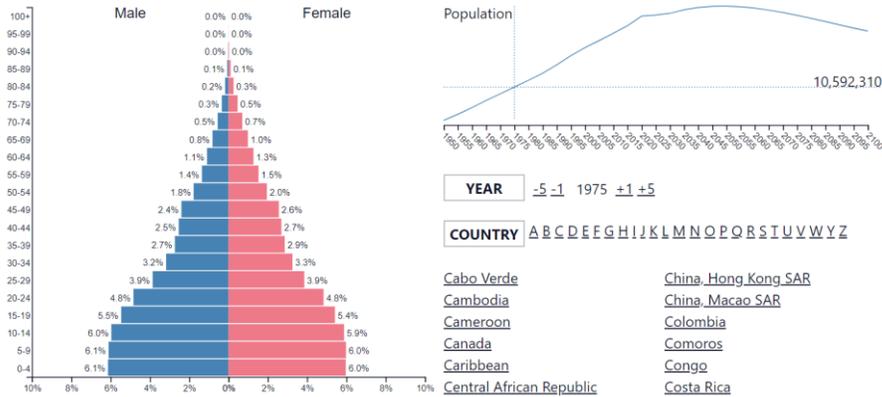




Chile: A multihazard country

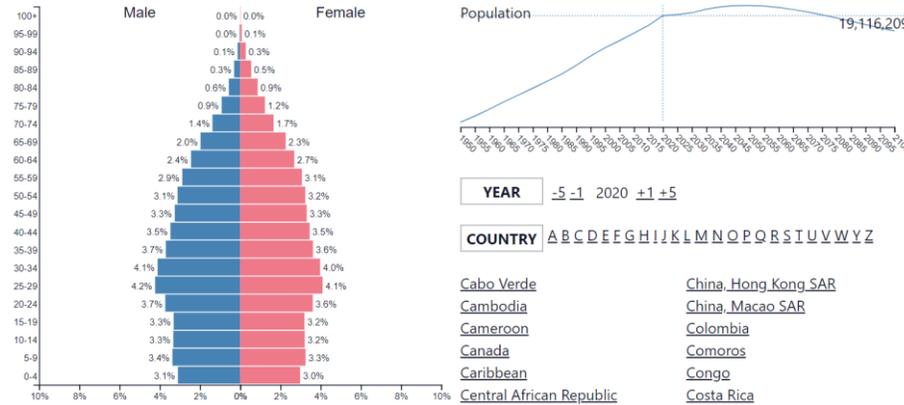
Chile ▼
1975

Population: 10,592,310



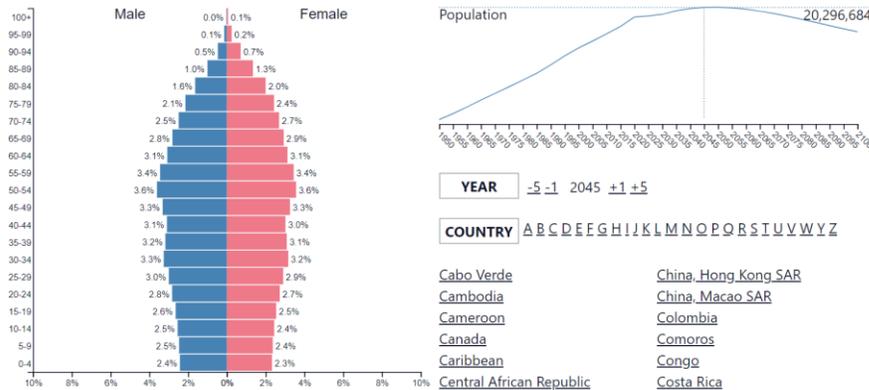
Chile ▼
2020

Population: 19,116,208



Chile ▼
2045

Population: 20,296,683



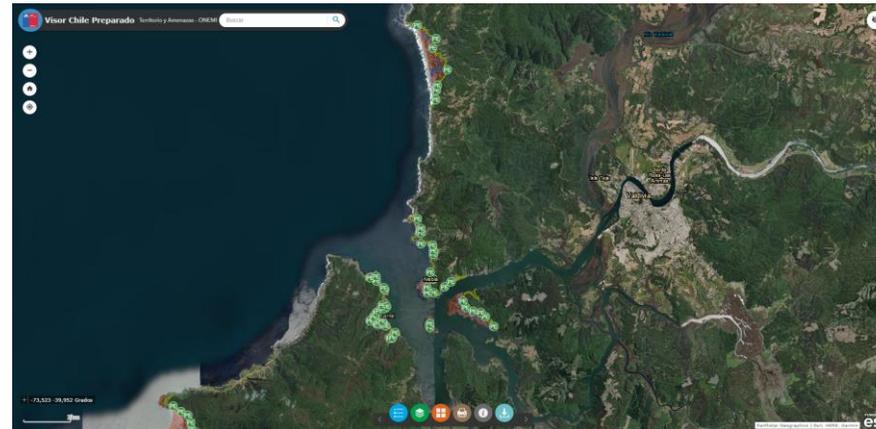
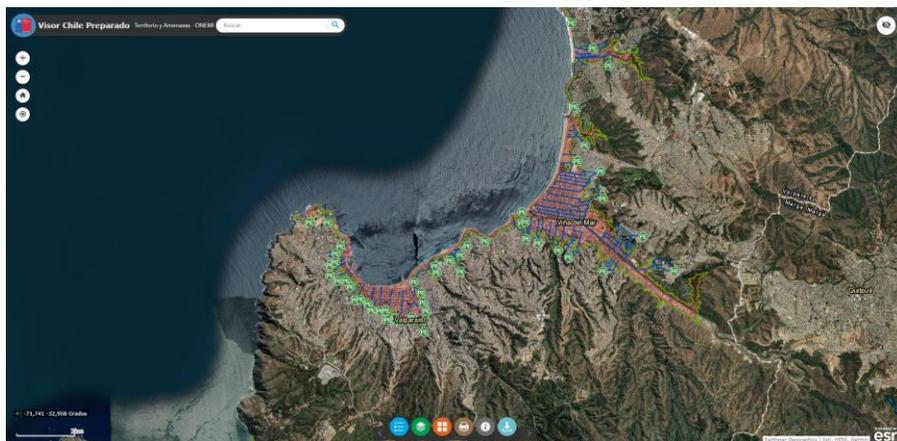
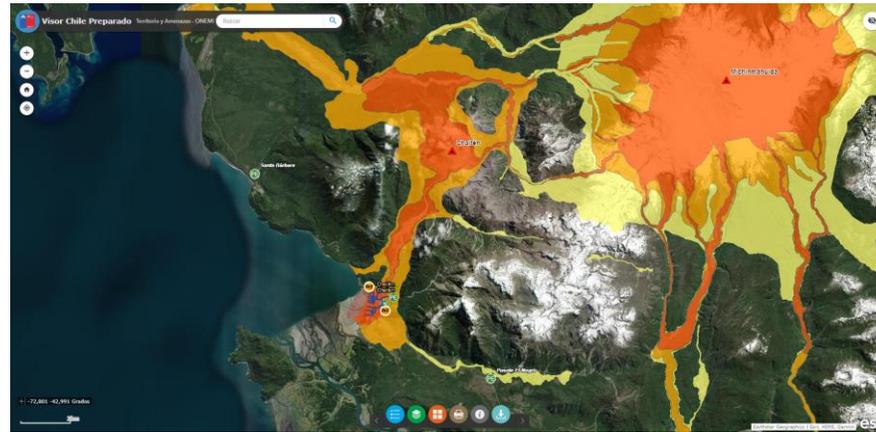
19,000,000 people.
8,000,000 in Santiago and surroundings.
GDP 24,700 U\$ per capita
One main language (spanish).



