

## TSUNAMI RESEARCH ADVANCEMENTS WITHIN THE JST-JICA SATREPS PROJECT

### SATREPS For the Earth, For the Next Generation

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International Symposium on Earthquake and Tsunami Disaster Mitigation in Latin America, Tokyo, March 7, 2014



## RESEARCH PROJECT ON ENHANCEMENT OF TECHNOLOGY TO DEVELOP TSUNAMI-RESILIENT COMMUNITY

□ Director: Ricardo TEJADA

Director Nacional de Obras Portuarias, Ministerio de Obras Públicas

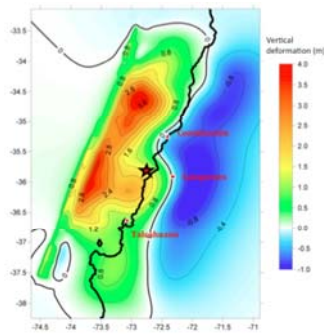
□ Japan-side PI: Dr. Takashi TOMITA  
Port and Airport Research Institute

□ Chilean-side PI: Dr. Rodrigo CIENFUEGOS  
CIGIDEN-Pontificia Universidad Católica de Chile

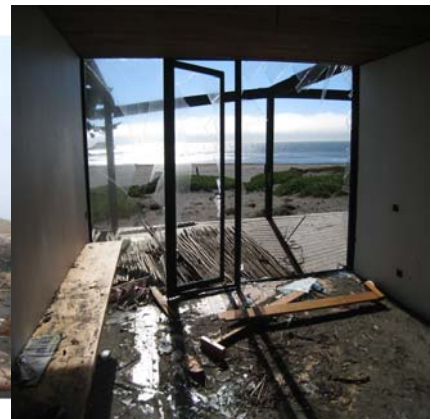
# MOTIVATION

- **8.8 Mw 2010 Great Maule Earthquake & Tsunami**

- Chile was relatively well prepared against earthquakes
- Important problems were evidenced when facing the tsunami disaster (emergency alert and response, public understanding, scientific knowledge, great damage)



NEIC's fault model



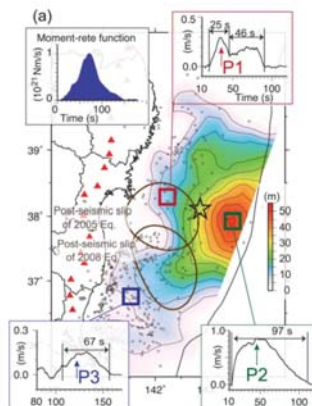
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# MOTIVATION

- **9.0 Mw 2011 Great Tohoku Earthquake & Tsunami**

- Much bigger than the Chilean event
- Important knowledge to share and many lessons to learn



Yagi & Fukuhata, 2011



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# MOTIVATION



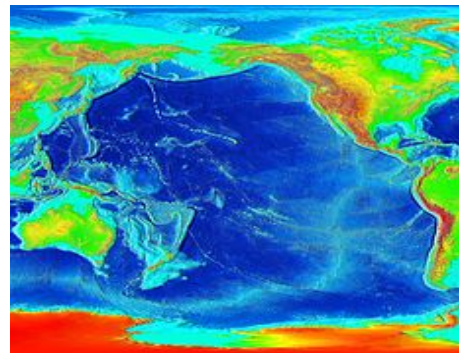
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research

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# PROJECT PURPOSE

- Technologies and measures are developed to improve communities and people in Chile, Japan and across the world to be well-prepared and resilient against tsunamis



