Universidad de Valparaíso
CHILE

Reducing tsunami impacts to port and harbors

INTERNATIONAL TSUNAMI INFORMATION CENTER
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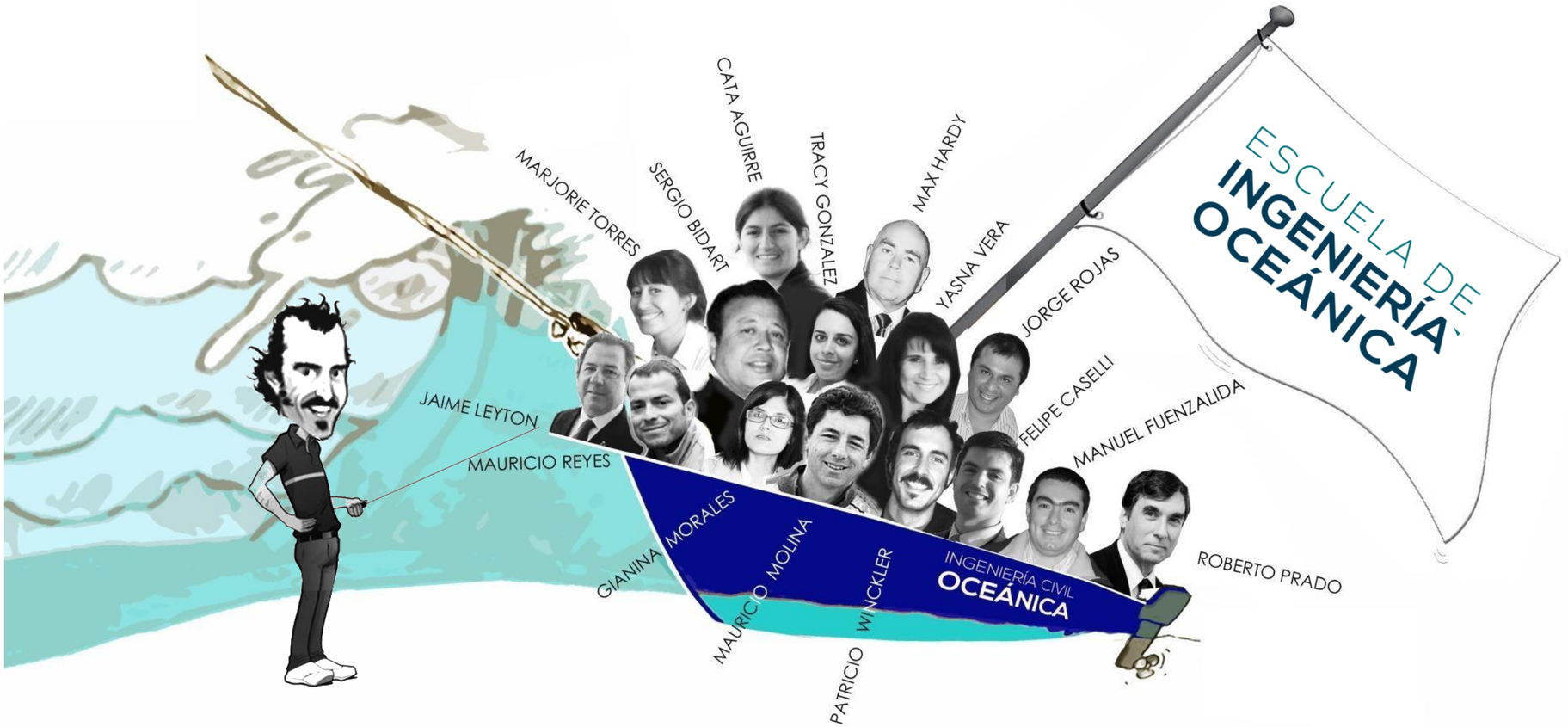
SERVICIO HIDROGRÁFICO Y OCEANOGRÁFICO
ARMADA DE CHILE

unesco
Intergovernmental Oceanographic Commission

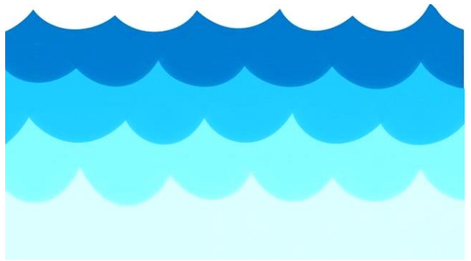


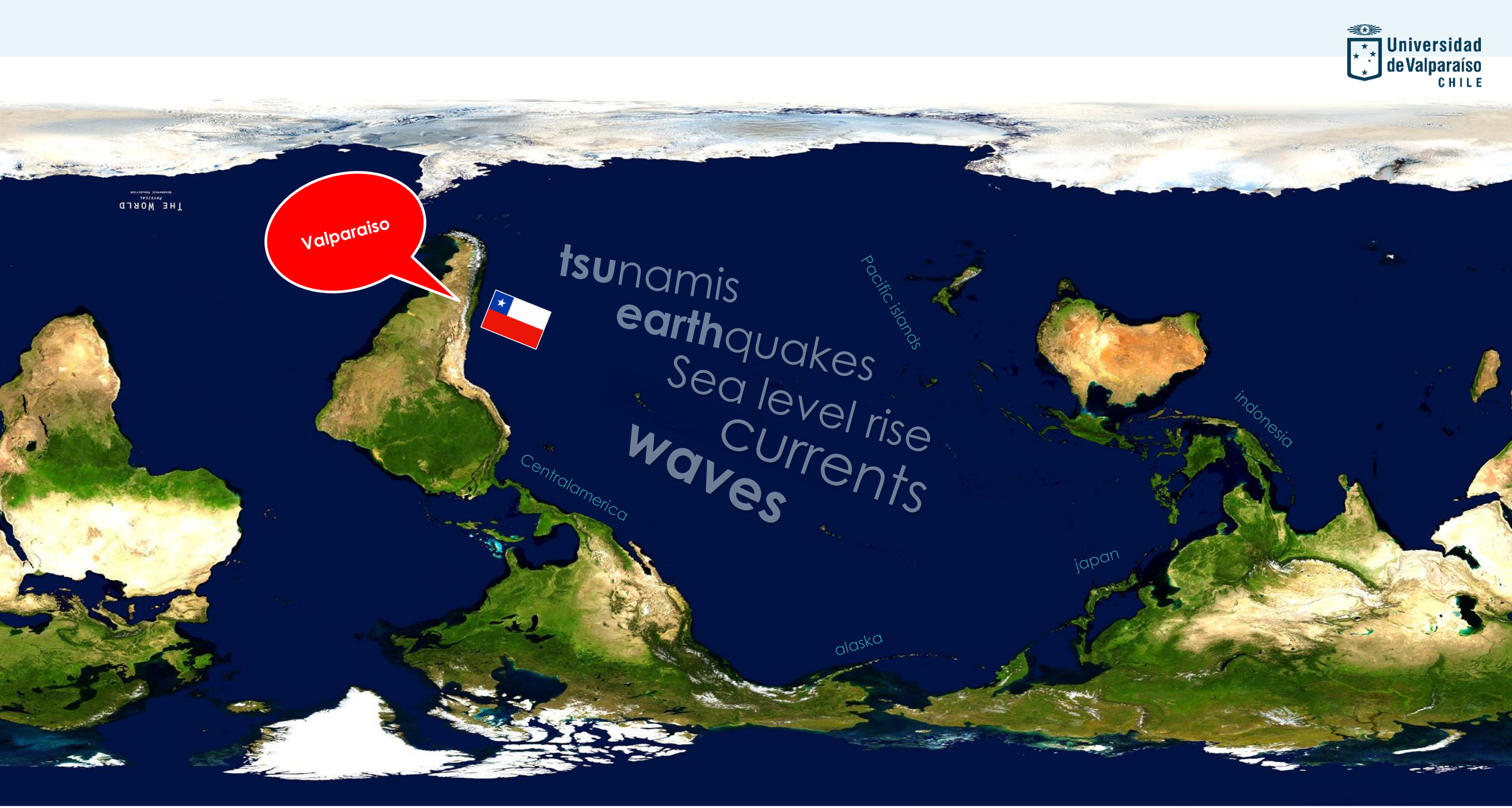
Ingeniero Civil, PhD.
Patricio Winckler
Patricio.winckler@uv.cl

CIGIDEN
Centro de Investigación
para la Gestión Integrada
del Riesgo de Desastres

physical context

south-america

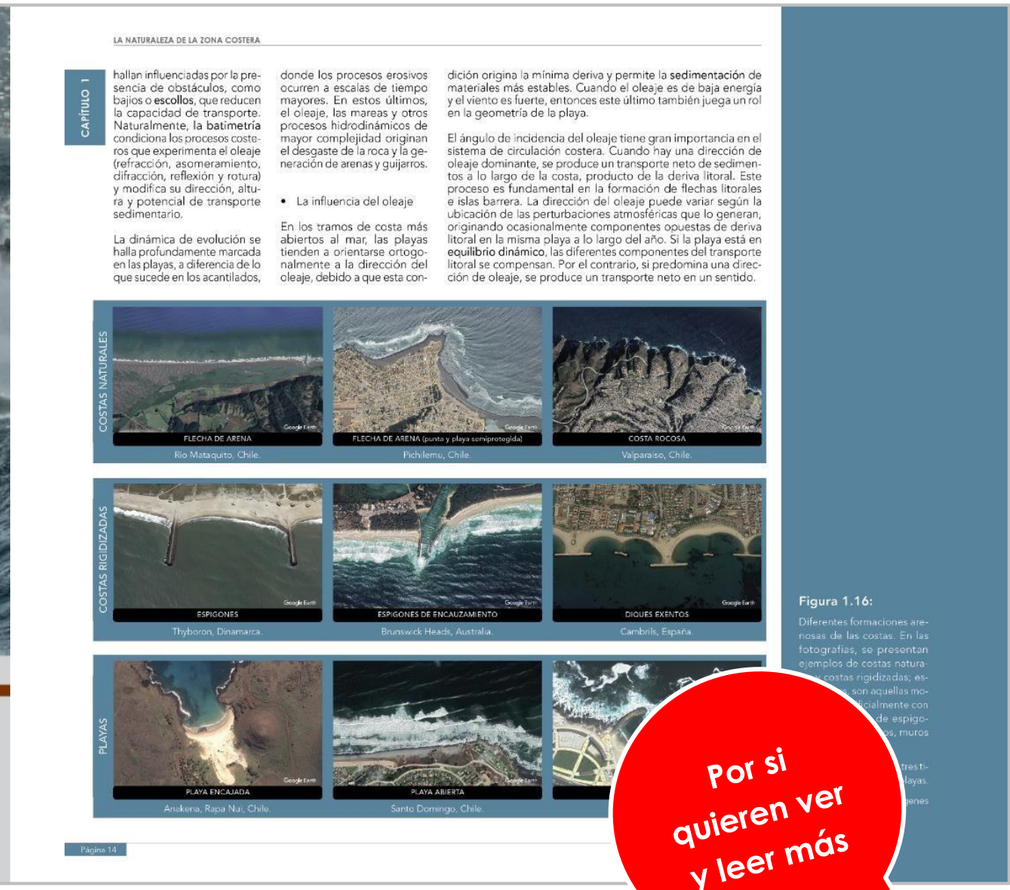




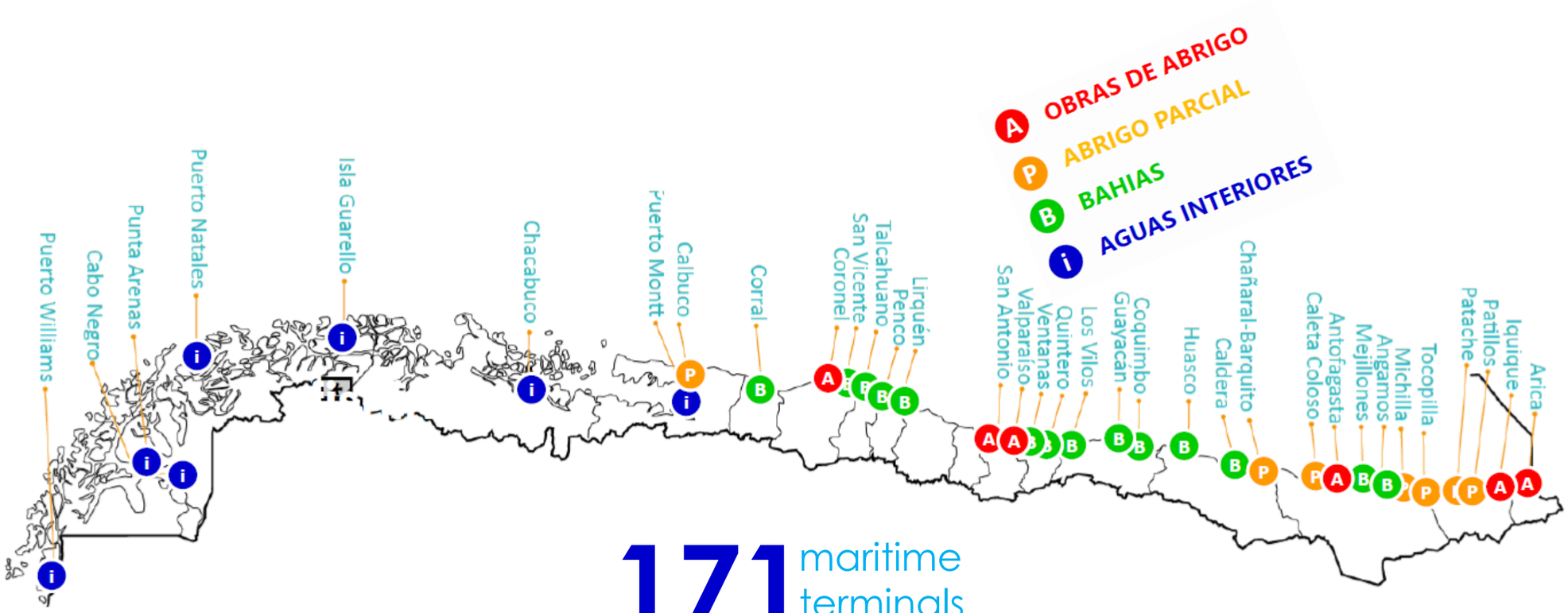
Costas de Chile (Morales, Winckler & Herrera, 2020)

Fuente: South_America_satellite_orthographic.jpg

www.cona.cl/pub/libros/Costas_de_Chile.pdf



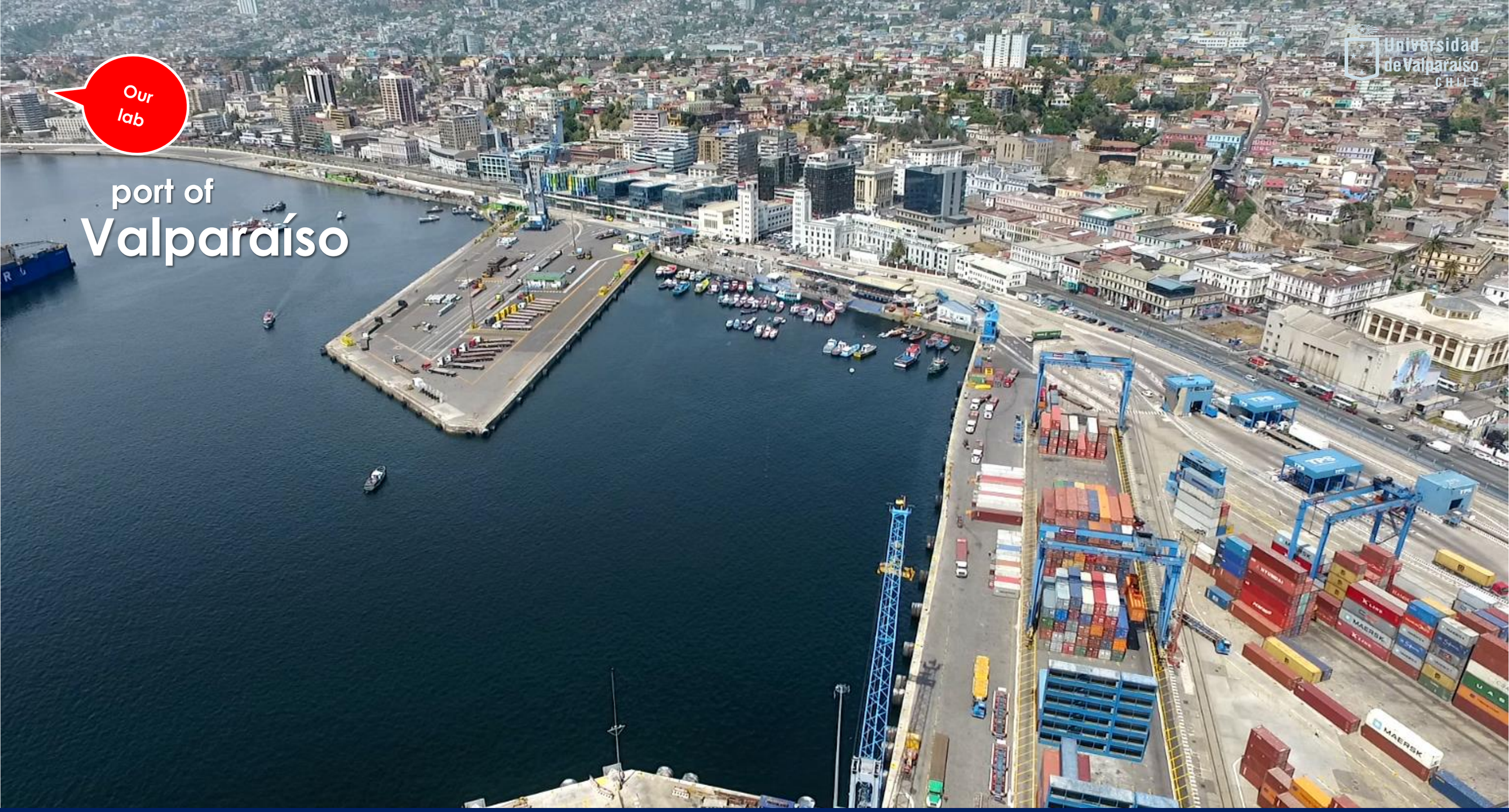
Por si quieren ver y leer más

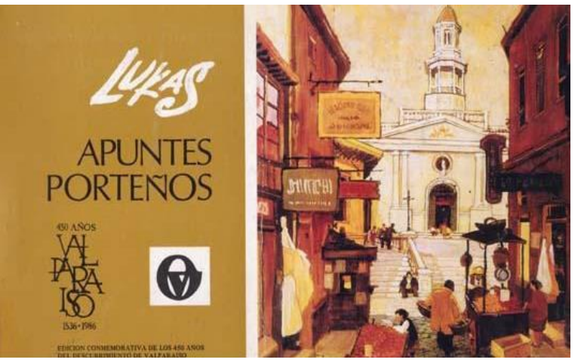


171 maritime terminals

433 settlements

1 millón people


Our lab
port of
Valparaíso
Universidad de Valparaíso
CHILE
MAERSK



1931

...mayor envergadura en todo el siglo XX

(Ortega et al., 2013)

1912

obras marítimas complejas!