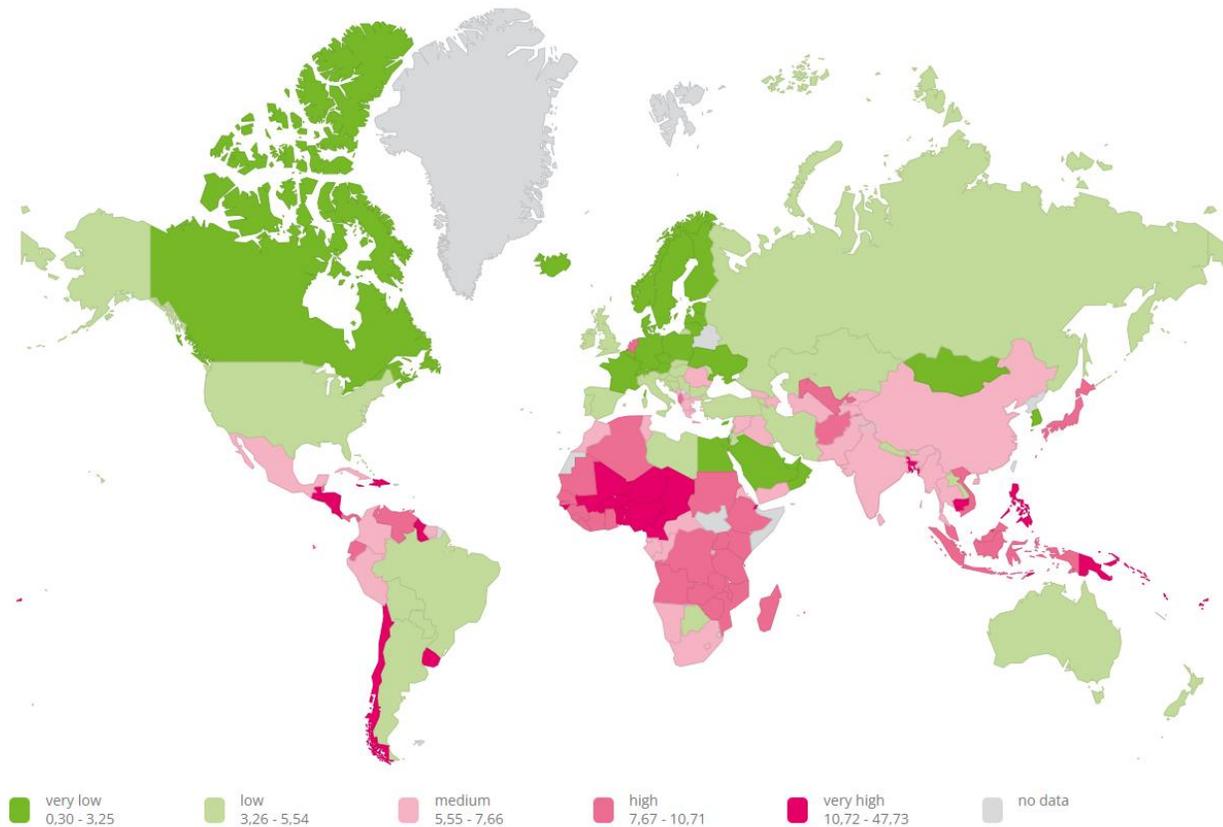
Chile: A multihazard country

<https://arclim.mma.gob.cl/atlas/index/>

<https://www.onemi.gov.cl/visor-chile-preparado/>



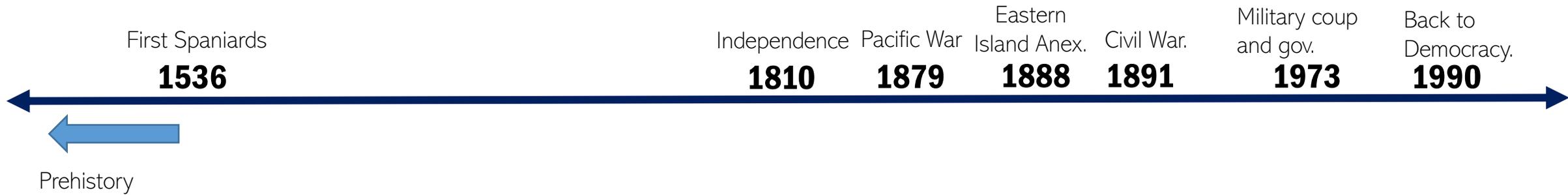
Disaster Risk Management



So, Chile is a large country, not so populated, but with vulnerabilities and under the threat of several hazards.



Chile: A multihazard country



Principales desastres ocurridos desde 1980 en Chile ⁽¹⁾

A través de este documento, el Servicio Nacional de Geología y Minería (Sernageomin) pone a disposición pública un registro dinámico de los principales desastres relacionados con Peligros Geológicos (remociones en masa², sismos, maremotos, inundaciones, aluviones, erupciones, etc.), con base en la documentación disponible en la Biblioteca del Sernageomin y en medios de comunicación. Esto incluye información sobre pérdidas de vidas humanas y montos gastados por el fisco en reconstrucciones.