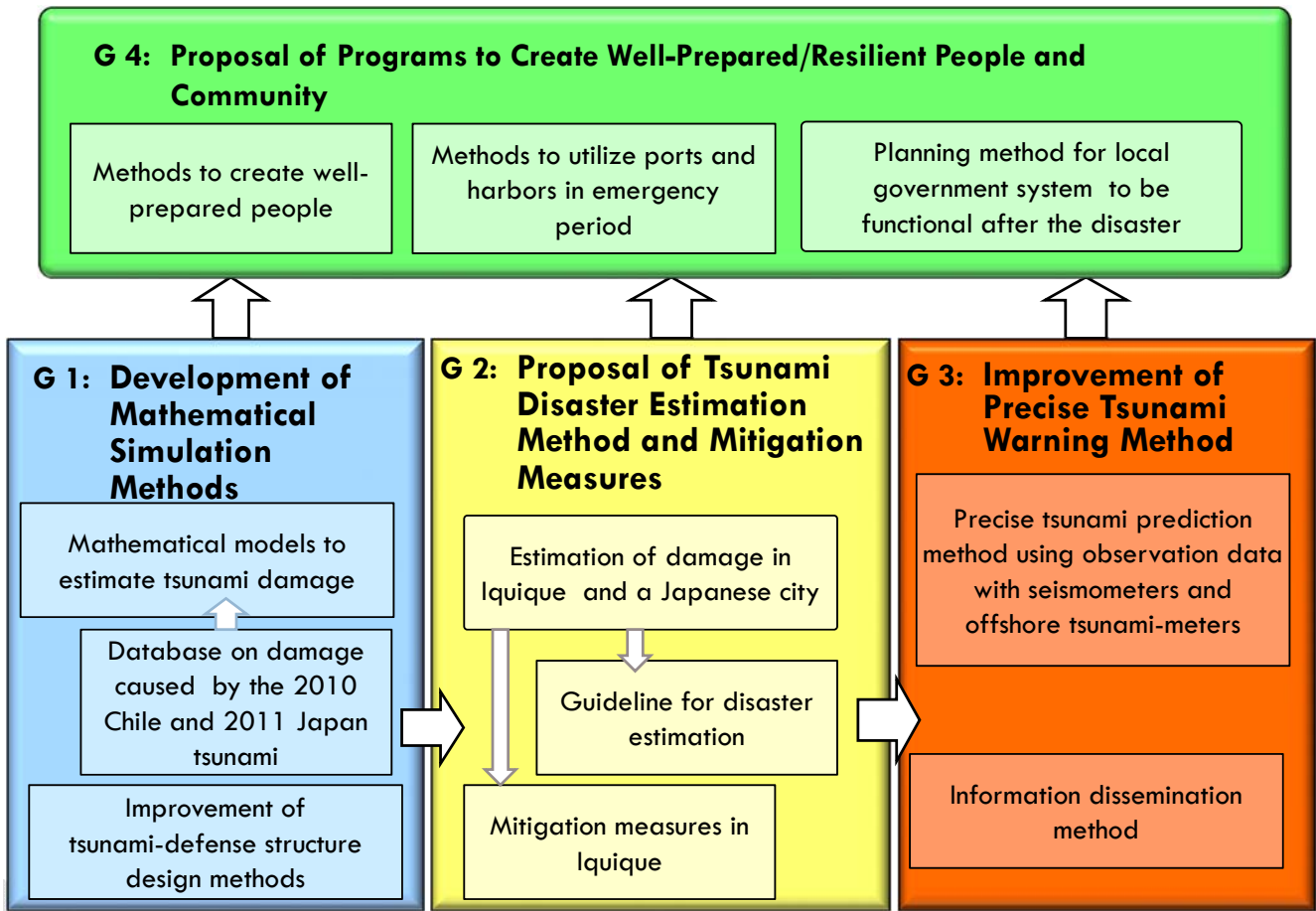
2012-03

2013-11

2016



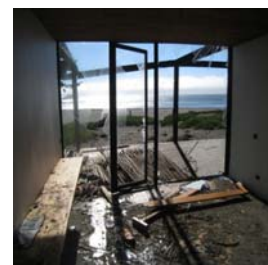
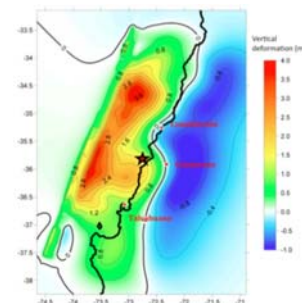
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## General objectives / Group 1

Mathematical simulation models are developed/improved to estimate tsunami damage.

- Databases on disasters by the 2010 Chilean earthquake tsunami and 2011 Japanese earthquake tsunami are constructed to understand and estimate tsunami disasters by possible tsunamis in the future.
- Mathematical simulation models are developed and improved to estimate tsunami damage accurately..
- Improve the plans and designs methods of structures of mitigation for disaster tsunami from the experienced disasters by the earthquake - tsunami in Chile 2010 and earthquake - tsunami in Japan 2011.