Fuente: Apuntes Porteños, de Lukas

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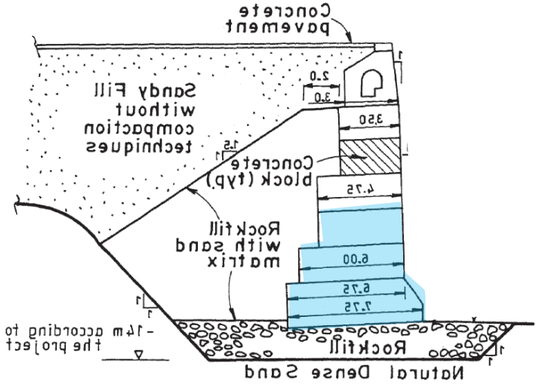
ciclo de vida de obras marítimas!

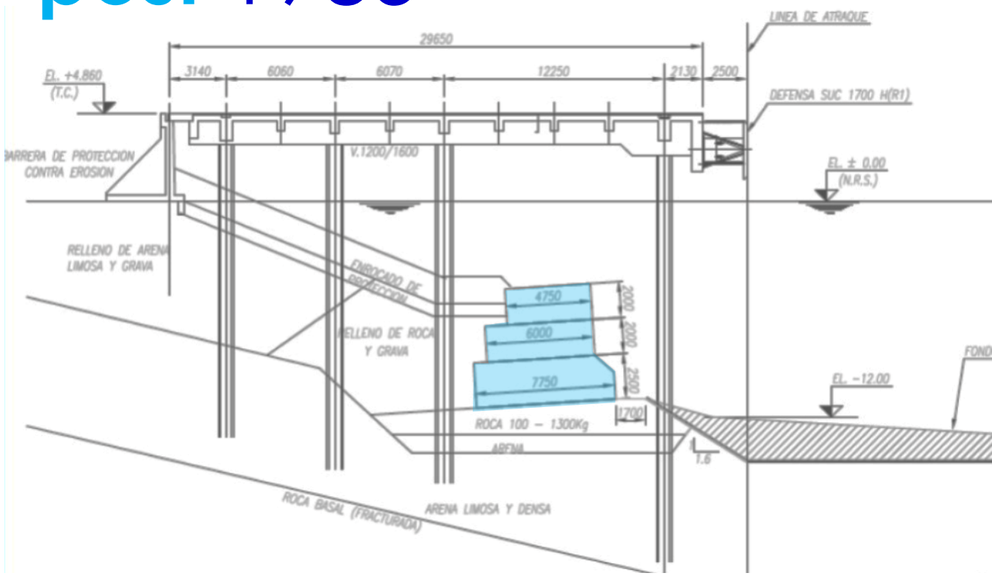
muy largo!

En su vida son afectas a sismos!



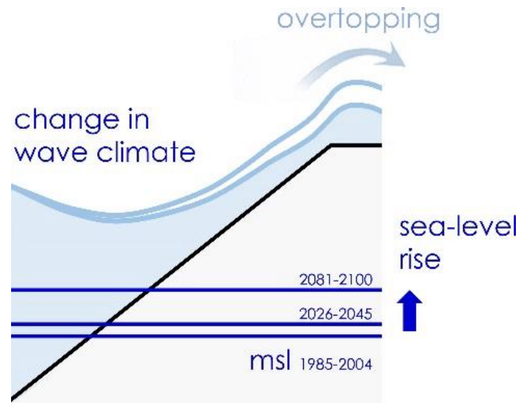
pre 1985

post 1985



Gentileza de Marcelo Muñoz, EPV

10 m



Gentileza de Francisco Ghisolfo

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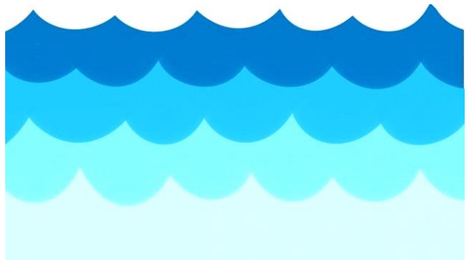
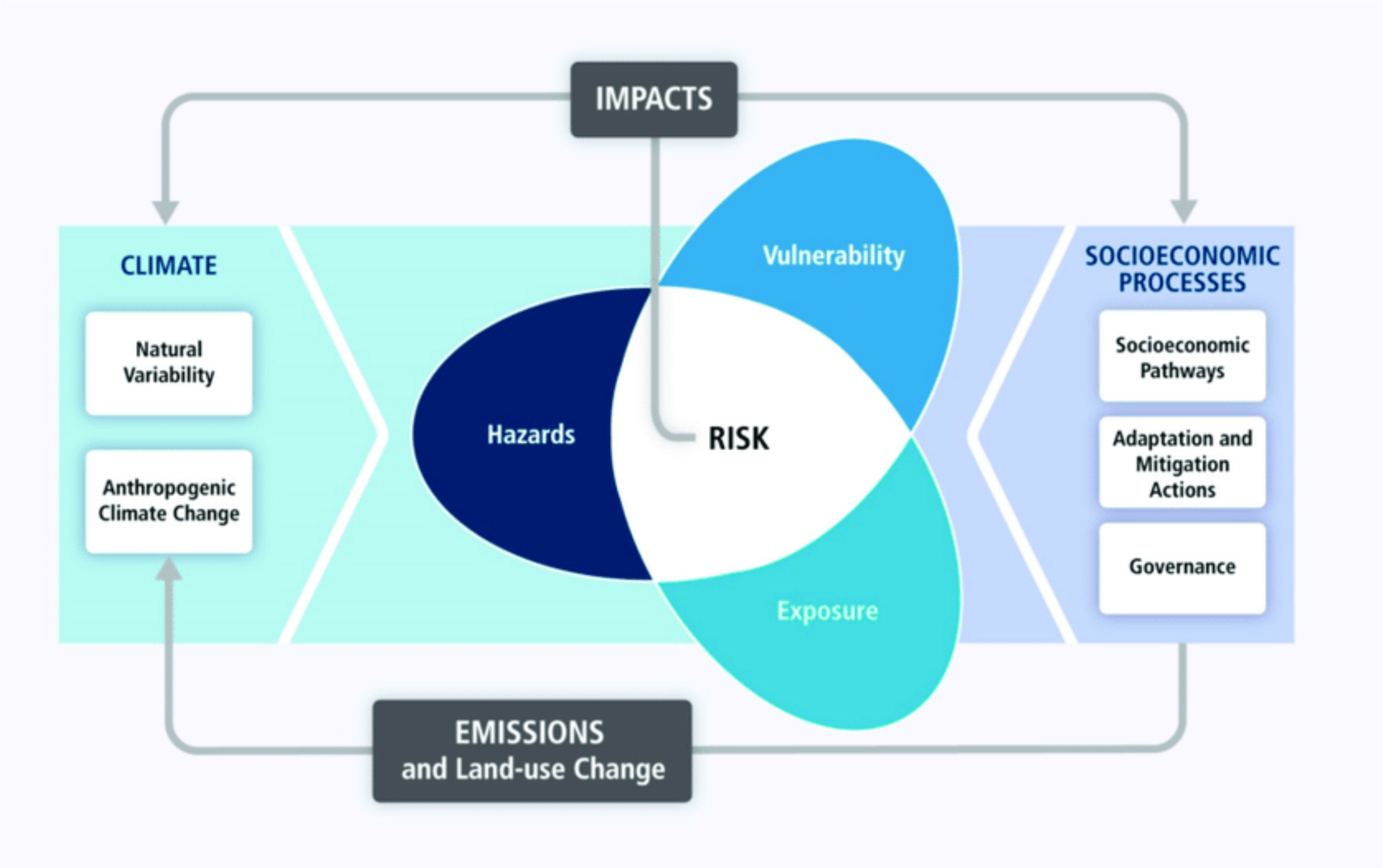
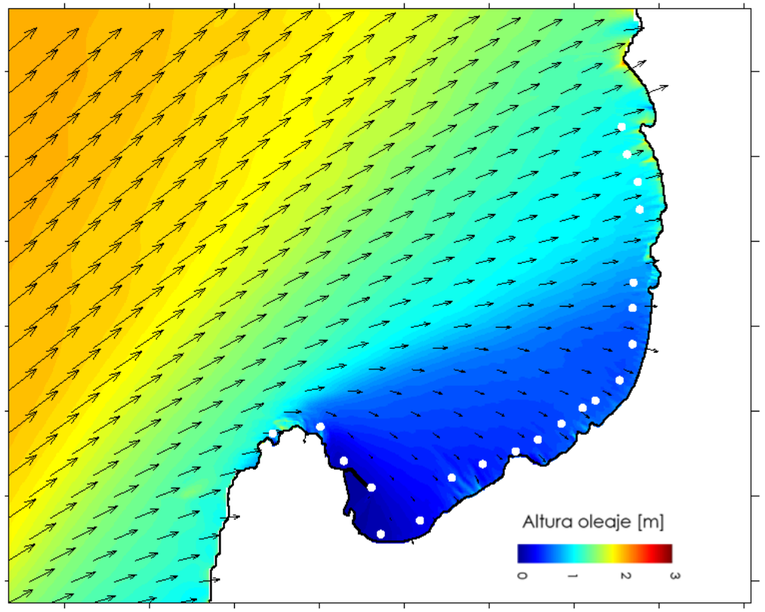
engineering
Tools & methods



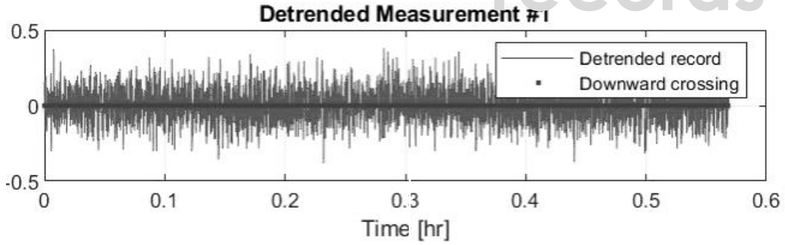

IMPACTS
CLIMATE
Natural Variability
Anthropogenic Climate Change
Hazards
Vulnerability
RISK
Exposure
SOCIOECONOMIC PROCESSES
Socioeconomic Pathways
Adaptation and Mitigation Actions
Governance
EMISSIONS and Land-use Change