Ortigosa (1993). Failures of quay walls during Chilean earthquake of March 1985



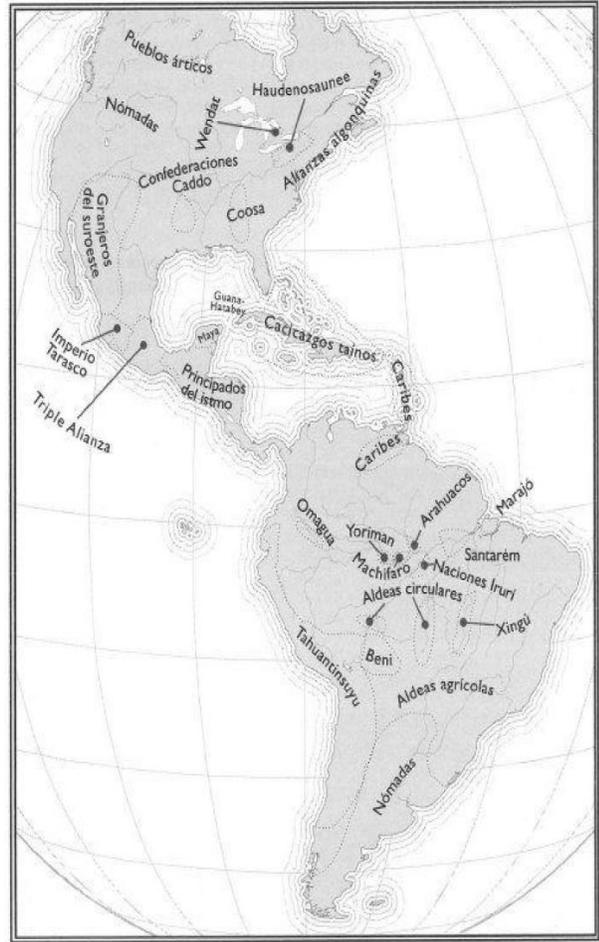
Earthquakes

First Spaniards
1536

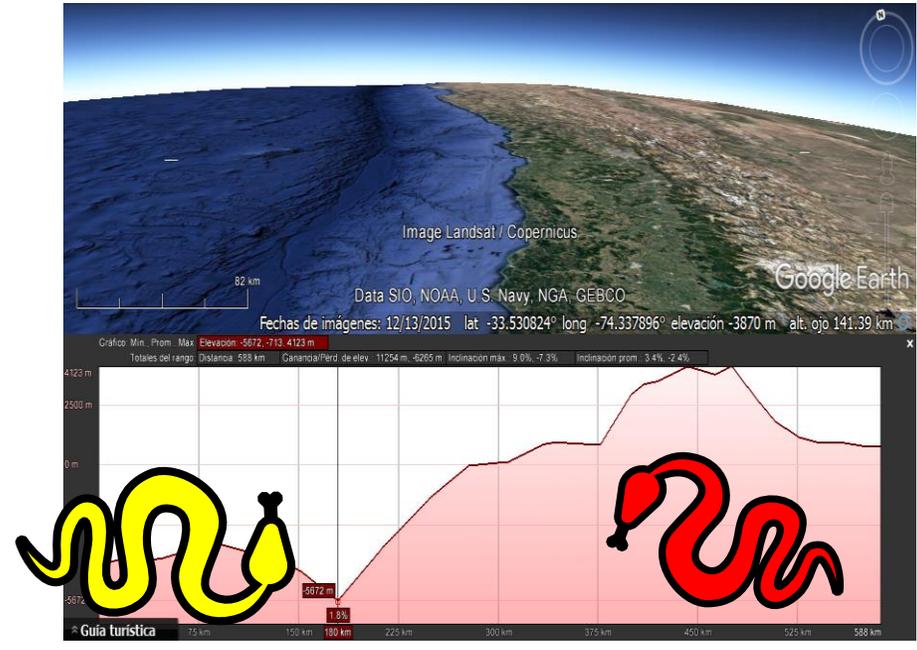
Independence	Pacific War	Eastern Island Anex.	Civil War.	Military coup and gov.	Back to Democracy.
1810	1879	1888	1891	1973	1990



Prehistory
←



América indígena, 1491.



Mapuche people: Oral tradition... no written language.

Earthquakes

First Spaniards
1536

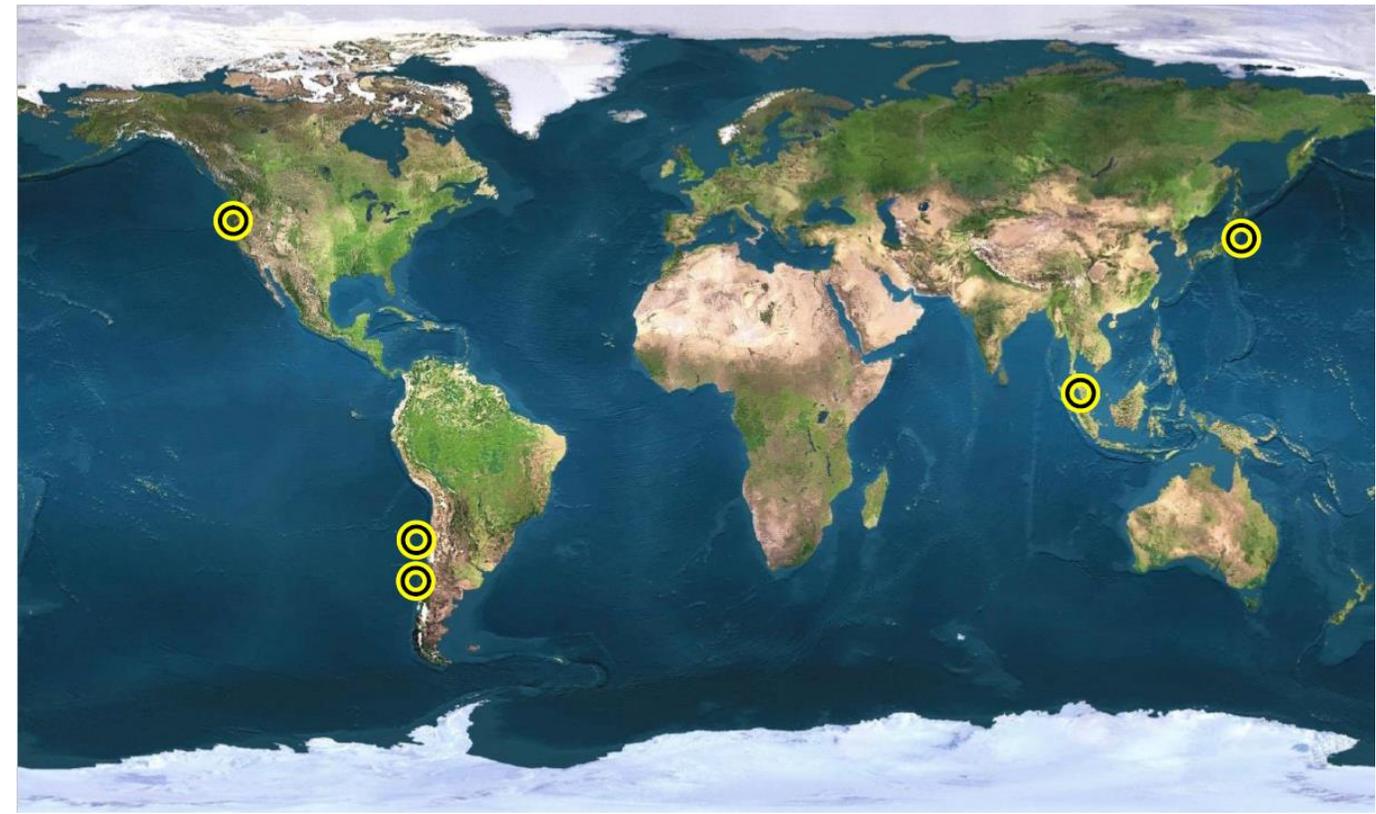
Independence **1810** Pacific War **1879** Eastern Island Anex. **1888** Civil War. **1891** Military coup and gov. **1973** Back to Democracy. **1990**