# General objectives / Group 2

## Propose estimation and the tsunami disaster mitigation measures

- To develop a guideline for estimation of the disaster, tsunami, based on mathematical simulations about possible tsunamis generated in the coast of Chile in the future.
- To estimate damage from the tsunami in Japan based on mathematical simulations about possible tsunamis generated in the coast of Chile in the future.
- Develop and improve measures of mitigation of disaster tsunami in accordance with Chile and Japan tsunami disaster scenarios.



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### MADERA

Mala resistencia salvo que se utilicen viviendas con tipología de palafito

### HORMIGON ARMADO

Buena resistencia ante el tsunami

### ADOBE

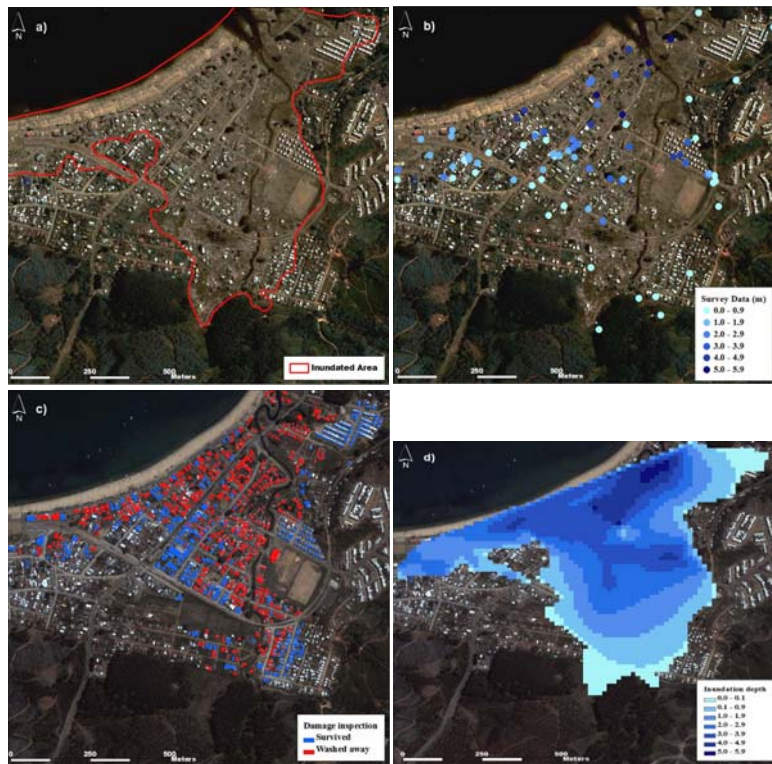
Resistencia débil ante el tsunami



Iloca, VII Región

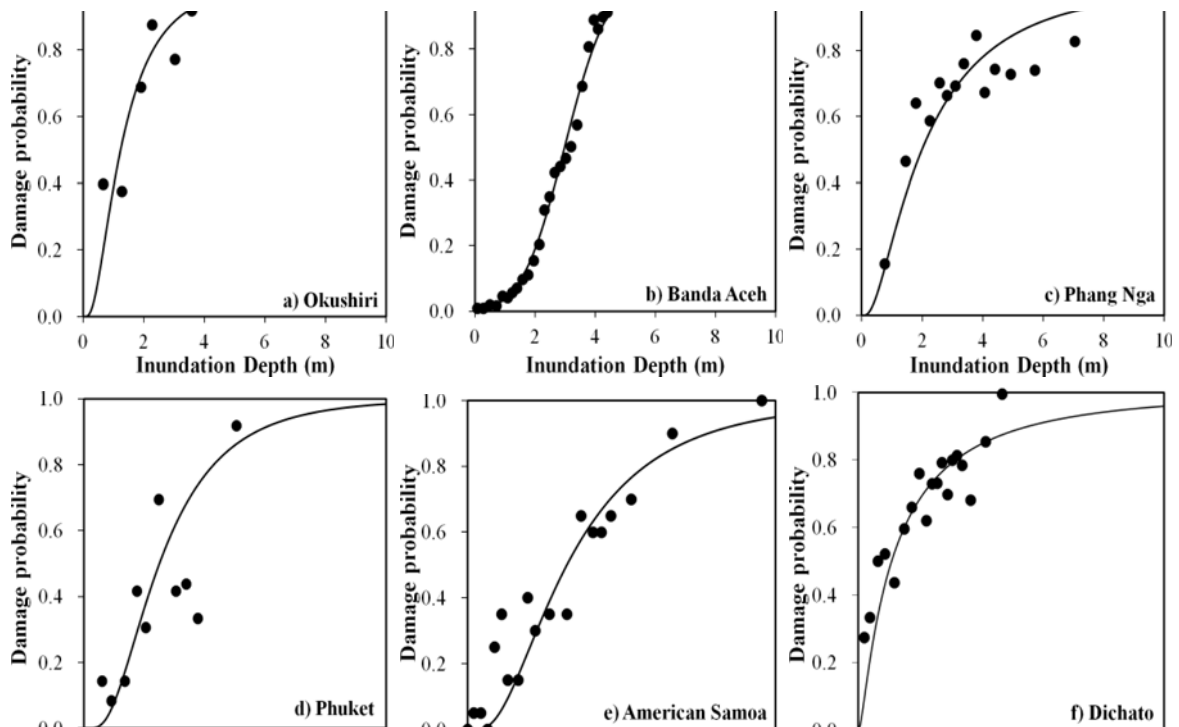
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# Dichato