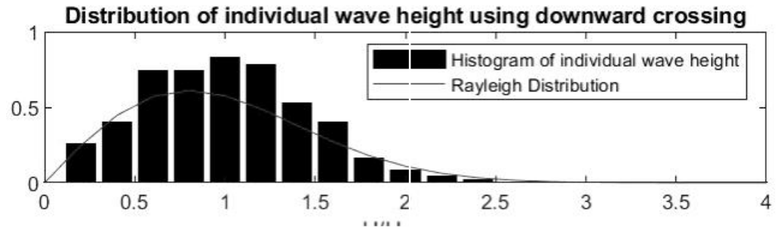
models

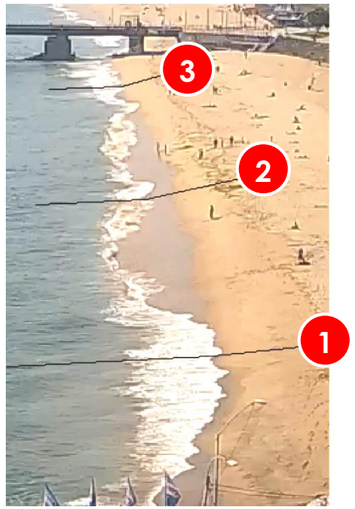
cameras

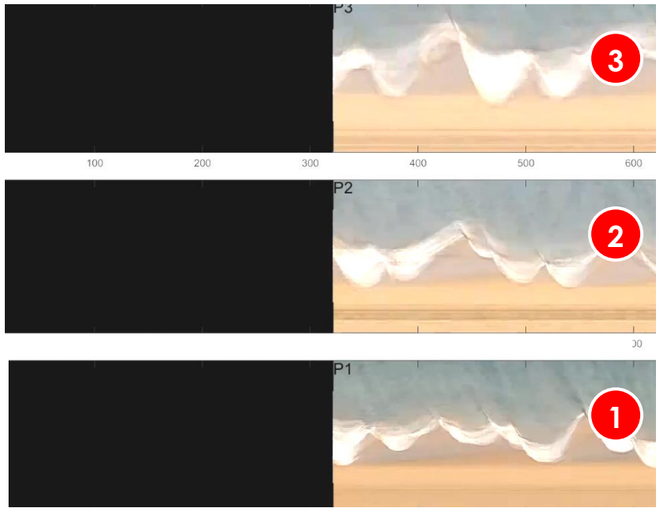


records

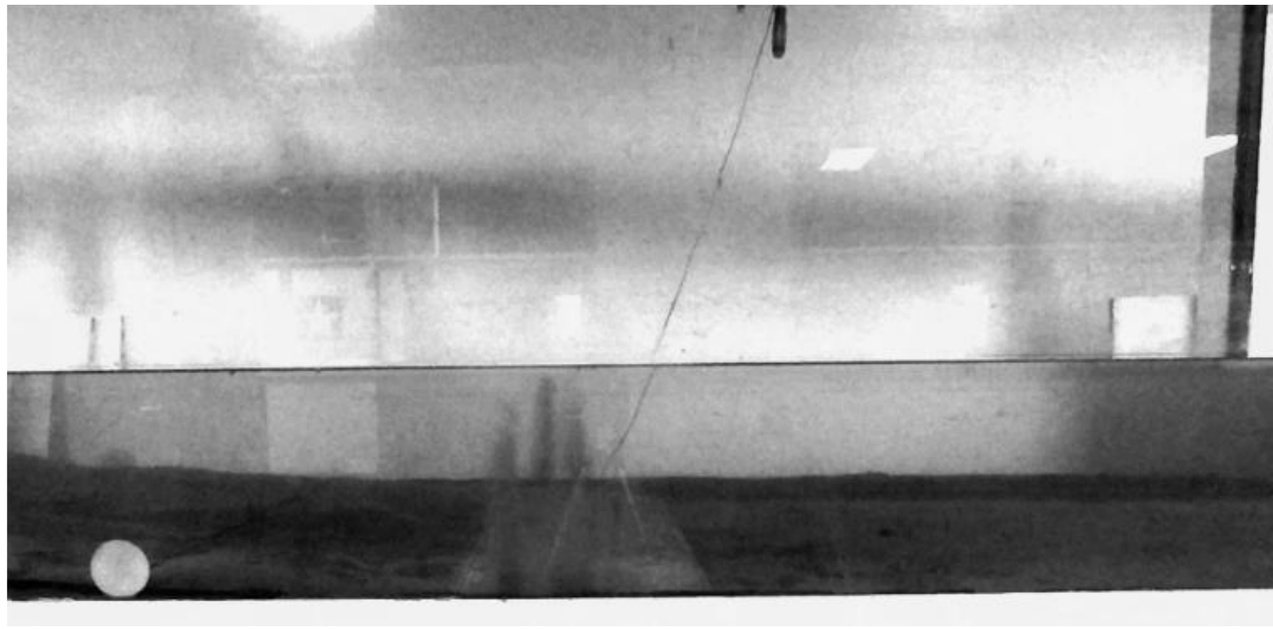


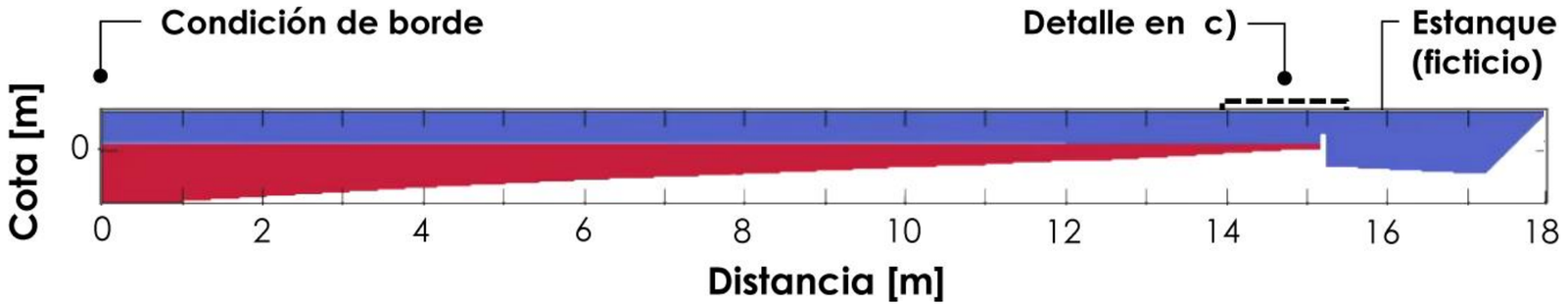


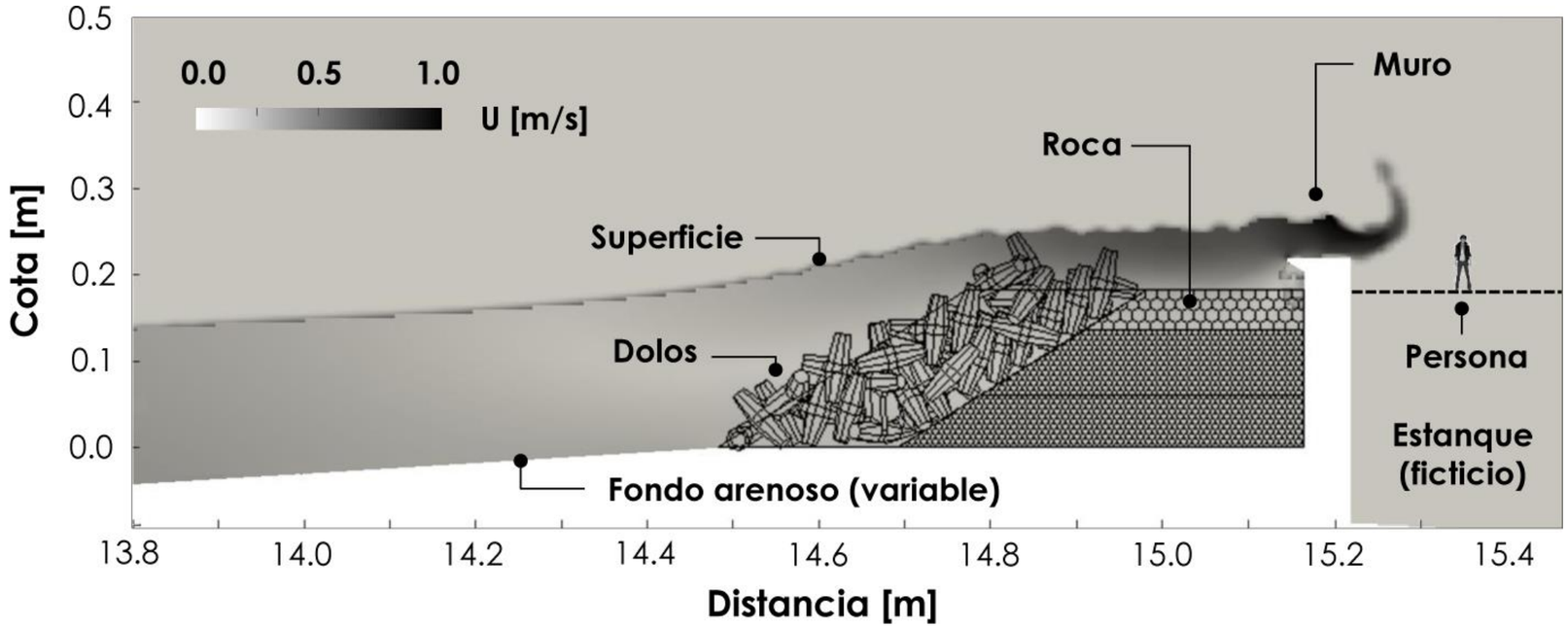





LabOcéano




Condición de borde
Detalle en c)
Estanque
(ficticio)
Cota [m]
0
0
2
4
6
8
10
12
14
16
18
Distancia [m]


0.0
0.5
1.0
U [m/s]
Muro
Roca
Superficie
Dolos
Persona
Estanque
(ficticio)
Fondo arenoso (variable)
Cota [m]
0.5
0.4
0.3
0.2
0.1
0.0
13.8
14.0
14.2
14.4
14.6
14.8
15.0
15.2
15.4
Distancia [m]


Mejores
modelos

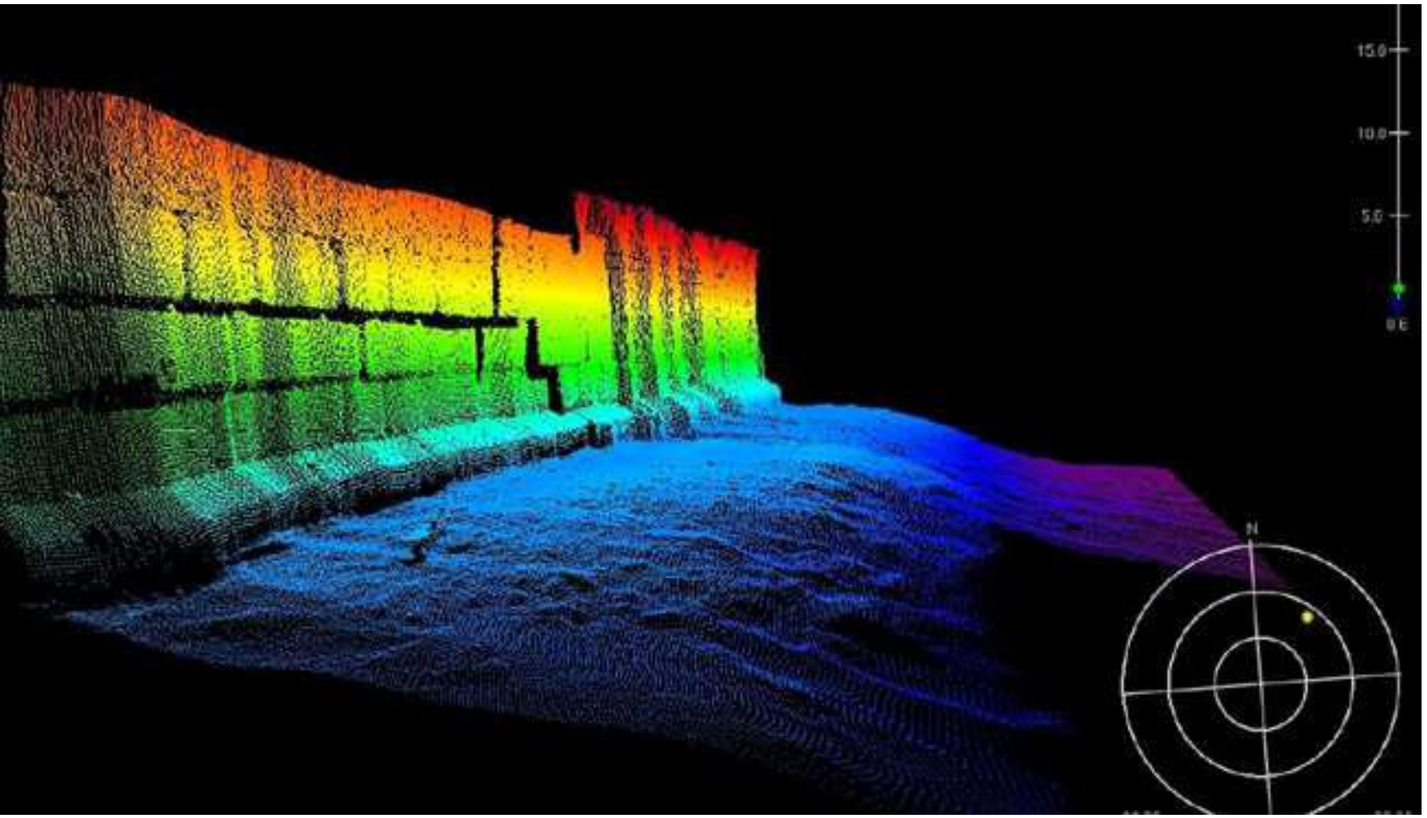
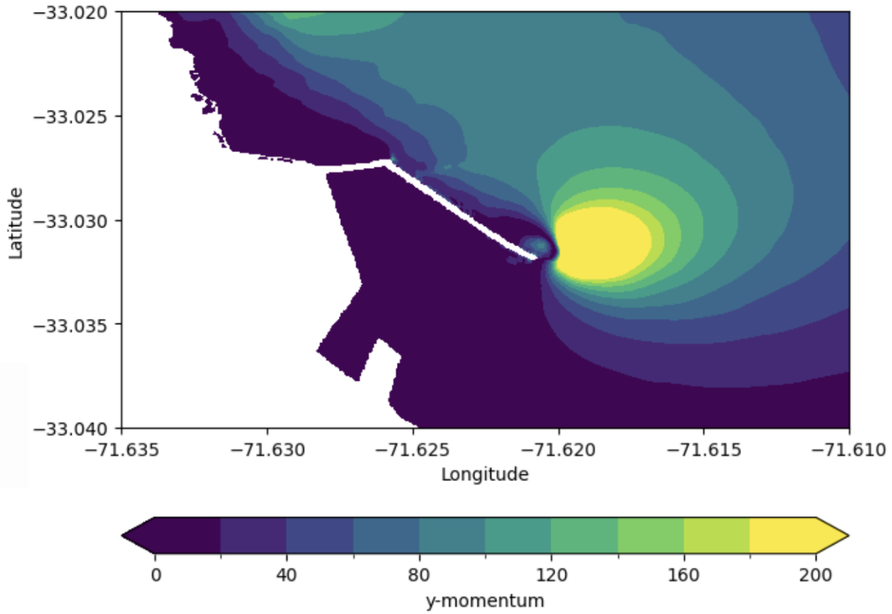

15.0
10.0
5.0
0.0
N


Image © 2014 DigitalGlobe

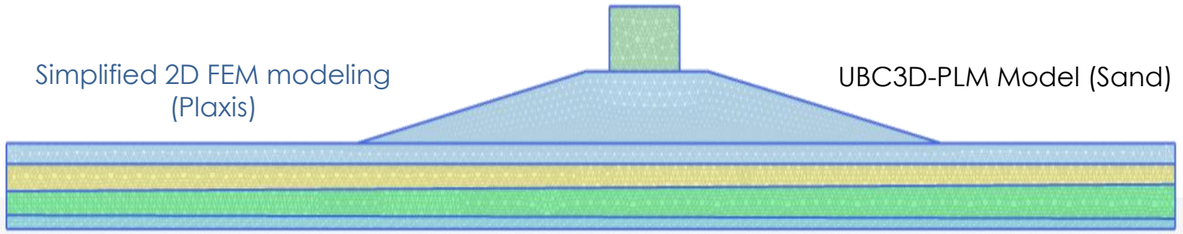


Recovery from 2011 quake, tsunami disaster

Compiled photo shows the bay of Kamaishi, Iwate Prefecture, on April 5, 2011, just weeks after its breakwater was destroyed (L) by the massive tsunami that hit northeastern Japan, and on Feb. 23, 2018, as a 65 billion yen project to restore the seawall

TARO ARIKAWA

Simplified 2D FEM modeling (Plaxis)



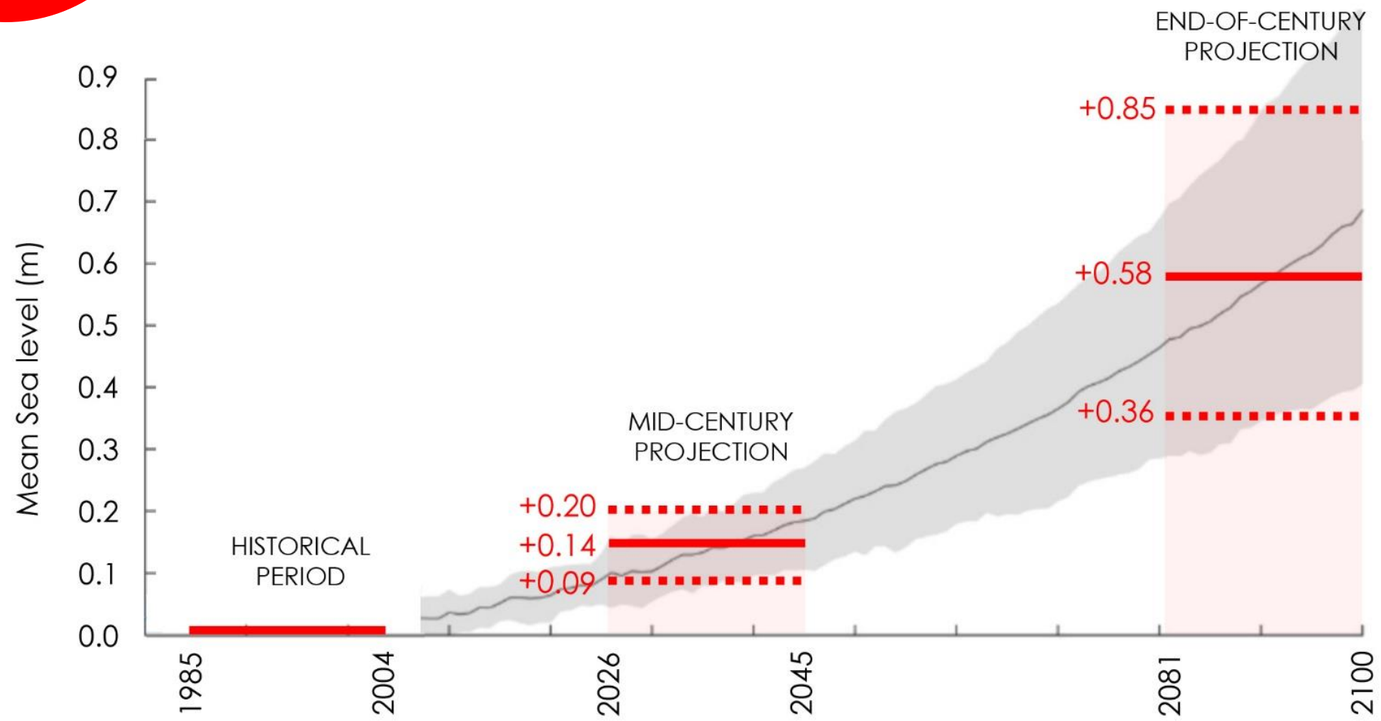
UBC3D-PLM Model (Sand)