Prehistory



RECURRENCE





Earthquakes

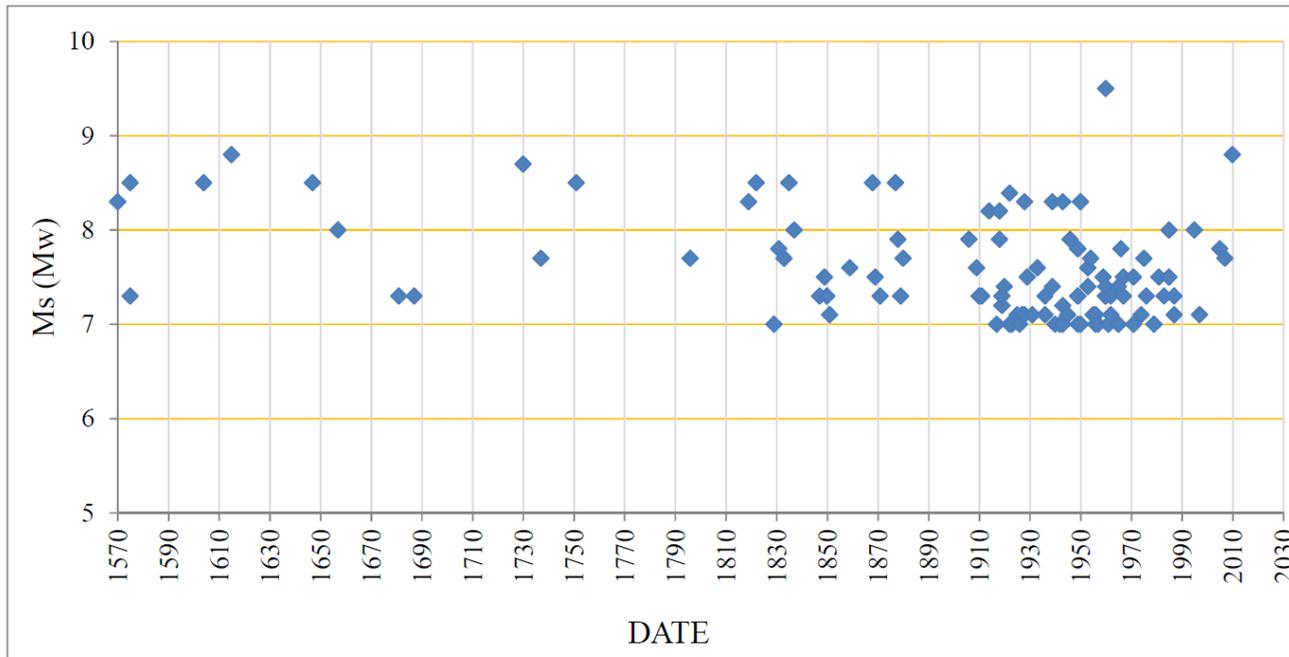
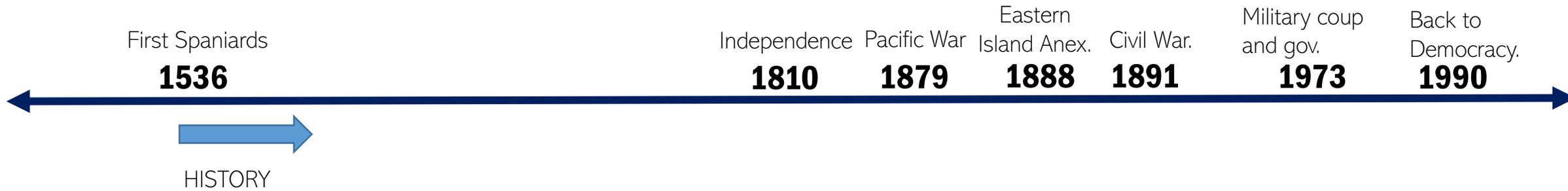


Figure A-2. Historical Earthquakes in Chile. Elaborated with data from (Servicio Sismológico de Chile, 2012).

Screenshot of the CSN website showing earthquake data and educational resources.

CSN CENTRO SISMOLÓGICO NACIONAL UNIVERSIDAD DE CHILE

fcfm FACULTAD DE CIENCIAS FÍSICAS Y MATEMÁTICAS UNIVERSIDAD DE CHILE

Sismicidad **Educación** **Noticias**

Últimos Sismos

Fecha Local	Lugar	Magnitud
2022/03/08 16:01:08	87 km al O de Pisagua	2.5 ML
2022/03/08 15:11:41	56 km al S de Tierra Amarilla	3.1 ML
2022/03/08 13:33:52	37 km al SO de La Ligua	3.0 ML
2022/03/08 13:31:26	60 km al SO de Caldera	2.5 ML
2022/03/08 09:44:04	40 km al NE de Mina La Escondida.	2.7 ML
2022/03/08 08:42:36	34 km al NE de Pica	2.5 ML
2022/03/08 07:35:53	98 km al O de Pisagua	4.3 ML
2022/03/08 06:09:44	71 km al S de Baquedano	4.2 ML
2022/03/08 04:58:24	126 km al NO de Hualco	2.5 ML
2022/03/08 03:25:41	41 km al SE de Mina Los Pelambres	3.0 ML
2022/03/08 02:57:31	158 km al NO de Bahía Mansa	3.3 ML
2022/03/08 01:28:20	79 km al NO de Tocopilla	2.5 ML
2022/03/08 01:16:12	81 km al SE de Socaire	4.0 ML
2022/03/08 00:59:40	30 km al S de Camiña	2.9 ML
2022/03/07 23:56:11	29 km al N de La Ligua	2.7 ML

Educación

¿Te apasiona la ciencia? ¿Te interesa conocer el mundo de la Geofísica? Da el primer paso familiarizándote con material científico que exponemos para ti.

Ver más...