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# Fragility Curves

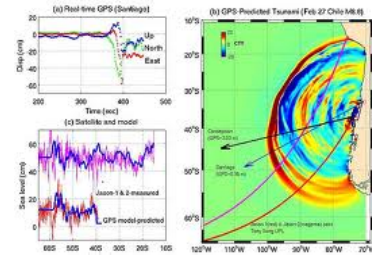


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# General objectives / Group 3

Precise tsunami warning method is proposed.

- Precise tsunami prediction method is developed, incorporating data of seismometers and offshore tsunami-meters.
- Developing a new tsunami database system for Chile (Chile DB).
- A method to disseminate tsunami information is developed in Chile with the use of Japanese experiences as references.



# General objectives / Group 4

**To propose a program to create a well prepared and resilient population and community.**

- To develop a program to create a population well prepared and resilient to tsunamis, and promotes leaders for Chile tsunami disaster mitigation.
- To develop a procedure to use ports in a phase of rescue after tsunami disaster with using Japanese experiences as references.
- Develop a method of planning of local governments so that they can work quickly after a tsunami disaster.



# RESEARCH ADVANCEMENTS

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## TSUNAMI MODELING

## TSUNAMI EVACUATION

## TSUNAMI EARLY WARNING SYSTEM



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## TSUNAMI MODELING

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***Assessing and improving the capabilities of tsunami models at several scales:***

- ***Regional scale***
- ***Inundation, run-up, propagation on river/estuaries***
- ***Damage estimation and mitigation countermeasures***

***The recent tsunamis of Chile and Japan offer unique opportunities to test and improve models since important information is available***



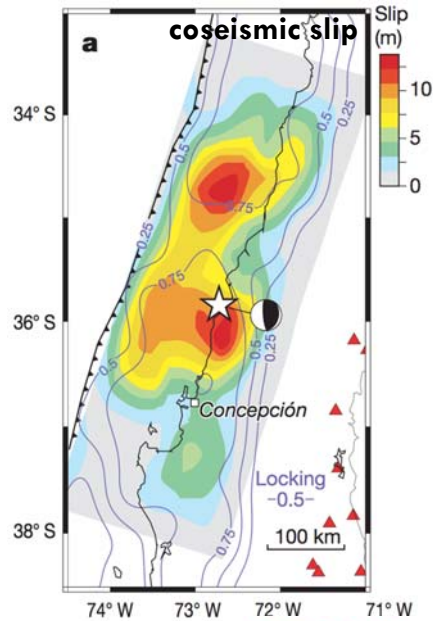
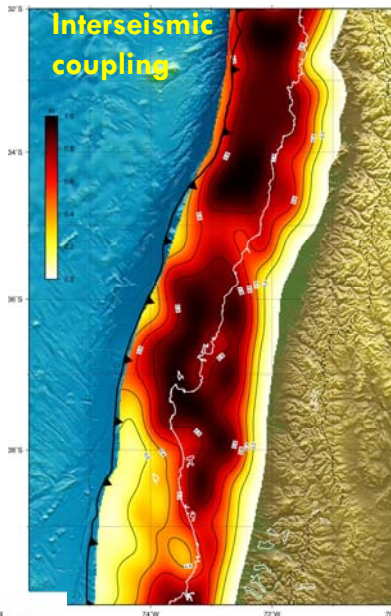
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# TSUNAMI MODELING