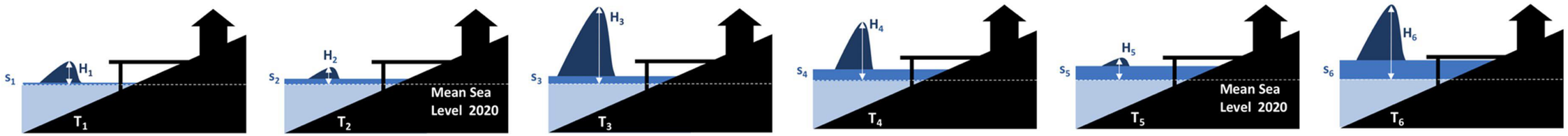
Gentileza de Francisco Ghisolfo


I'm 1.2 meters height

±0.3 m

0.58 m

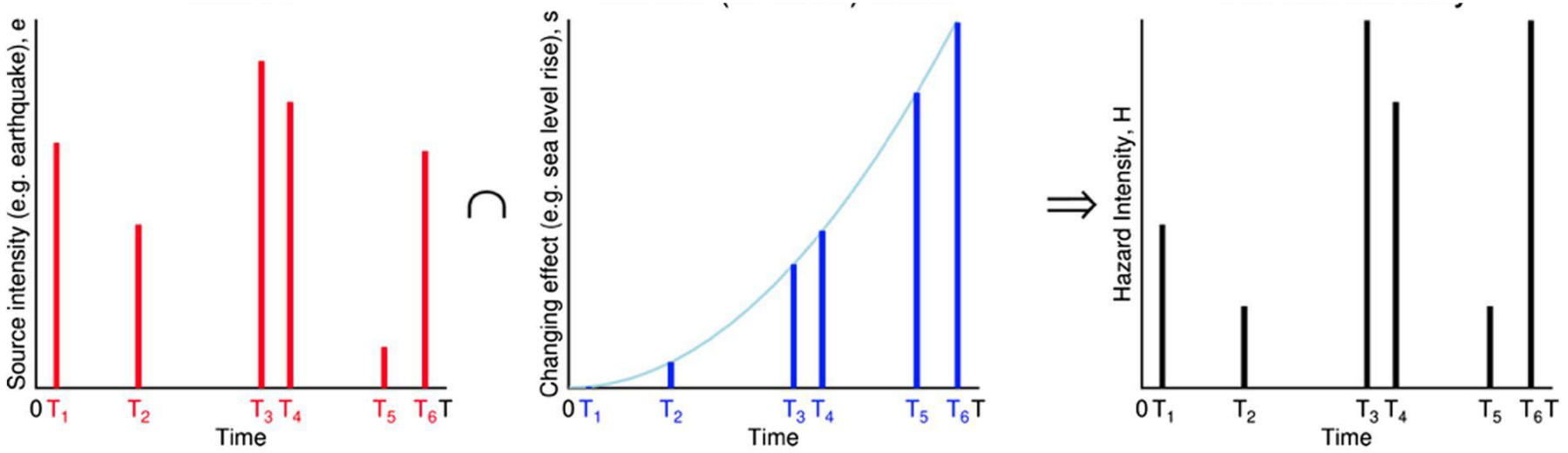

END-OF-CENTURY PROJECTION
+0.85
+0.58
+0.36
MID-CENTURY PROJECTION
+0.20
+0.14
+0.09
HISTORICAL PERIOD
Mean Sea level (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1985
2004
2026
2045
2081
2100



earthquake

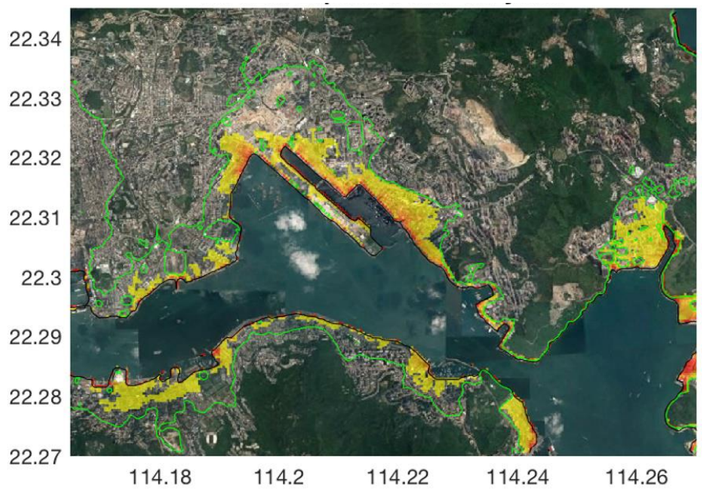
sea level rise

flooding

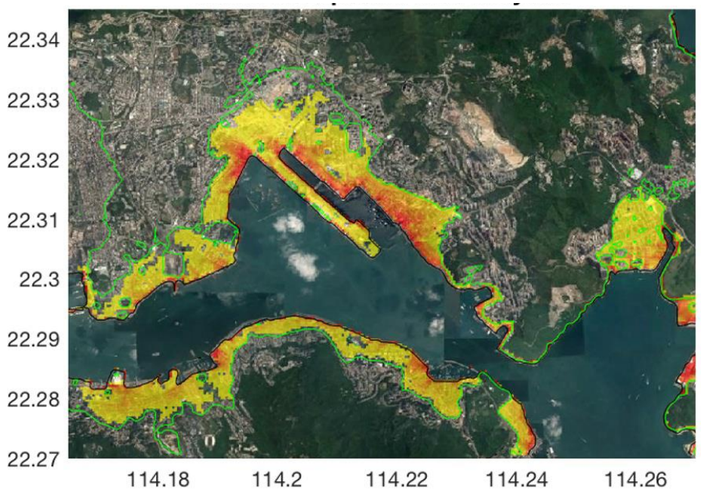


Non-sttaionary probabilistic tsunami hazard assessments incorporating climate-change-driven sea level rise (Sepúlveda et al., 2021)

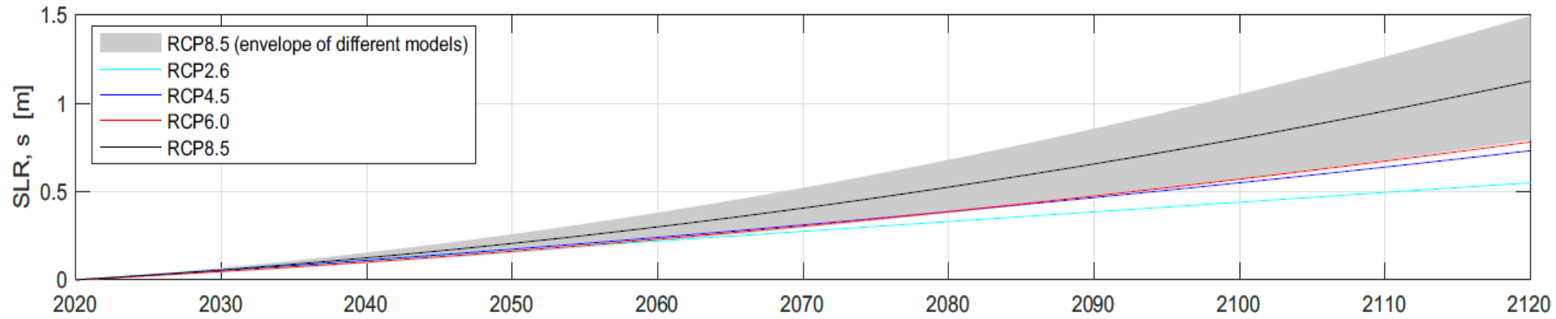
Sin aumento del NMM



Con aumento del NMM



$P(N_h(T)>0)$



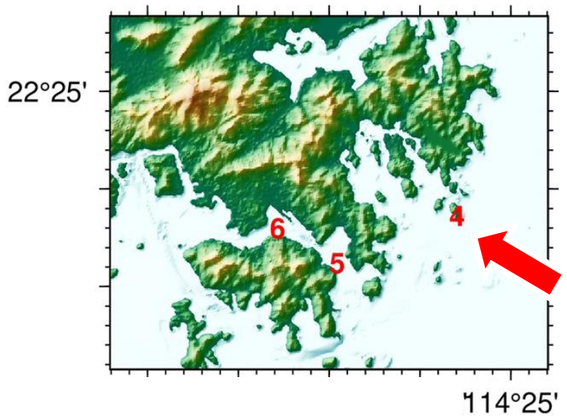
Aumento del NMM

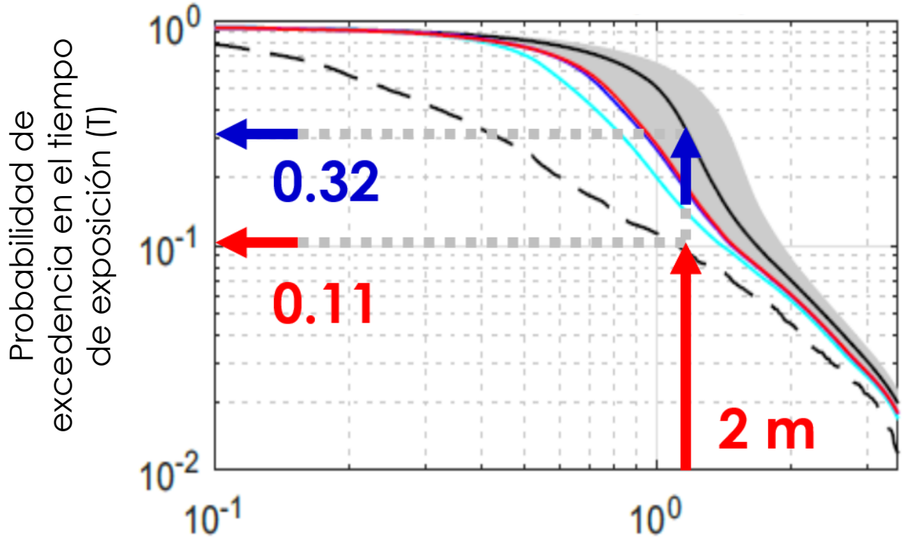
Tiempo de exposición

T = 100 años

2020-2120

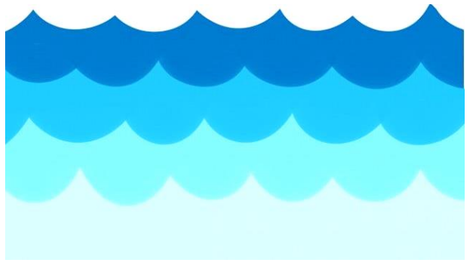
Hong Kong



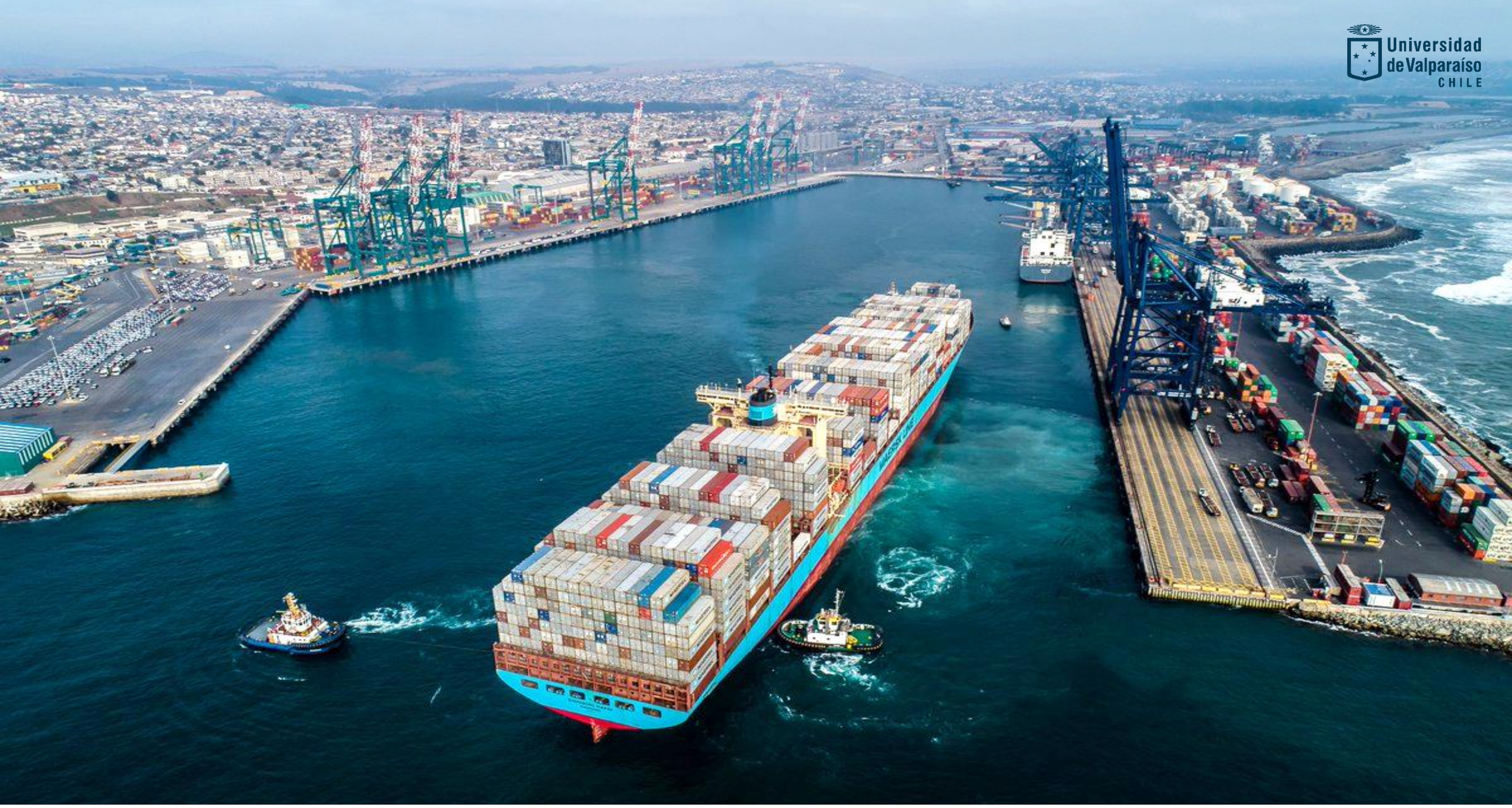


Non-sttaionary probabilistic tsunami hazard assessments incorporating climate-change-driven sea level rise (Sepúlveda et al., 2021)

Earthquakes Science & engineering



Fuente: Google Earth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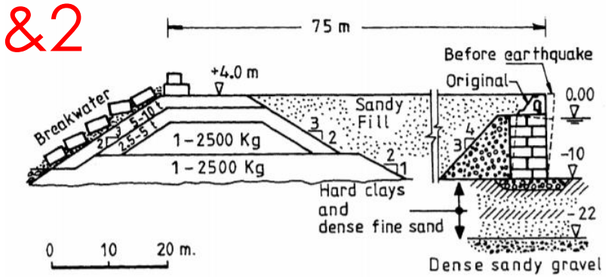
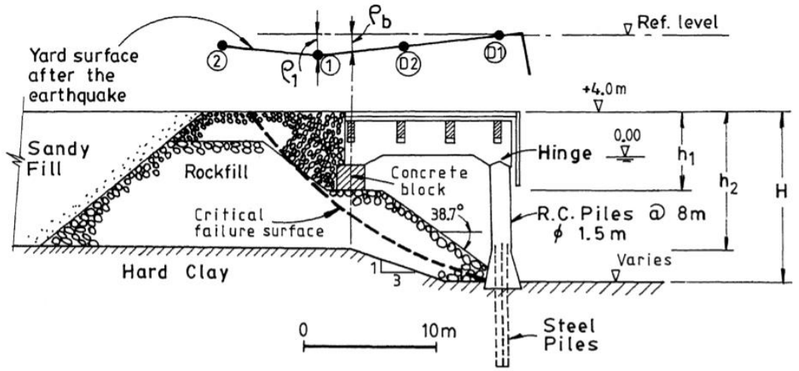
Berth 1&2