Noticias

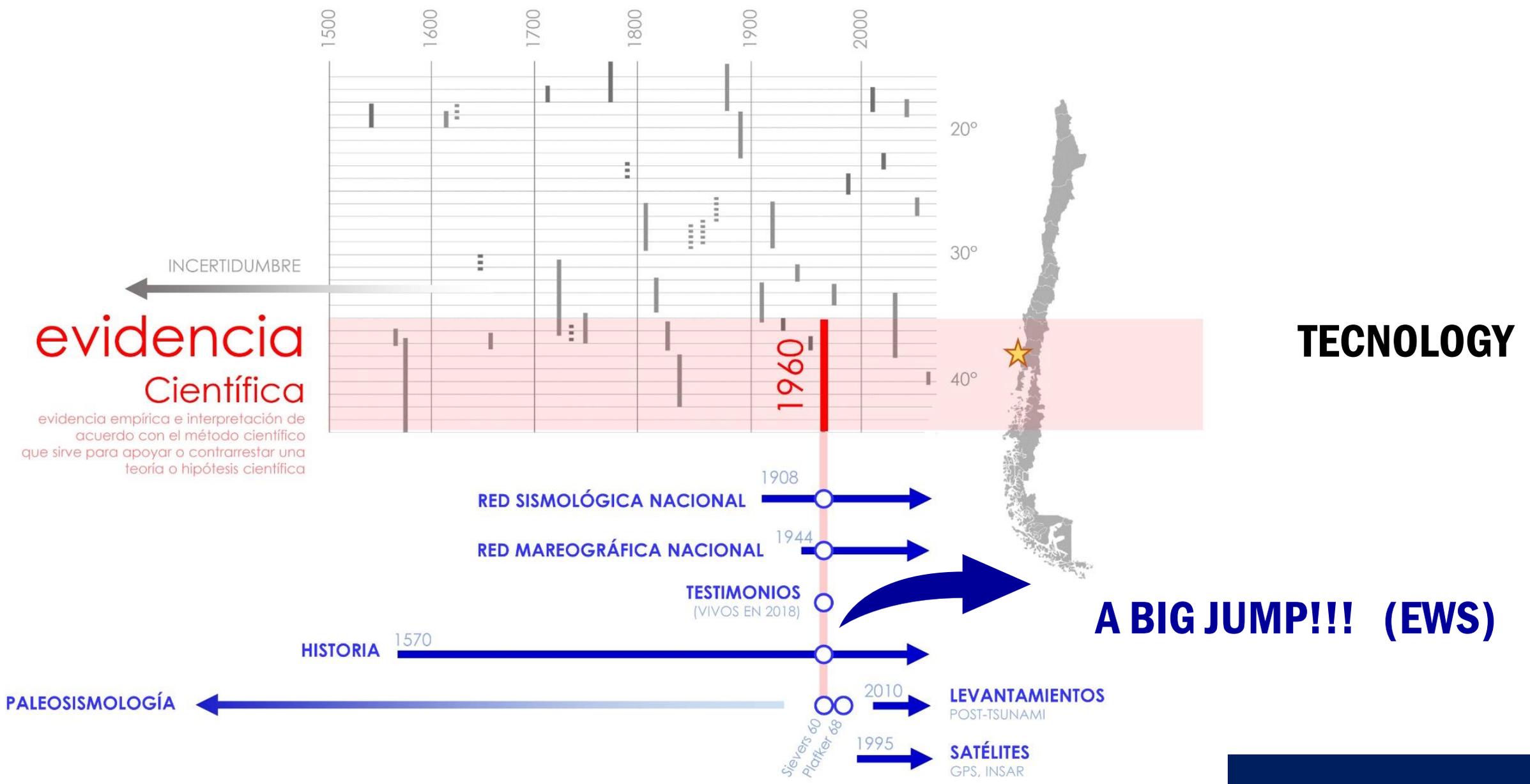
Visita el sitio institucional del Centro Sismológico Nacional, conoce más sobre la red sismológica y entréate de las novedades que tenemos para ti.

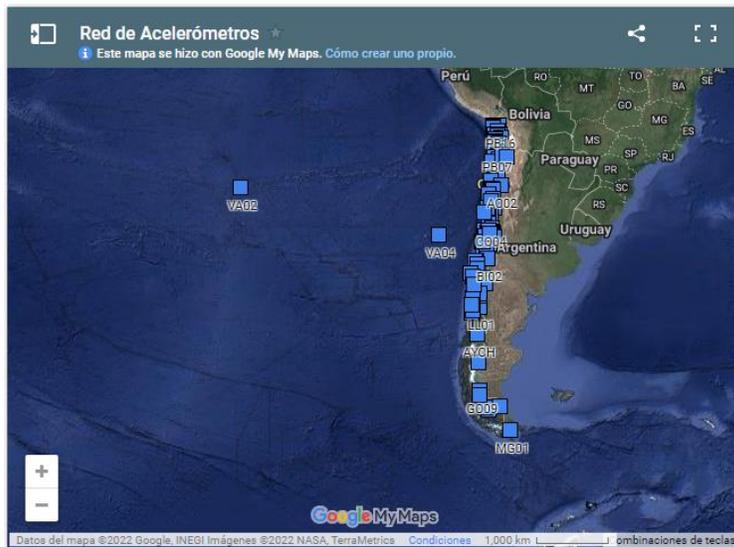
Ver más...

Centro Sismológico Nacional, Universidad de Chile, Blanco Encalada 2002 - Casilla #2777 Santiago, Chile. Email: contacto@csn.uchile.cl

Síguenos en: [f](#) [t](#)

Earthquakes





TECNOLOGY

Measurement / monitoring / forecasting / communicating

Research
Education



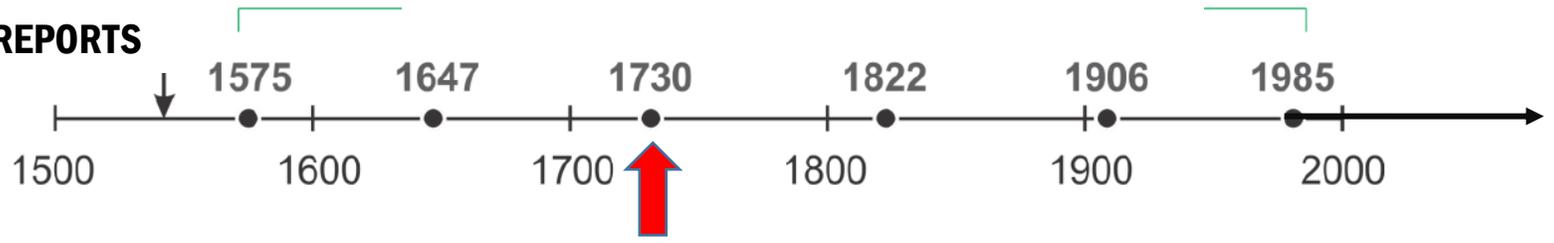


Earthquakes

BIG EQ IN HISTORY

CENTRAL CHILE

FIRST WRITTEN REPORTS



EARTHQUAKE MAGNITUDE UNDERESTIMATED FROM PARTIAL HISTORICAL RECORDS.



UNDERESTIMATION OF HAZARD



CARVAJAL (2015)
PROPOSED 8,5Mw TO

9,1Mw

Earthquakes



**CHILLAN 1939:
EQ 8,3Mw**

INLAND (100KM DEPTH)

AROUND 24000 VICTIMS (THE LARGEST ONE)

RF MASONRY / CORFO / BUILDING CODE

Tsunami:

VALDIVIA 1960:

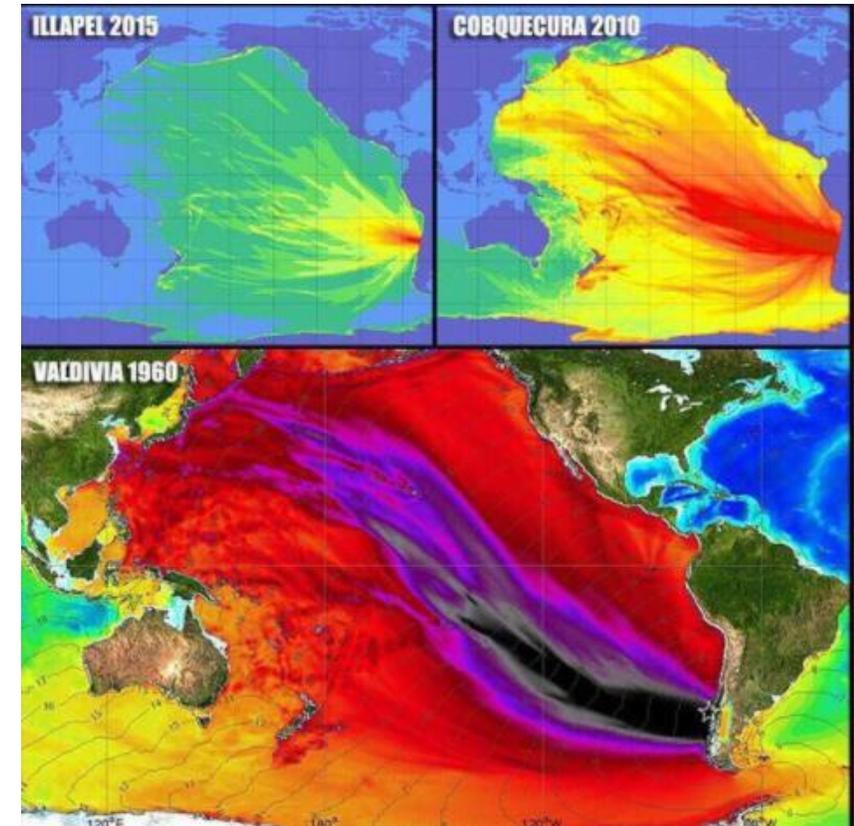
FORESHOCK 8,2Mw

EQ 9,5Mw

TSUNAMI

AROUND 2000 VICTIMS

SOIL MECHANICS / ONEMI / PTWC



Earthquakes

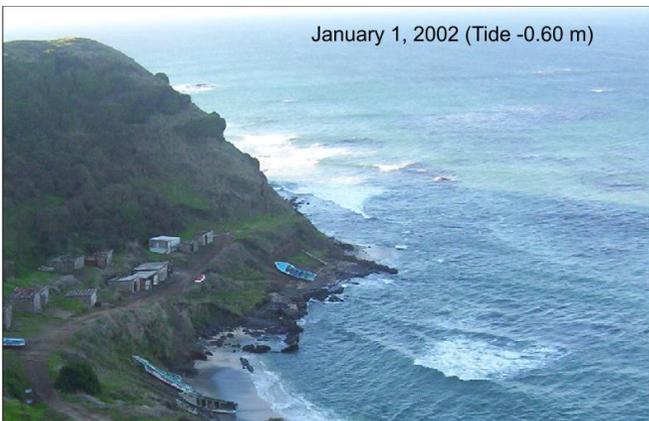


**LLOLLEO 1985:
EQ 7,8Mw
NO TSUNAMI
AROUND 180 VICTIMS
MEASUREMENT / NCh433/ ONEMI**



THERE IS EVIDENCE!

SOUTH-CENTRAL CHILE (27F2010)

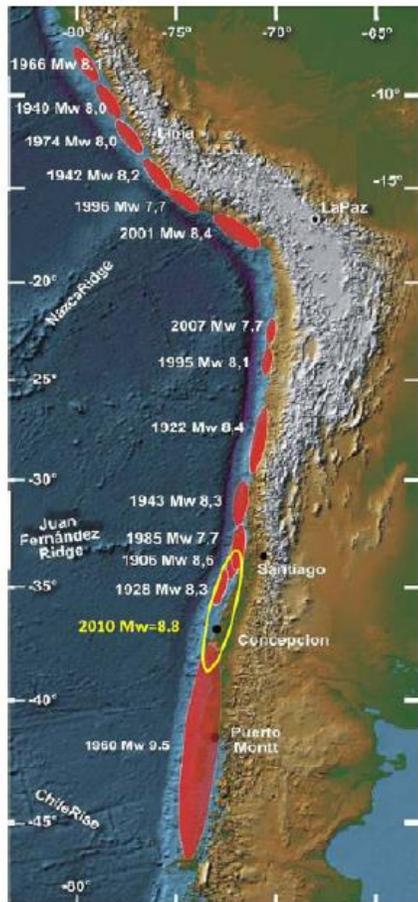


January 1, 2002 (Tide -0.60 m)

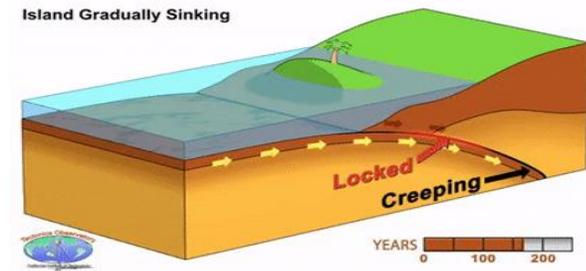


March 12, 2010 (Tide -0.40 m)

Isla Santa María.
Melnick et al., 2012, Geology



Earthquakes



**MAULE 2010:
EQ 8,8Mw
TSUNAMI**

AROUND 600 VICTIMS

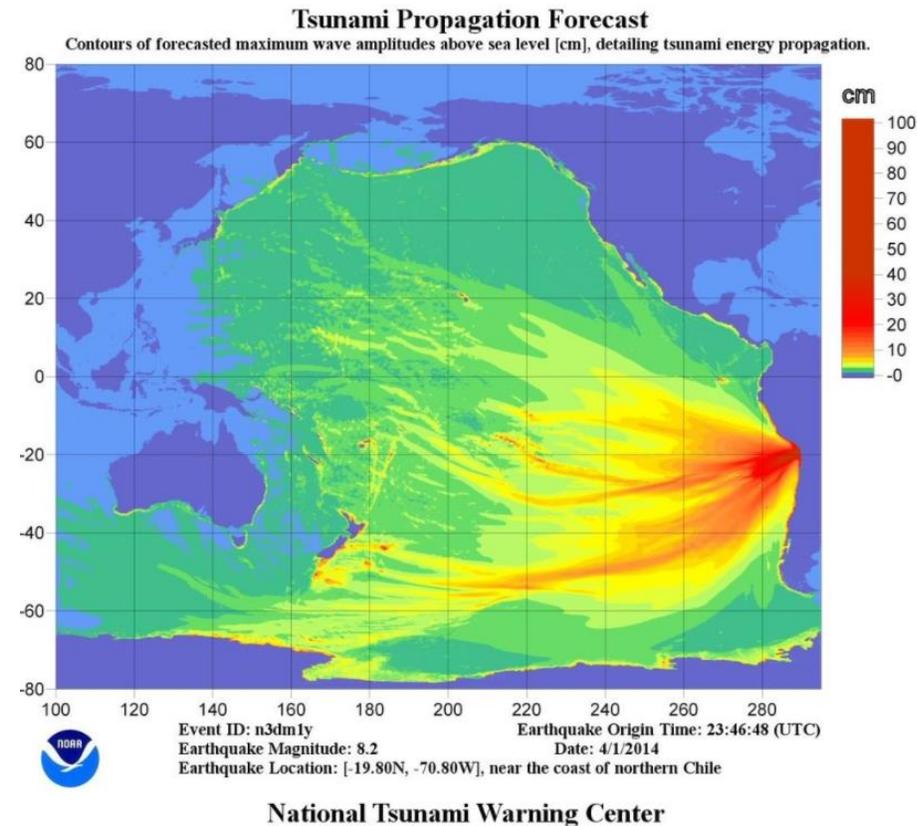
SOIL MECHANICS / RC CODE / ONEMI / SNAM



THERE IS EVIDENCE!