## Different methods to assess tsunami source (2010 EQ)



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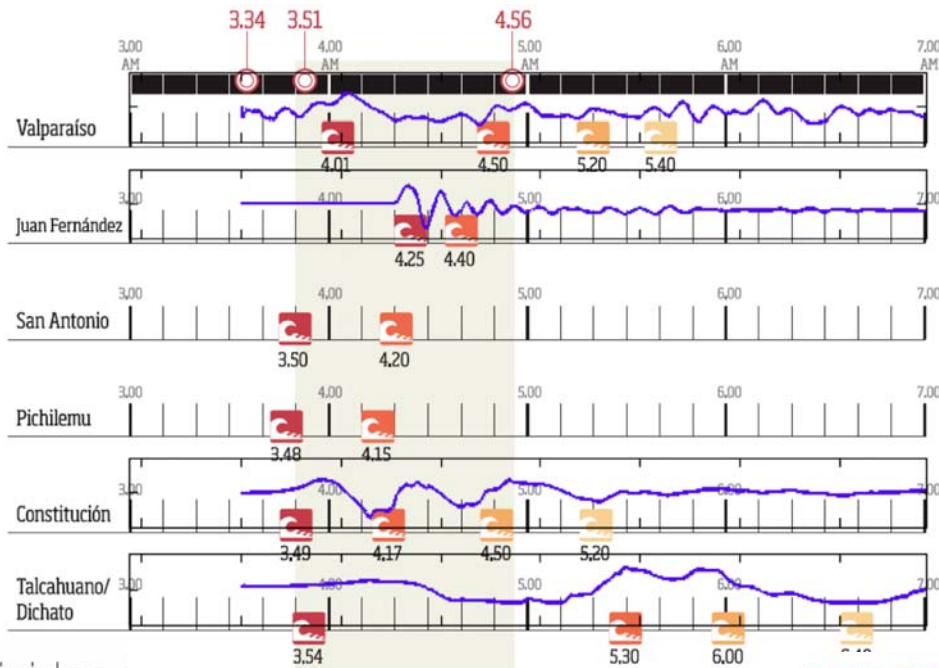
Moreno et al., (2010)

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# TSUNAMI MODELING

## Tsunami arrival times (La Tercera 2010, SHOA)



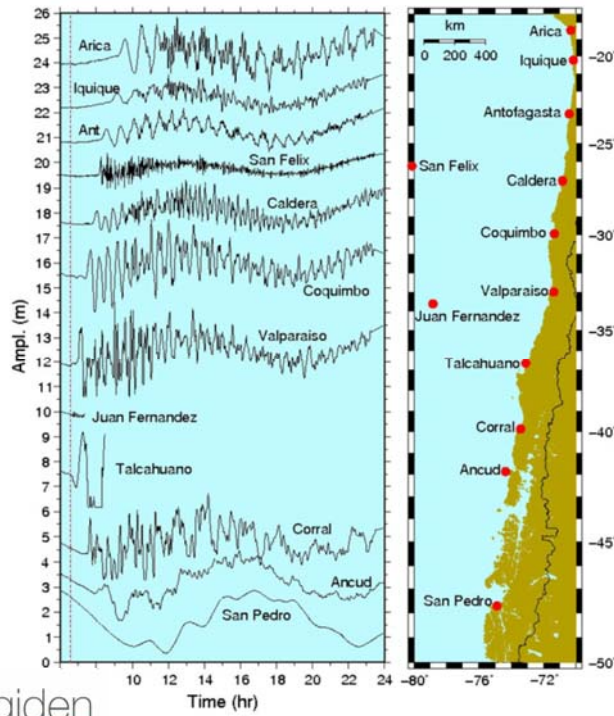
Carrón et al. (2011)