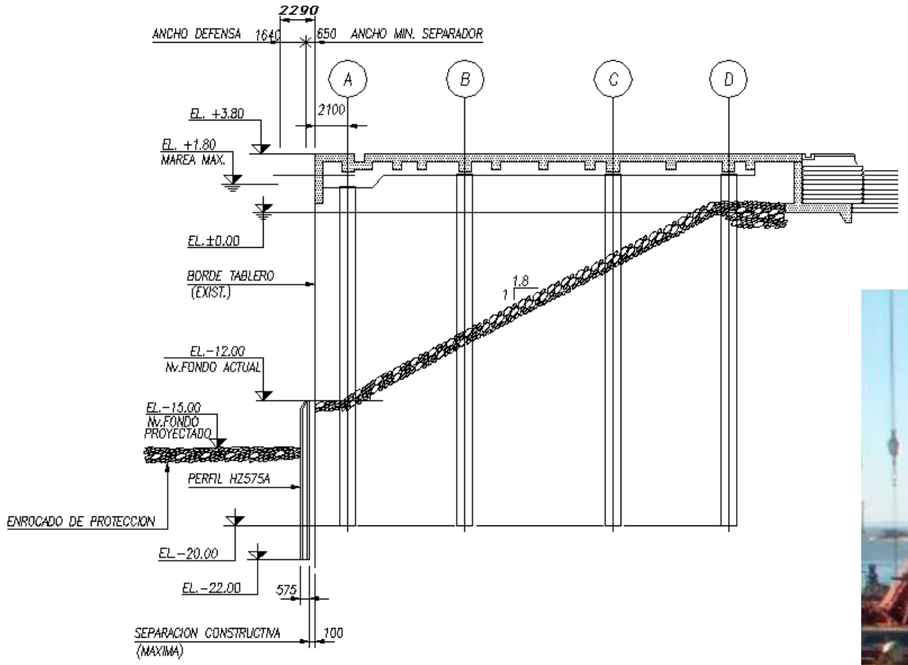


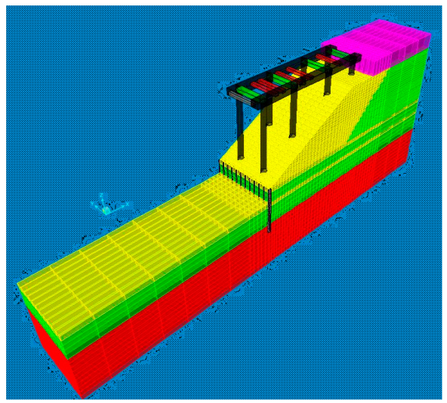


Berth 6&7

Earthquake 1985

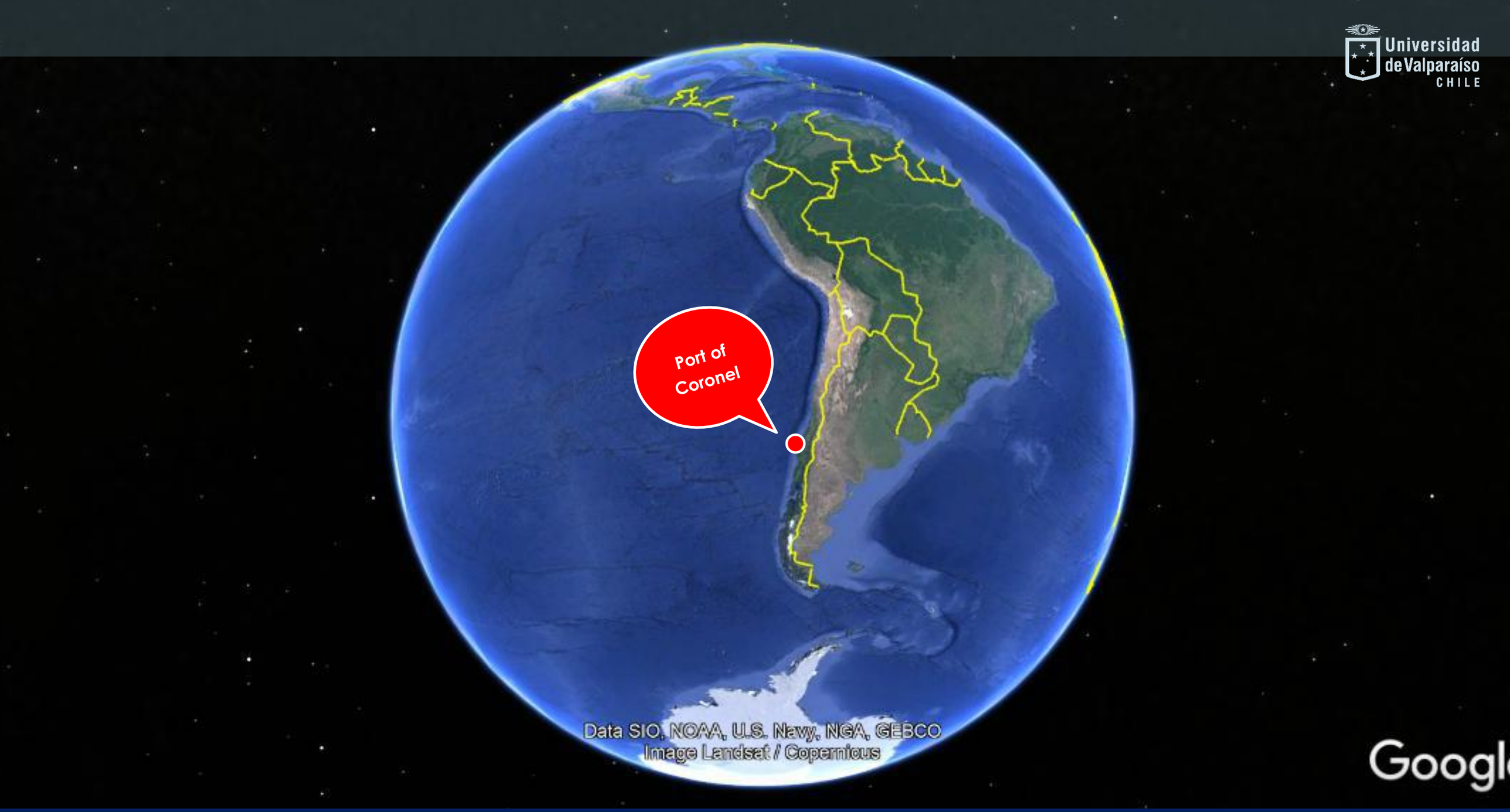
Ortigosa (1993). Failures of quay walls during Chilean earthquake of March 1985





Post-earthquake 1985

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



Fuente: Google Earth

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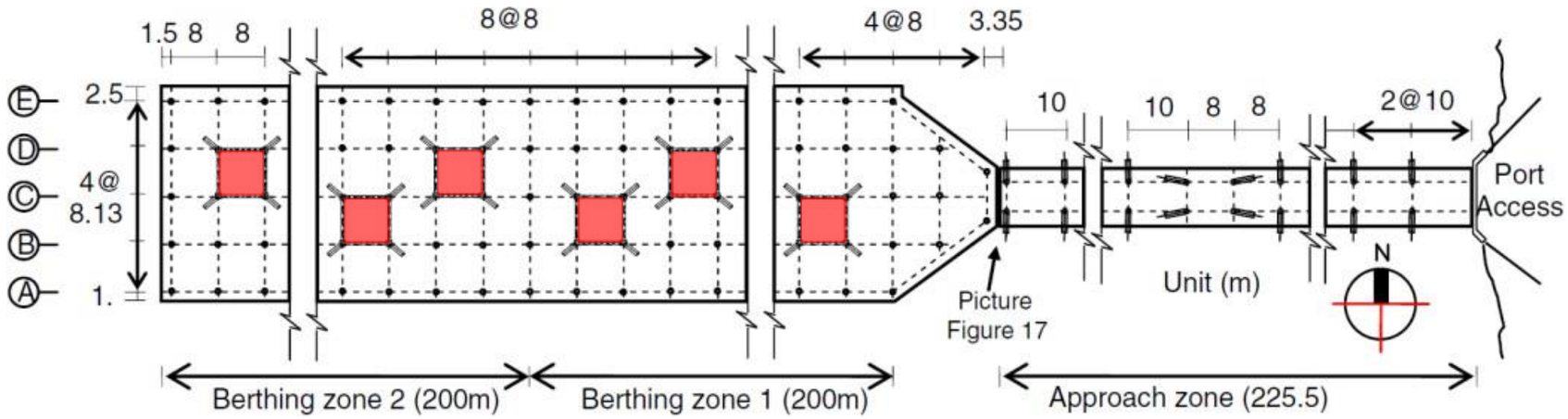
Fuente: PRDW


Puerto de Coronel


1.5 8 8
8@8
4@8 3.35
2.5
4@
8.13
1.
10
10 8 8
2@10
Port
Access
N
Unit (m)
Picture
Figure 17
Berthing zone 2 (200m)
Berthing zone 1 (200m)
Approach zone (225.5)

Fuente: PRDW

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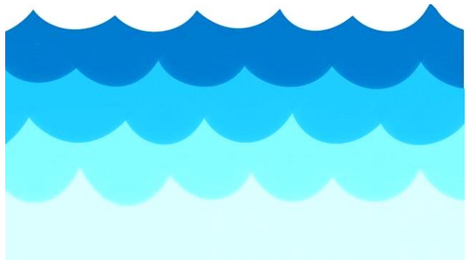
Tsunamis
Science & engineering



post 2010

J. Carlos Domínguez
Pontificia Universidad Católica
CHILE

Hermann Fritz
Georgia Institute of Technology
UNITED STATES

Rafael Almar
Pontificia Universidad Católica
FRANCE

Rodrigo Cienfuegos
Pontificia Universidad Católica
CHILE

Carl Ebeling
Northwestern University
UNITED STATES

Catherine Petroff
University of Washington
UNITED STATES

Patricio Catalán
Universidad Técnica Federico Santa María
CHILE

Patricio Winckler
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CHILE

Manuel Contreras
Universidad de Playa Ancha
CHILE

Sergio Barrientos
Universidad de Chile
UNITED STATES

Nikos Kalligers
Technical University of Crete
GREECE

Robert Weiss
Texas A&M University
UNITED STATES

Thanasis Kalligers
Technical University of Crete
GREECE

Gianina Meneses
Universidad de Chile
CHILE

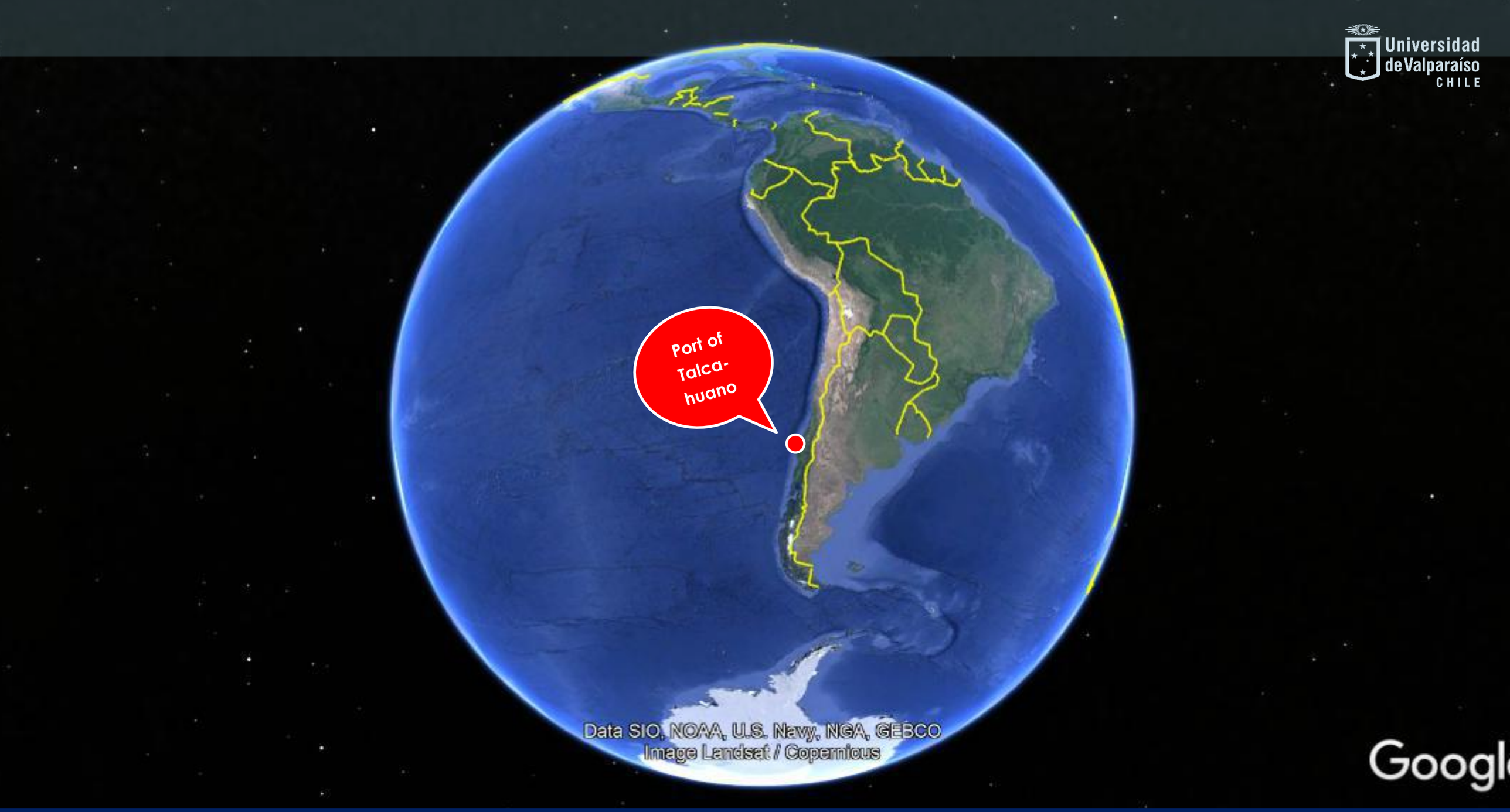
United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

The International Tsunami Information Center

National Oceanic and Atmospheric Administration

Source: International tsunami survey team



Fuente: Google Earth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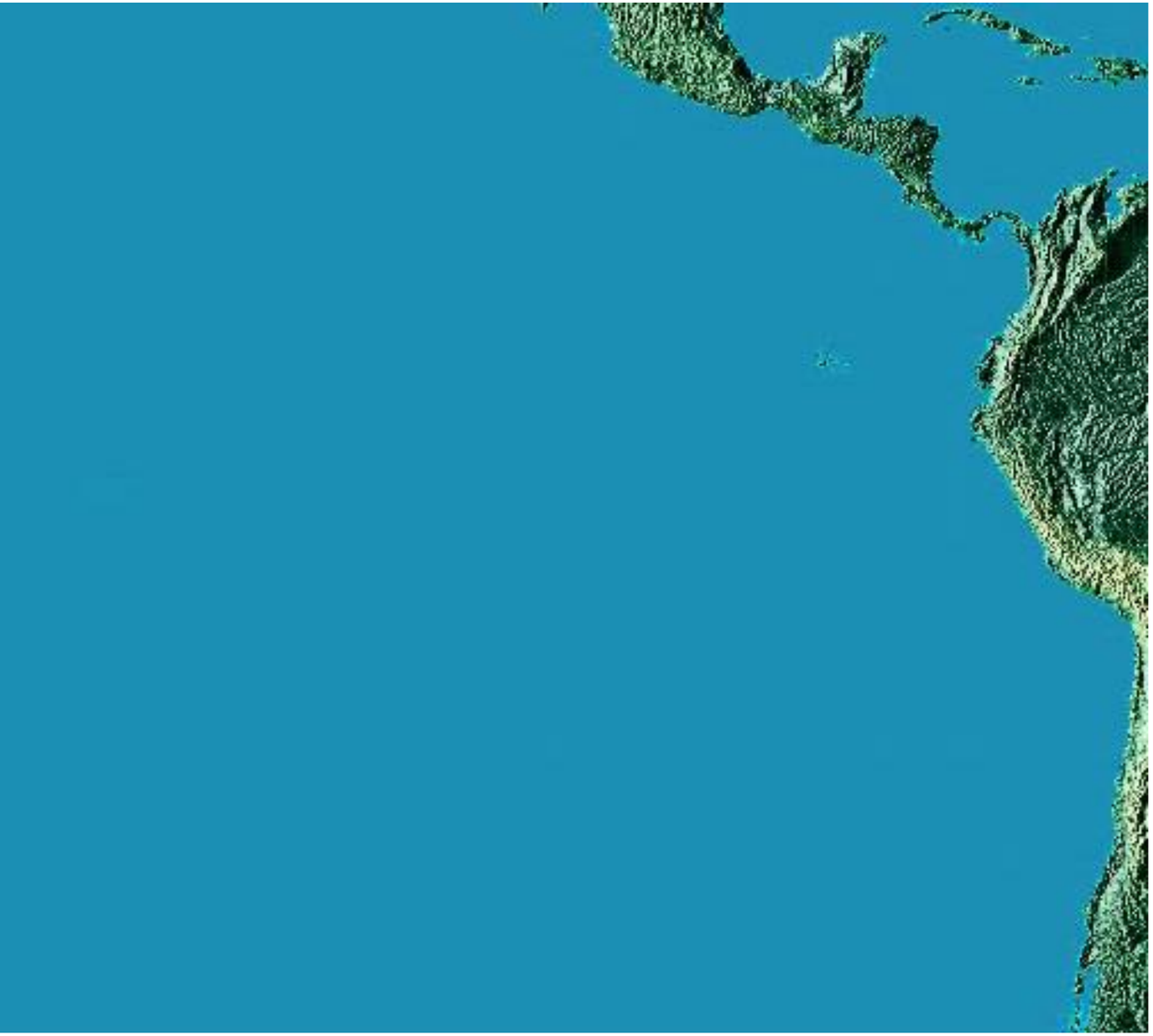
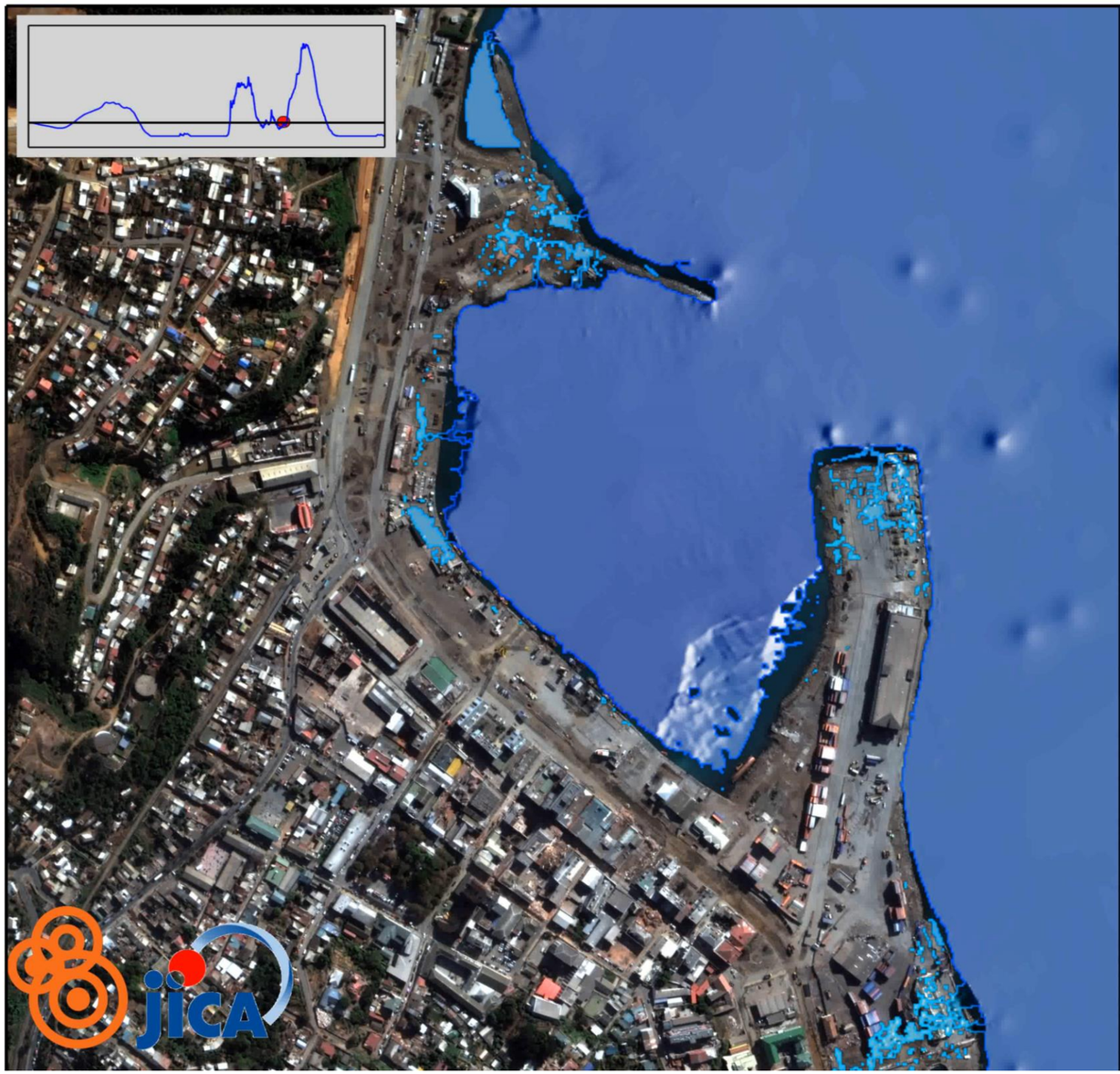
CHILE
san vicente
talcahuano
Ya !?
tsunamis