Earthquakes

NORTHERN CHILE (2014)



**IQUIQUE 2014:
EQ 8,2Mw
TSUNAMI**

7 DEAD, 200 INJURED

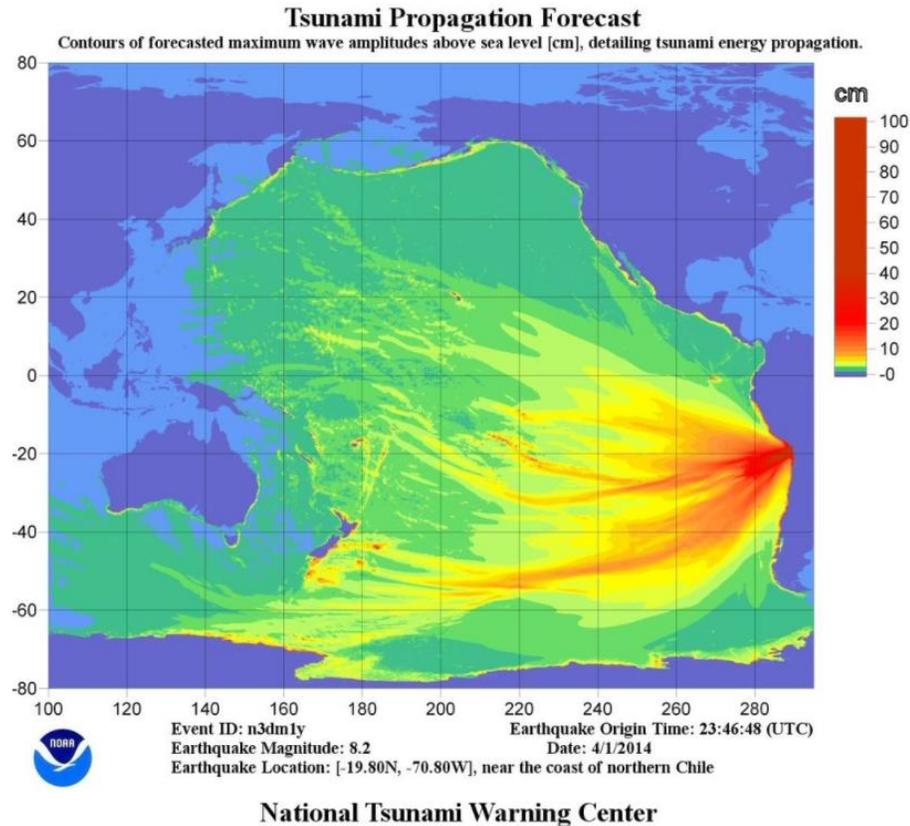
EVACUATION USING EWS / PORTS BCP



THERE IS EVIDENCE!

Earthquakes

NORTHEN CHILE (2014)



ILLAPEL 2015:

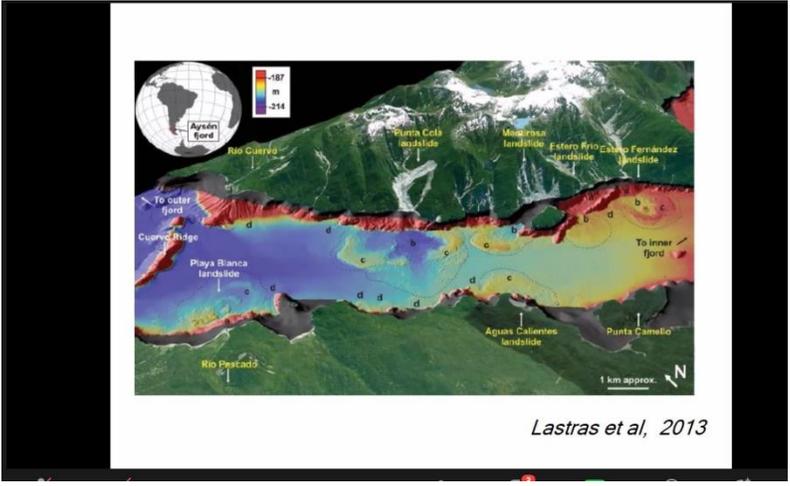
EQ 8,4Mw

TSUNAMI

7 DEAD, 200 INJURED

EVACUATION USING EWS / LESS THAN 10 MIN

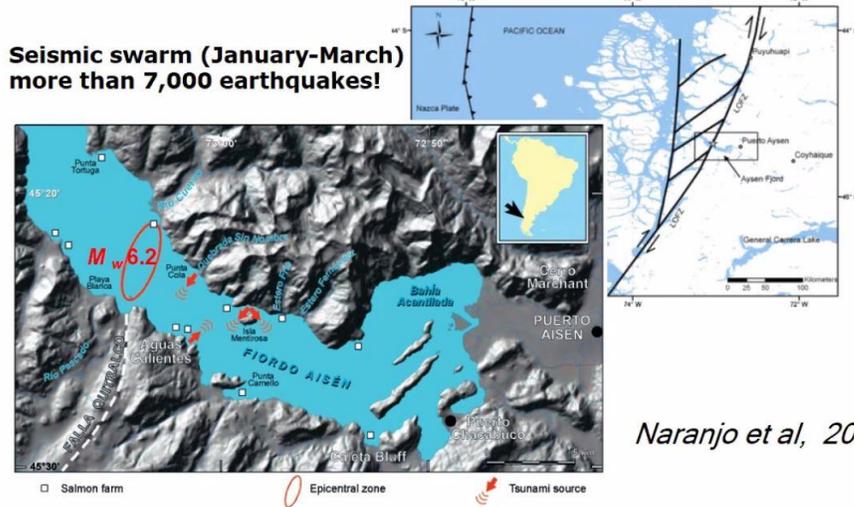
Tsunami: AYSÉN 2007



Lastras et al, 2013

Earthquake-induced rock slide and tsunami in Aysen fjord (2007)

Seismic swarm (January-March)
more than 7,000 earthquakes!