cigiden research

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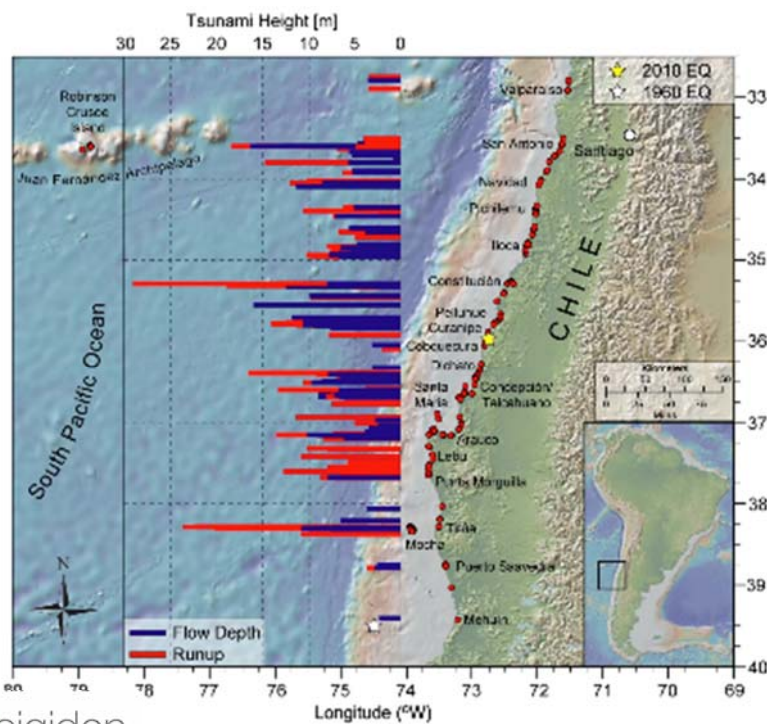
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# TSUNAMI MODELING



Tidal gauge data for the 2010 tsunami (Fritz et al., 2011)

# TSUNAMI MODELING



Post tsunami observations (Fritz et al., 2011)

- 156 casualties attributed to the tsunami, 24 missing (523 in total)

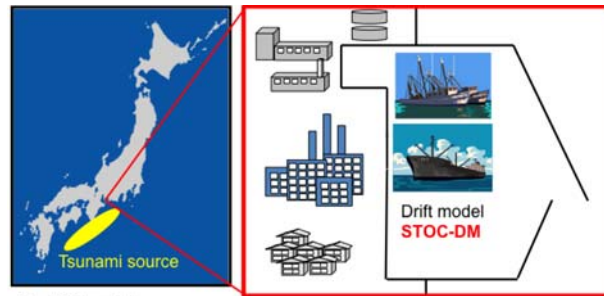
- Run-ups and inundation depths highly variable

- ☐ Maximum observed run-up (~30m)

# TSUNAMI MODELING

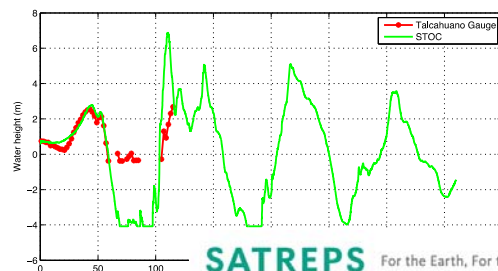
## Modeling of the 2010 Tsunami using the STOC Model (PARI)

- Implementation and validation of the STOC model (PARI) on the 2010 Tsunami
- High resolution data for inundation modeling (~2m)
- Analysis of container's drift and tsunami damage in the Talcahuano area