$t = 129$ min





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CABO DE HORNOS

Fuente: Google Earth

1

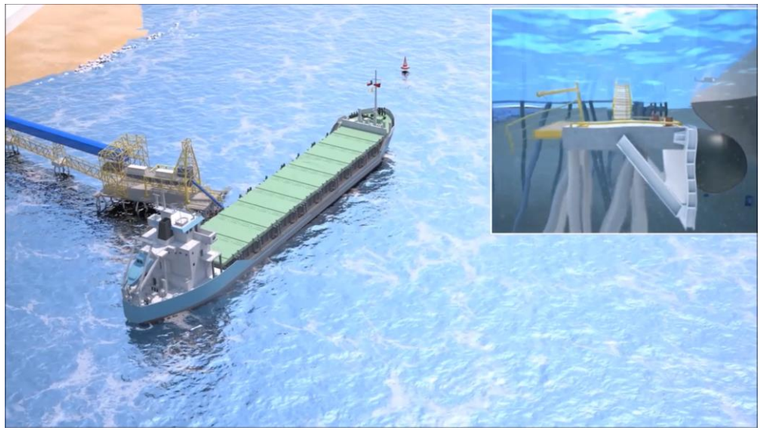
ROTURA
SHIP LOADER

2

ROTURA
AMARRAS

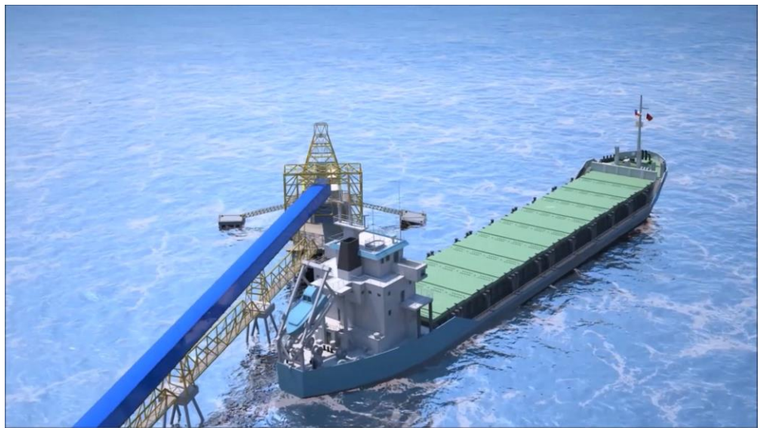
3

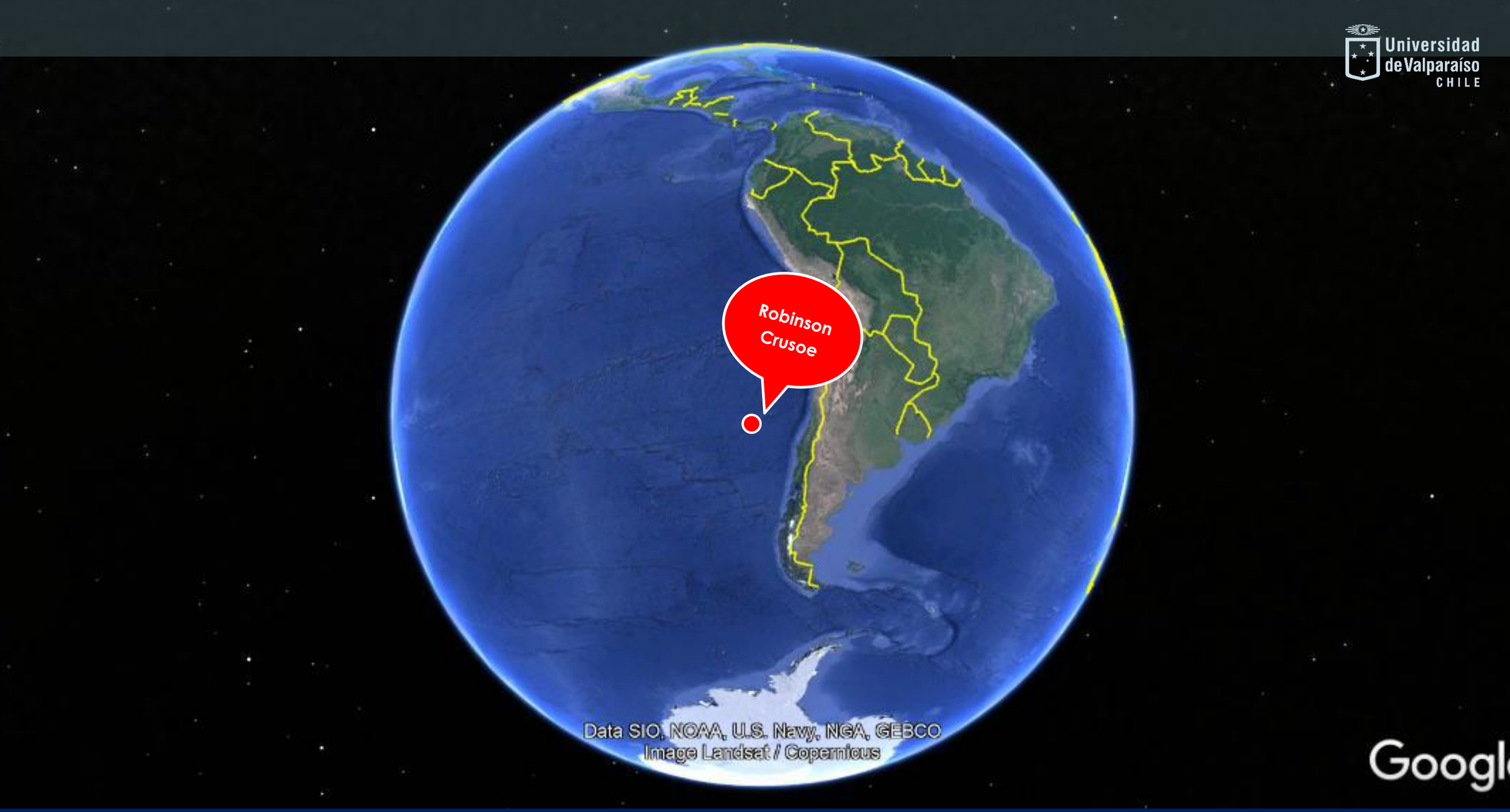
IMPACTO
CABEZO



4

IMPACTO
PUENTE





Fuente: Google Earth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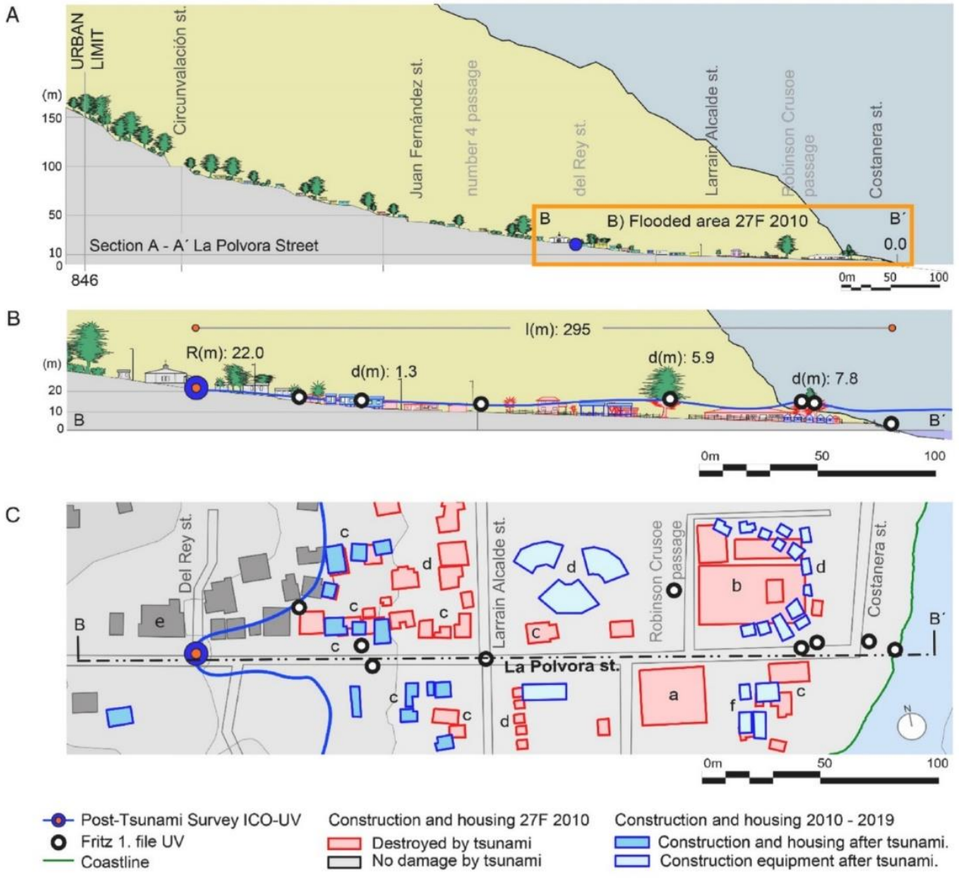
Military
civillian
collaboration

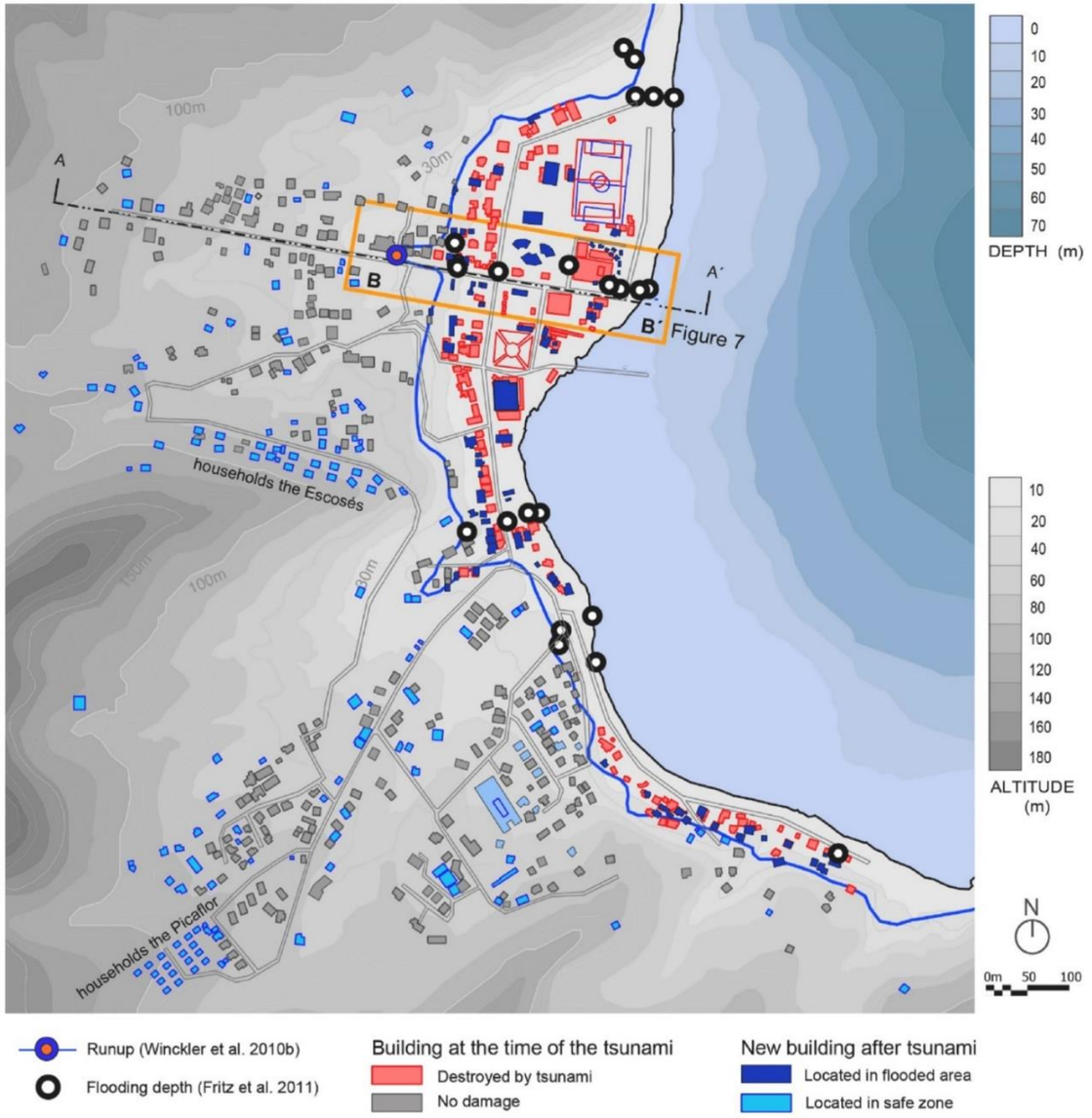
Ocean and Coastal Management

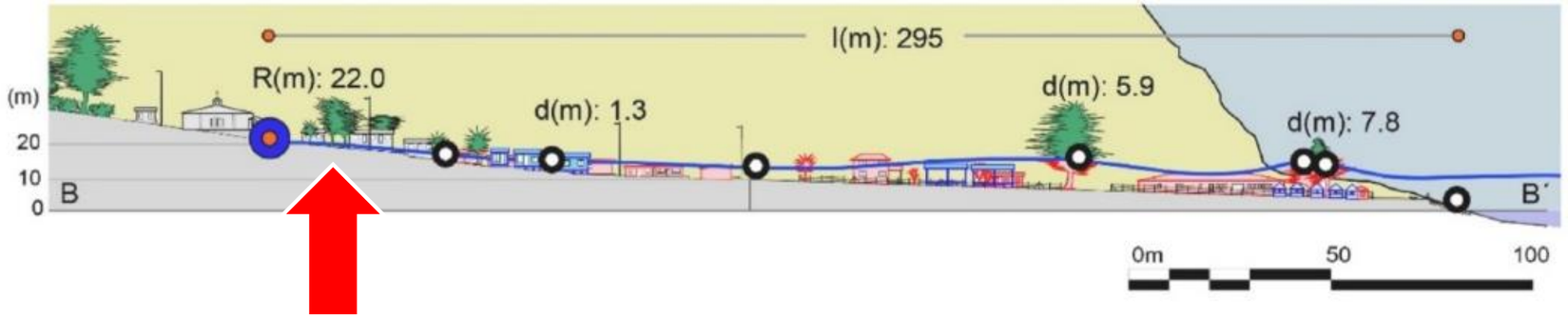
journal homepage: www.elsevier.com/locate/ocecoaman