Naranjo et al, 20



- a) Shallow soil slides
- b) Shallow soil-rock slide
- c) Rock slide in front of Mentirosa Island
- d) Rock slide and avalanche in Punta Cola area
- e) Rock falls
- f) Debris flow



Tsunami:

MAULE 2010

IQUIQUE 2014

ILLAPEL 2015

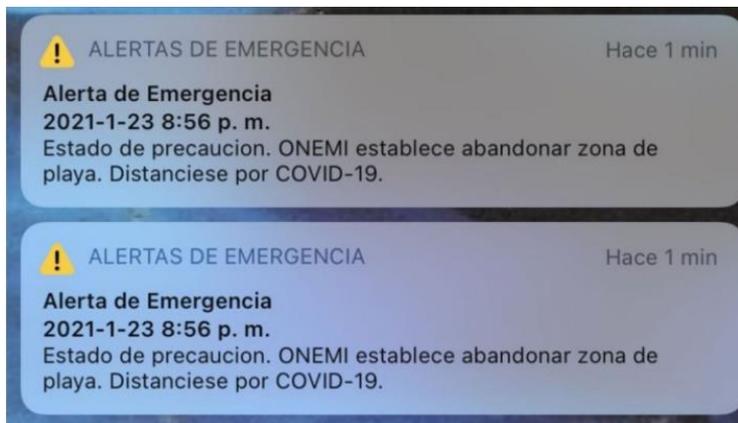
CHILOÉ 2016

ANTARTIC OCEAN 2021

TONGA 2022



Tsunami:



SNAM (Sistema Nacional de Alerta de Maremotos)

<https://www.snamchile.cl/index.php?p=snam&enl=3>

SIPAT (Sistema Integrado de Predicción y Alarma de Tsunamis)

<https://www.youtube.com/watch?v=1nvECsArJZY>





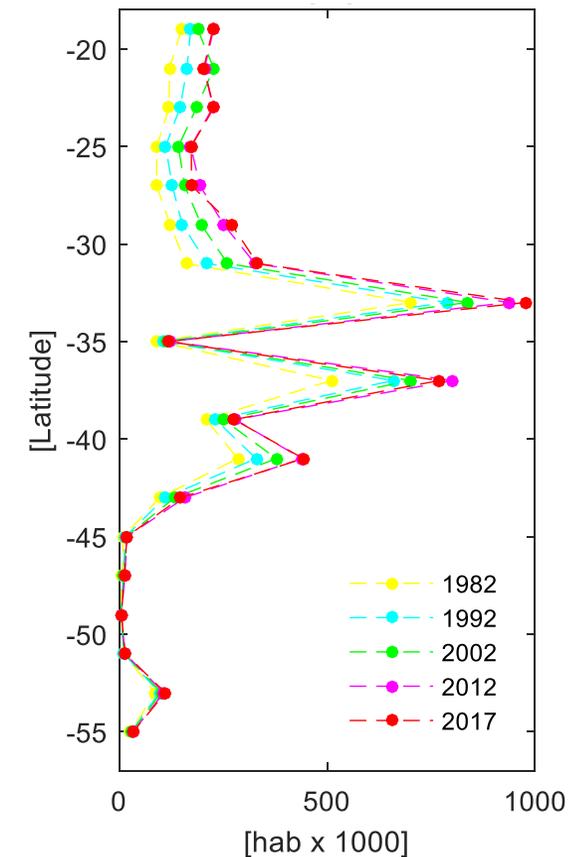
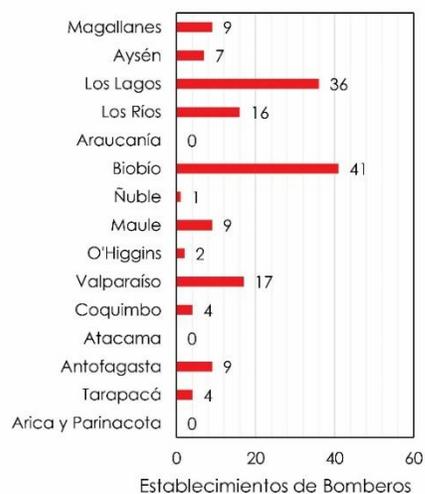
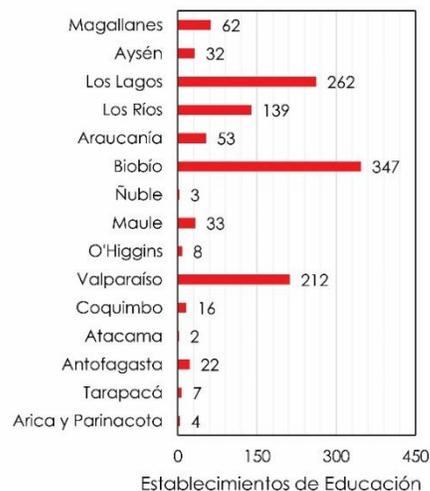
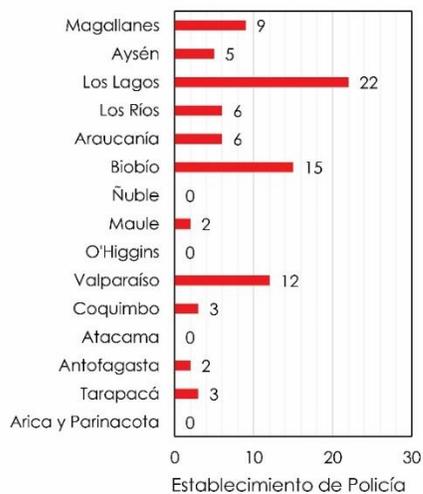
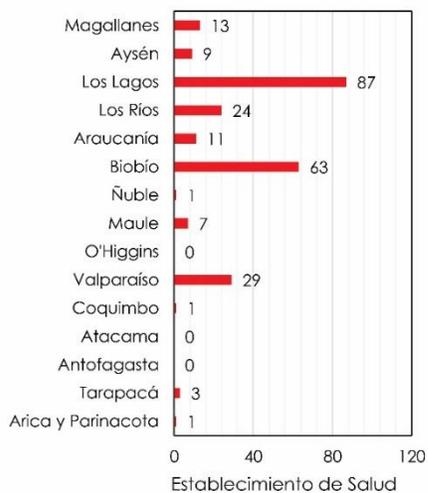
**WE HAVE TO TALK ABOUT OUR COUNTRY,
WITHOUT ANGER AND LOOKING FOR THE
COMMON BENEFIT.**

GOVERNANCE IS NEEDED

Our vulnerabilities:

- They are always present, no matter which country are we talking about.
- Inequality and lack of urban planning. Actually, I should say societal, ecological, economical, and other complex things.
- Ignorance and bad education. Bad use of technology (fake news).
- They are always present, no matter which country are we talking about.
- Inequality and lack of urban planning. Actually, I should say societal, ecological, economical, and other complex things.
- Our old infrastructure. The maintenance of infrastructure.
- Transportation systems.
- Etc...

Our vulnerabilities:



100 coastal municipalities: **4,5 millones** (26%, INE, 2017)

Below 10 [masl]: **972.623** (5,53%)

Below 10 [masl] es **71,3% urbana y 28,3% rural**



Our Capacities:

- We have learned from experience.
- We know our territory and we have good universities.
- We are doing science. Not as much as we would like to, but we are.
- One language (this is not so valid with immigration...).
- We can spend money. Not as much as we would like to, but we can.
- Very good application of building codes and good control of building processes.
- We can make political improvements. Slow, but we can.
- Etc...



Strategic Analysis and a sort of conclusions

- Open mind and tolerance (Maisa).
- Education (for everyone).
- Investment.
- Control and law.
- **GOVERNANCE**