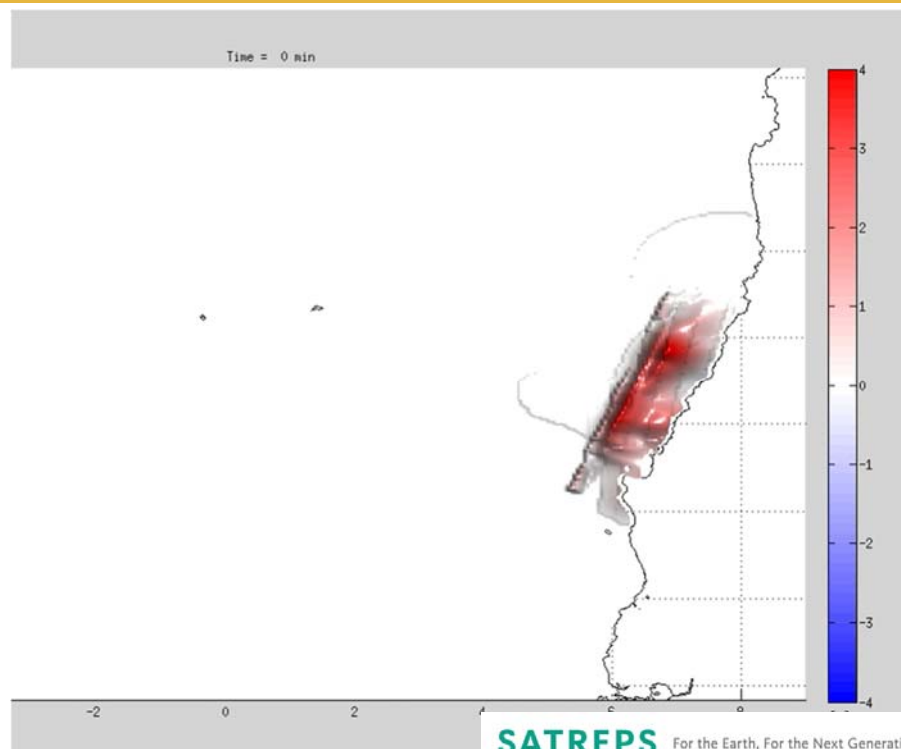
Semi-3d model (approximating hydrostatic pressure) **STOC-ML**

3d model **STOC-DM** (estimating coastal damage)