Tsunami impact and resilience cycle in an insular town: The case of Robinson Crusoe island, Chile

Wolfgang Alejandro Breuer [a,*], Felipe Igualt [b], Manuel Contreras-López [c], Patricio Winckler [d,e,f], Cristopher Zambra [g]



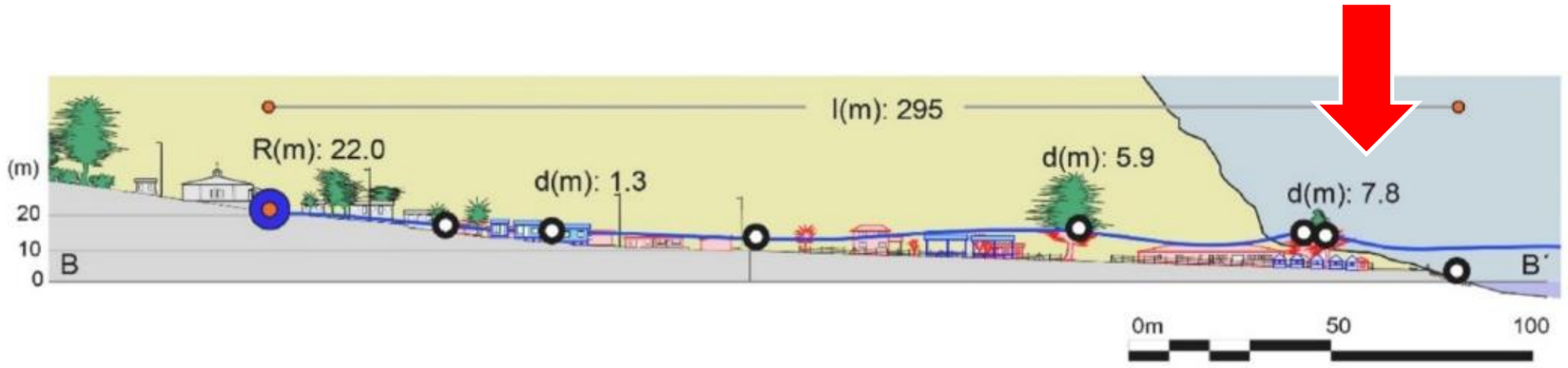




Post-Tsunami Survey ICO-UV
Fritz 1. file UV
Coastline

Construction and housing 27F 2010
Destroyed by tsunami
No damage by tsunami

Construction and housing 2010 - 2019
Construction and housing after tsunami.
Construction equipment after tsunami.



Post-Tsunami Survey ICO-UV
Fritz 1. file UV
Coastline

Construction and housing 27F 2010
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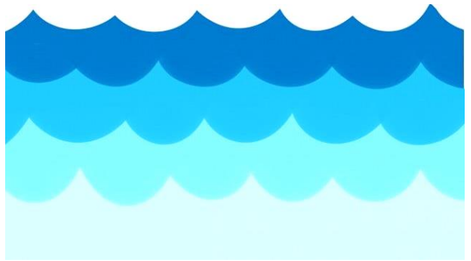
Construction and housing after tsunami.
Construction equipment after tsunami.

Coastal Resilience & **Adaptation**



Hurricane Sandy

October 29th 2012


2 Pisos
This blue color represents the height of potential flooding from future severe weather.
The Battery Park City Authority is responding to this threat through its resiliency projects, in conjunction with the City of New York.
This height is calculated for a 2050 100-year storm based on Sea Level Rise estimates as published by the NYC Panel on Climate Change.
NEW YORK STATE OF OPPORTUNITY.
Battery Park City Authority

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CHILE

EVACUAR
POBLACIÓN

REUBICAR
EDIFICACIONES

ADQUIRIR
EDIFICACIONES

ELEVAR
EDIFICACIONES

DRENAR
PLANTAS DE BOMBEO

BLOQUEAR
DIQUES

ESTABILIZAR
DEFENSAS COSTERAS

CONSERVAR
RESTAURAR
SISTEMAS ACUÁTICOS

CONSERVAR
RESTAURAR
SISTEMAS COSTEROS

RESTAURAR
DUNAS Y PLAYAS

DEFENDER
ROMPEOLAS

FUTURO

HOY

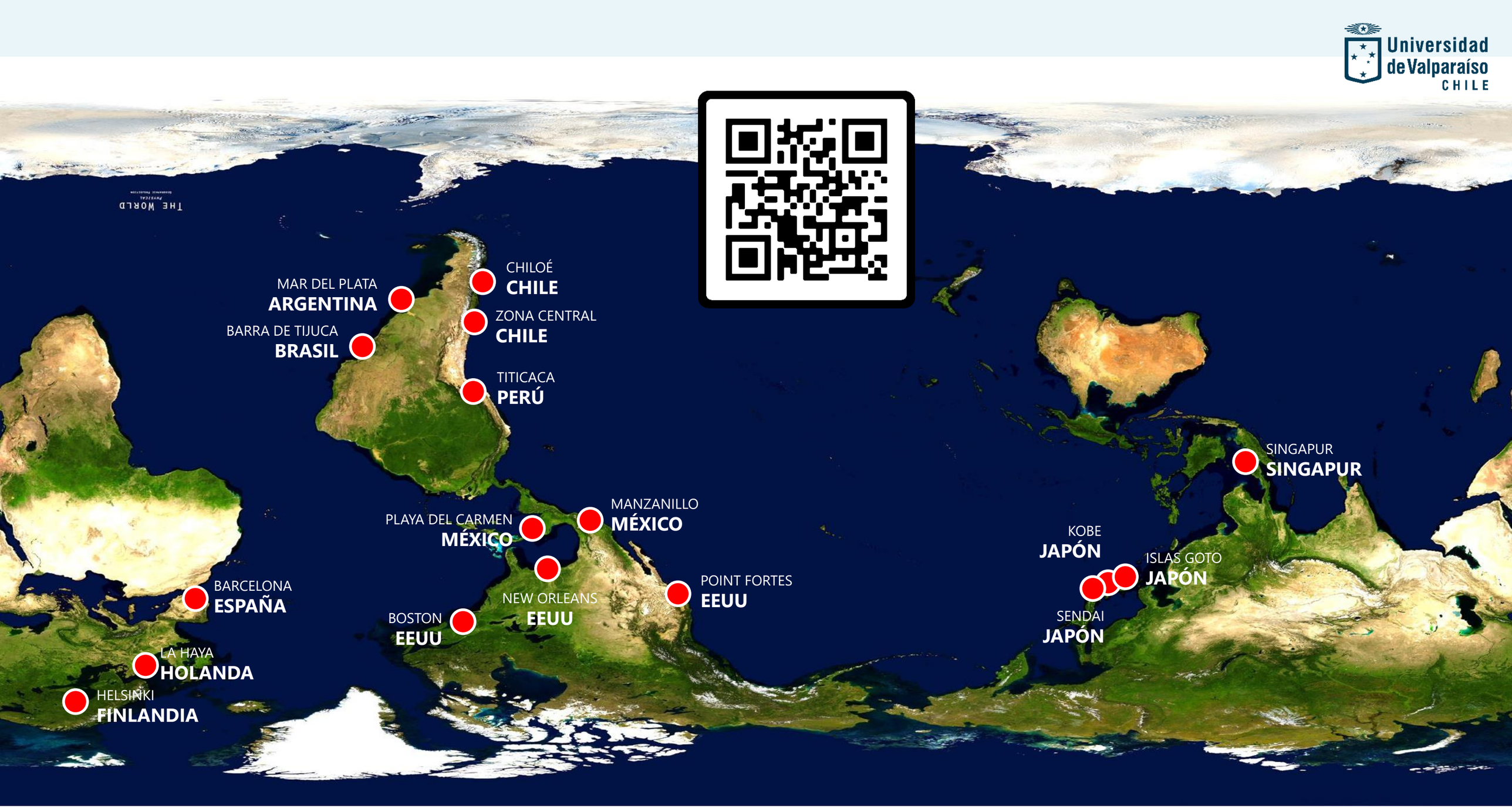
adaptación costera

INFRAESTRUCTURA **AZUL**

INFRAESTRUCTURA **VERDE**

INFRAESTRUCTURA **CAFÉ**

INFRAESTRUCTURA **GRIS**



Costas de Chile (Morales, Winckler & Herrera, 2020)

Fuente: Google Earth

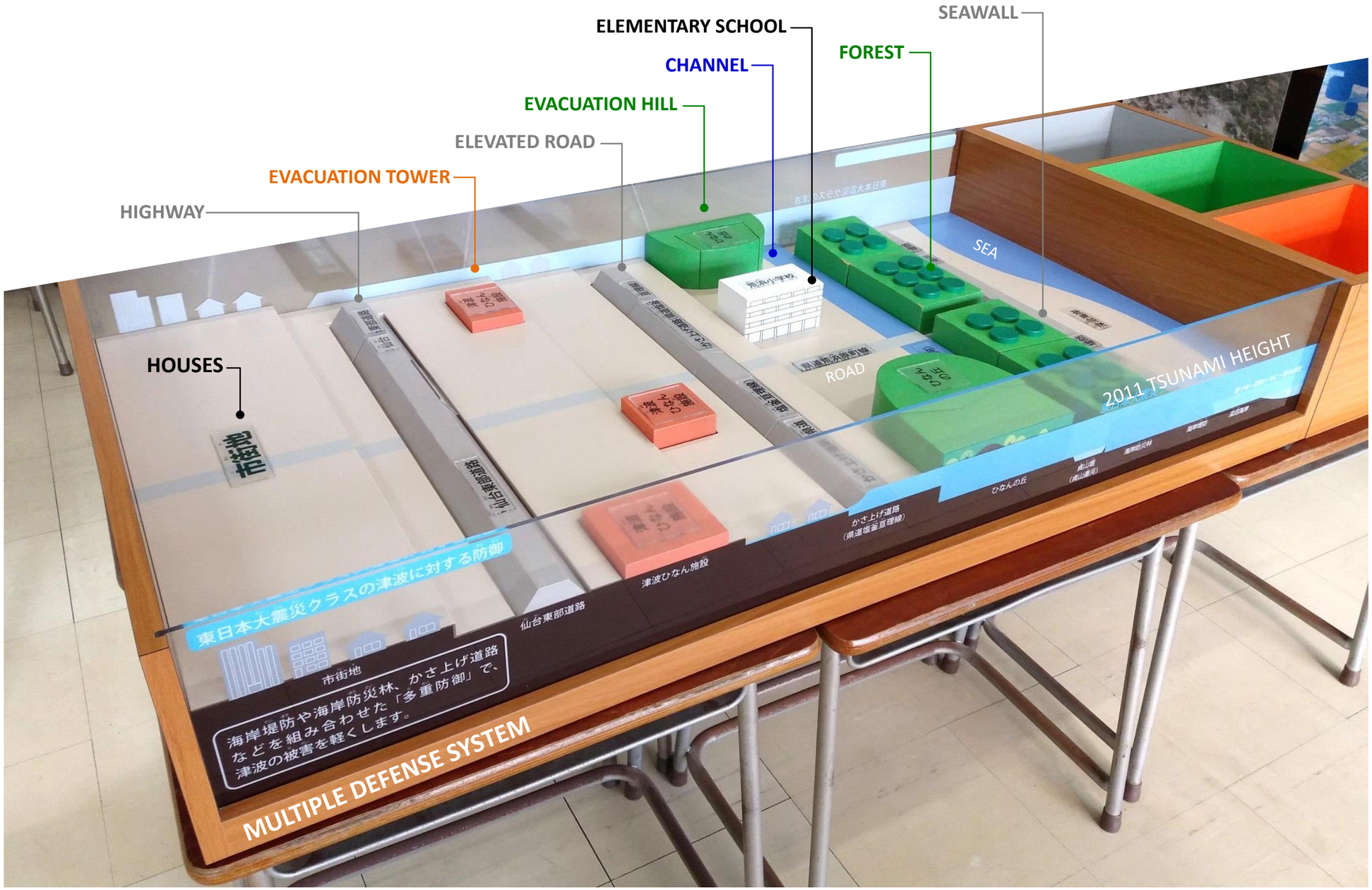

This is how we did it Pato !


This is how we should have done it!

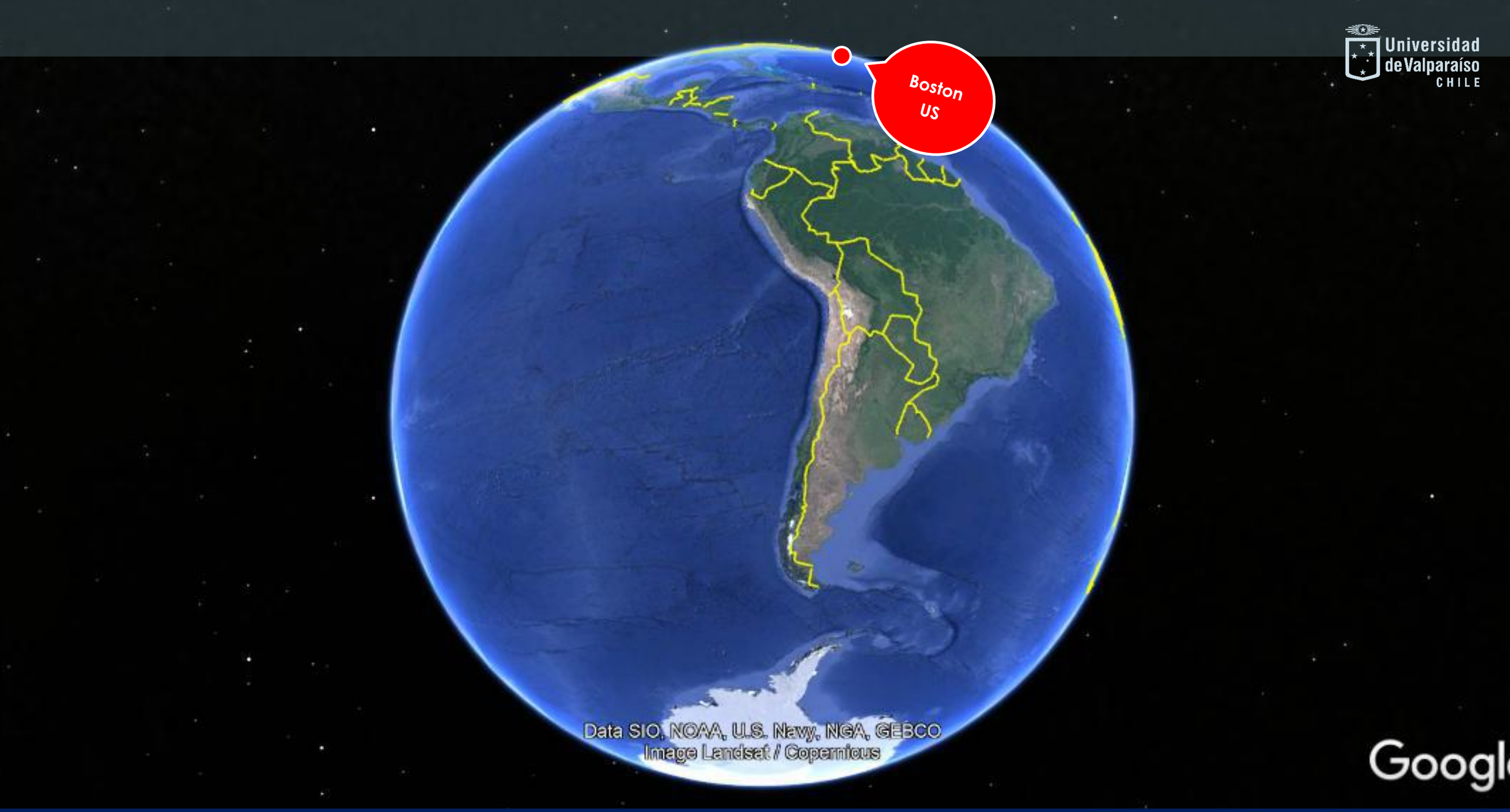
Fuente: Google Earth


三菱倉庫
三宮 2
Sannomiya
3 阪神高速
HANSHIN EXPWY
摩耶ふ頭
Maya Wharf
新港第1・2突堤
Shinko Pier No.1・2
平和憲法を守ろう

Source: Senadi Arahama Elementary School, Japan



Source: Senadi Arahama Elementary School, Japan



Fuente: Google Earth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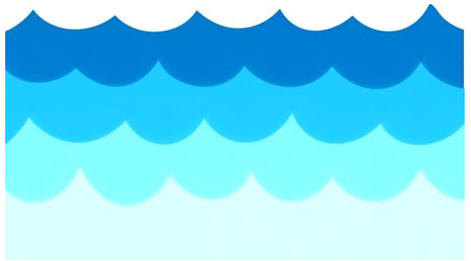
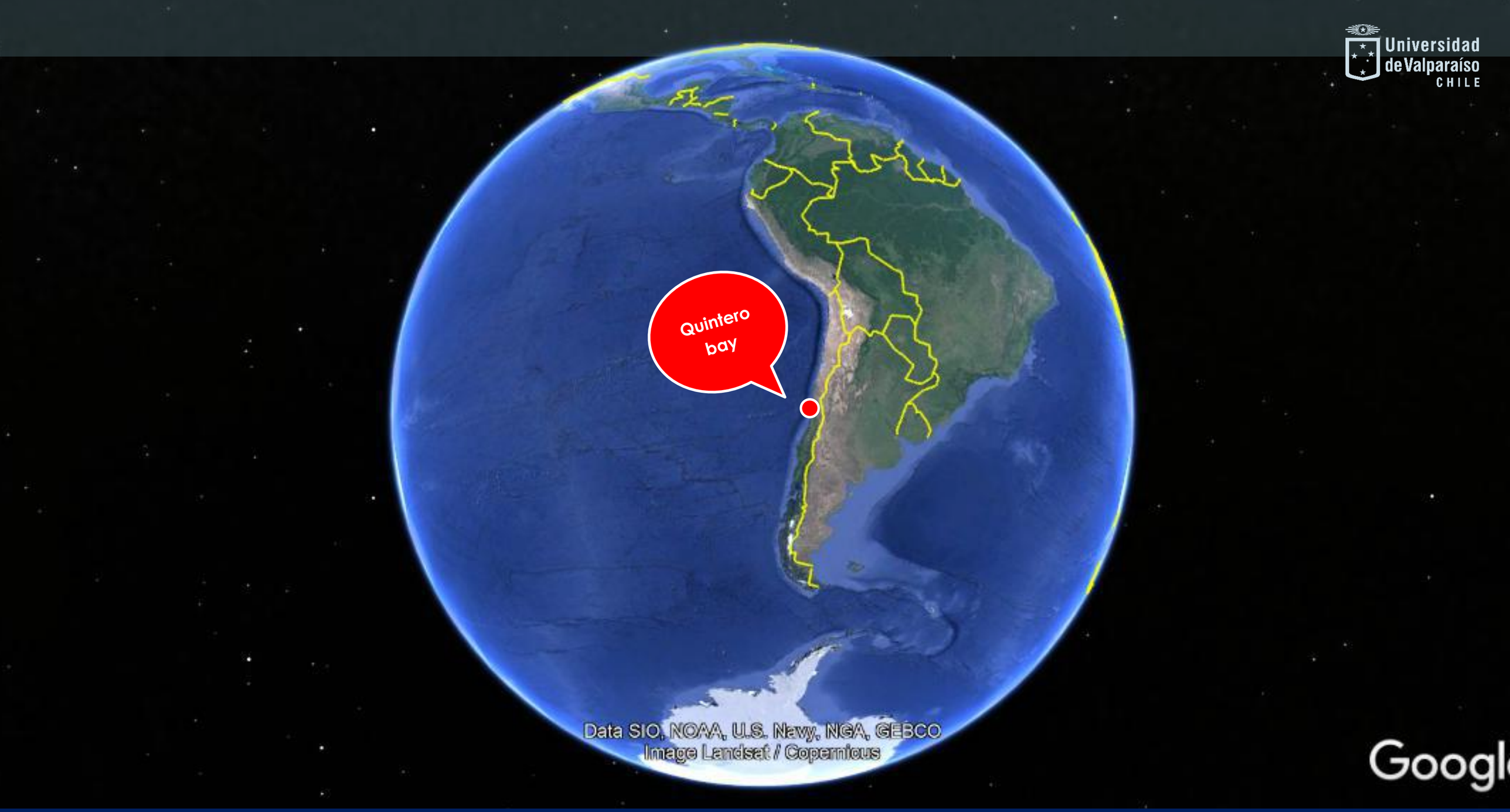
de Valparaíso
CHILE

Fuente: Google Earth

Tomorrow:
Field survey
Quintero





Fuente: Google Earth

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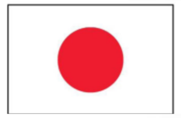
Tsunami **1960**

Una historia esquiva

cientific@s en constante búsqueda

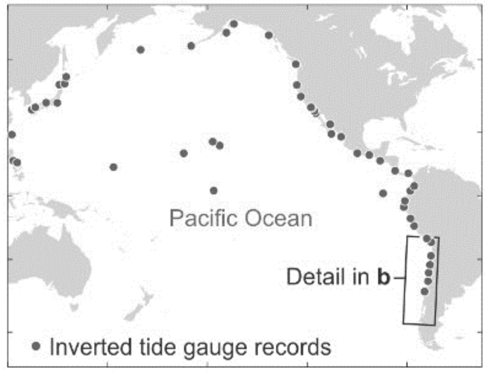
Cementerio Toltén Viejo



KENJI
SATAKE

MARCO
CSTERNAS

BRIAN
ATWATER



FAR FIELD TSUNAMI

"We must become storytellers"

HELLMUTH
SIEVERS

INÉS LUCÍA
CIFUENTES

SERGIO
BARRIENTOS

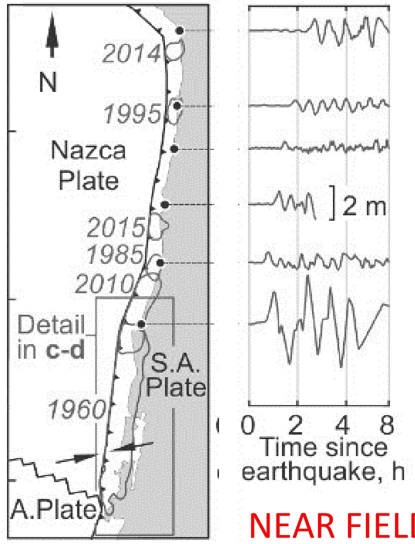
EARTHQUAKE

HIROO
KANAMORI

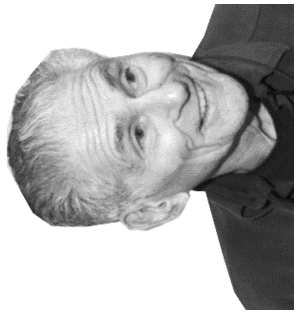
DANIEL MELNICK

MATÍAS CARVAJAL

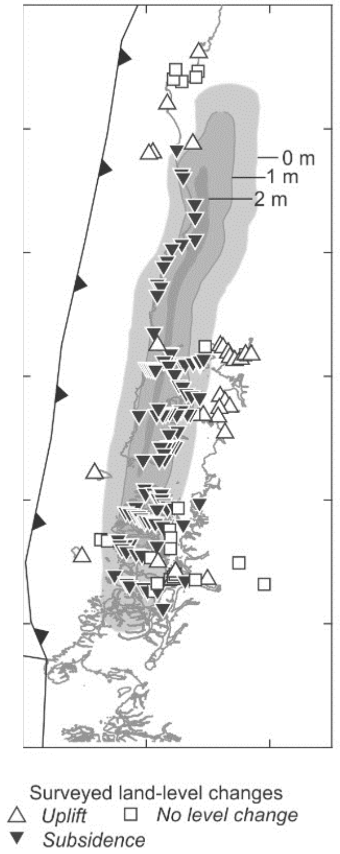
MARCOS MORENO



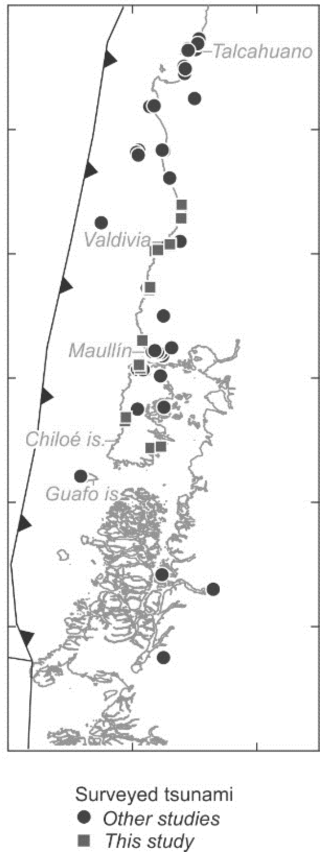
NEAR FIELD
TSUNAMI



GEORGE
PLAFKER geologist of earthquakes



COSEISMIC UPLIFT / SUBSIDENCE



INTERVIEWS

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Joaquín Martínez Silva
16 años en 1960
Toltén Viejo

Universidad de Valparaíso
CHILE


Baltazar Treviño, Chaihuín


Fermín Pradines Rodríguez, Bahías Mansa


Marcelo Antillán, Chaihuín


Joaquín Martínez Silva, Toltén Viejo


Jorge Huenuman, Huentemo (Chiloé)


María Rosa Acum, Pucatrihue


Héctor Aguayo, Chauhuín


Ricardo Mendoza, Niebla


Elsa Miranda, Niebla


Humberto Llancalahuen, Yaldad Este (Chiloé)


Luis Gutierrez Olivares, Faro Punta Coronas


Juan Agustín Pérez Barría, Chalcura, Chiloé


Agripina Paredes, Caleta Estaquilla


Doraliza Ojeda Díaz, Quenuir Bajo


Celinda Arteaga, Estero Oqueldán (Chiloé)


XXX, Puñihuil alto (Chiloé)


Diegla Venegas Ampuero, Puñihuil (Chiloé)


Fernando Mansilla, Chepu (Chiloé)


Hilda Trujillo, Huillinco (Chiloé)


Rosa Llancalahuen Carilepi, Yaldad Este (Chiloé)


Carmen Rosa Nuñez Barría, El Yuste (Chiloé)

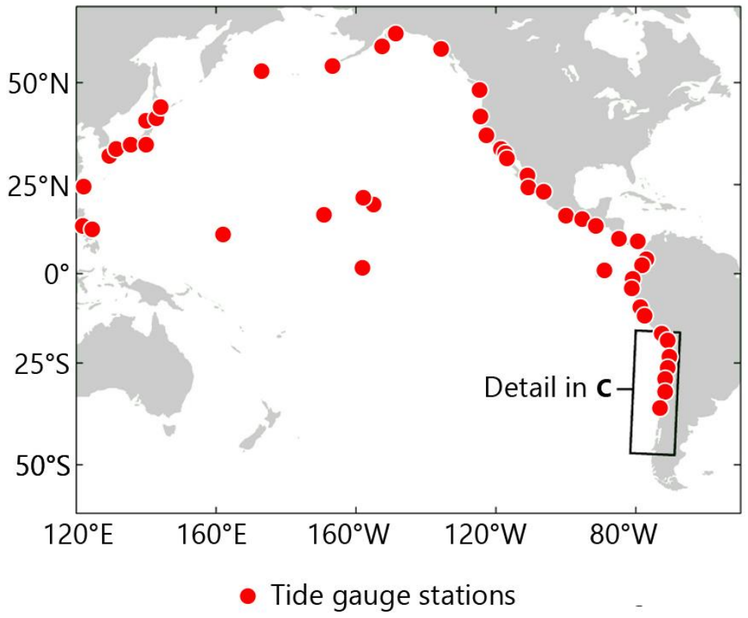

Arturo Gómez, Cucao (Chiloé)

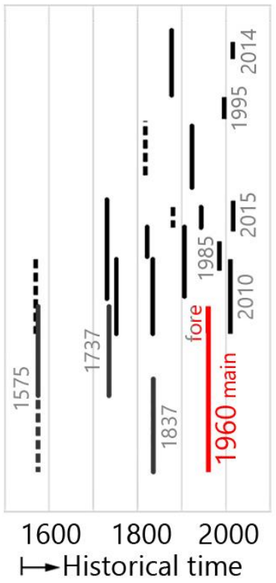

Paulino Gómez, Cucao (Chiloé)

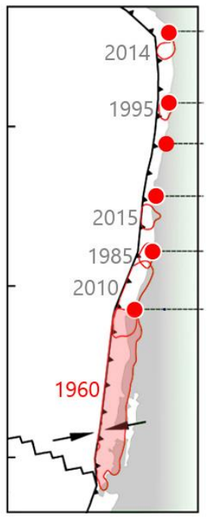

Orlando Vera, Rahue (Chiloé)

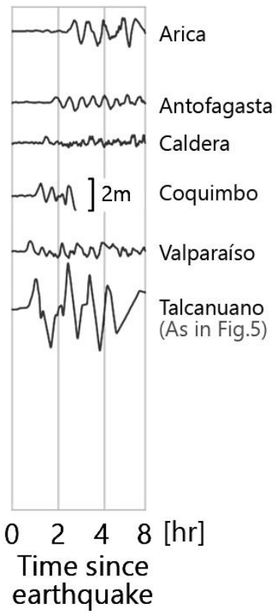

María Adelaida España, Estero Oqueldán (Chiloé)

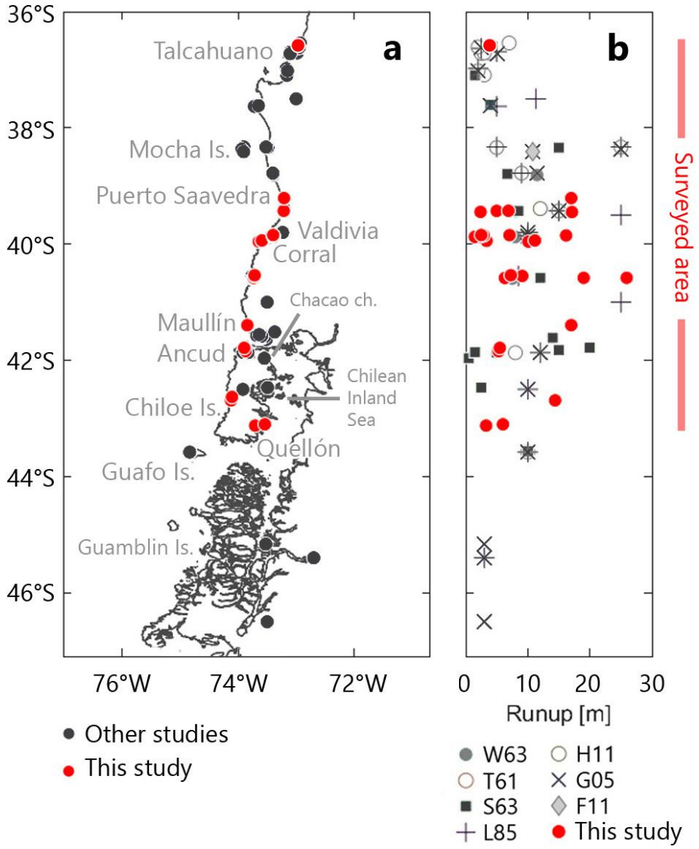
La emoción de los testimonios!


50°N
25°N
0°
25°S
50°S
120°E
160°E
160°W
120°W
80°W
Detail in c
Tide gauge stations


1575
1737
1837
fore
1960 main
1985
1995
2010
2014
2015
1600
1800
2000
Historical time


2014
1995
2015
1985
2010
1960


Arica
Antofagasta
Caldera
2m
Coquimbo
Valparaíso
Talcanuano
(As in Fig.5)
0
2
4
8
[hr]
Time since earthquake


36°S
38°S
40°S
42°S
44°S
46°S
Talcahuano
a
Mocha Is.
Puerto Saavedra
Valdivia
Corral
Chacao ch.
Maullín
Ancud
Chilean Inland Sea
Chiloe Is.
Quellón
Guafo Is.
Guamblin Is.
76°W
74°W
72°W
Other studies
This study
b
0
10
20
30
Runup [m]
W63
H11
T61
G05
S63
F11
L85
This study
Surveyed area


David Rockefeller Center
For Latin American Studies
Harvard University