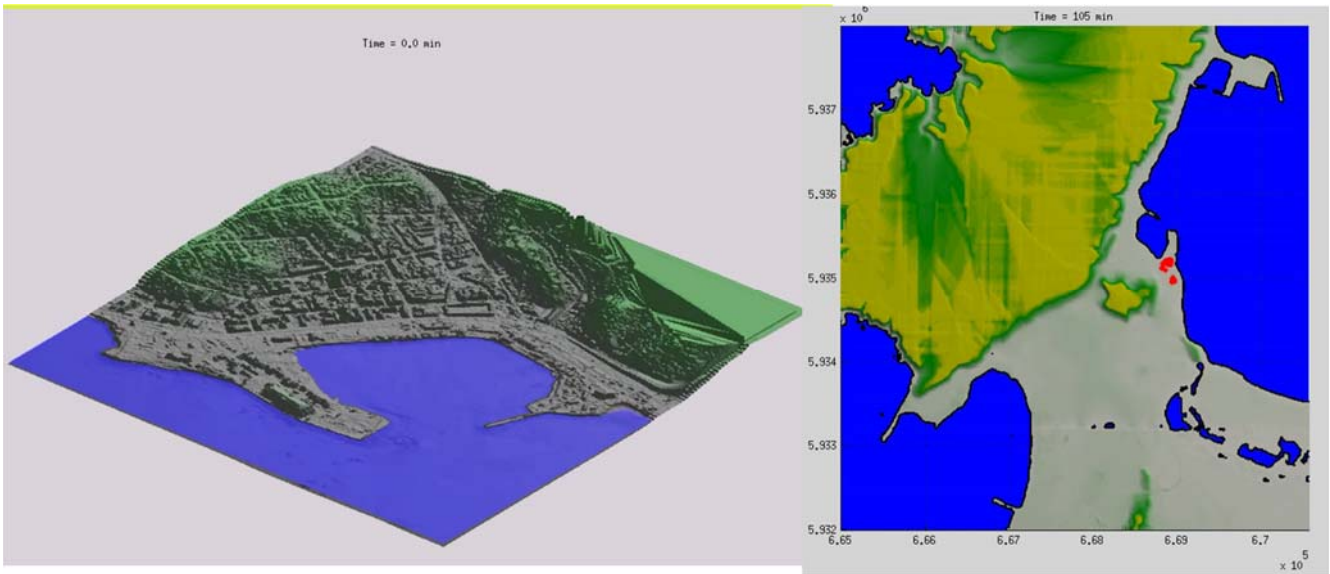
# TSUNAMI MODELING

Edge waves and shelf resonance computed using the STOC model from PARI



# TSUNAMI MODELING

## Inundation and container's drift modeling in the Talcahuano area



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# TSUNAMI MODELING

## Model Validation in the Talcahuano area



**Observations**

**Modeling**

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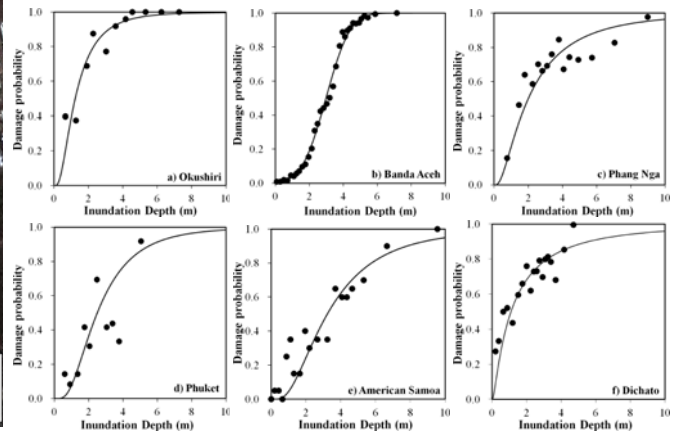
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# TSUNAMI MODELING

## Empirical fragility curves in Dichato



Mas et al. (2012)



## RESEARCH ADVANCEMENTS

### TSUNAMI MODELING

### TSUNAMI EVACUATION

### TSUNAMI EARLY WARNING SYSTEM

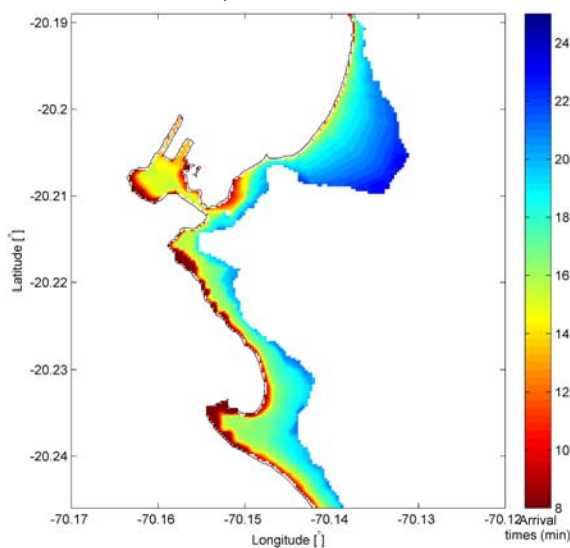
# TSUNAMI EVACUATION CASE STUDY IN THE CITY OF IQUIQUE

## Diagnostic Analysis of the City of Iquique

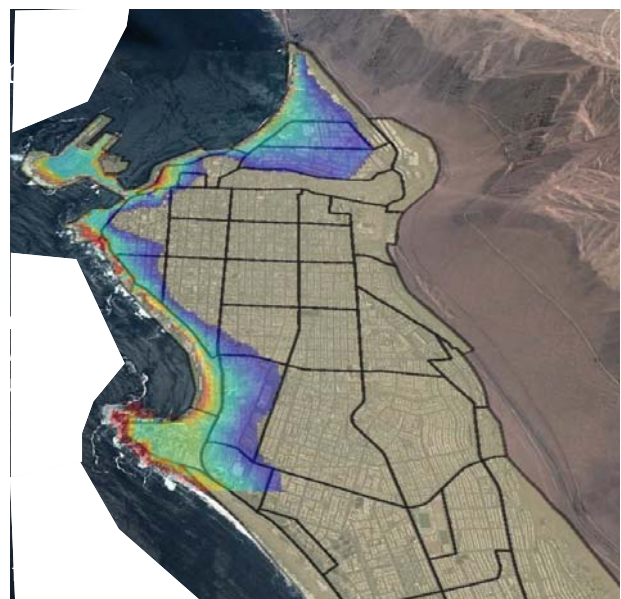
- **Definition of preliminary tsunami source scenarios**
- **Characterization of population at risk**
- **Evacuation routes, possible damage and interferences**
- **Psycho-social behavior in emergency situation**

# TSUNAMI EVACUATION CASE STUDY IN THE CITY OF IQUIQUE

- **Tsunami scenario based on Chlieh et al. (2011) (Mw ~8.6-8.8 Arica-Antofagasta uniform source)**



**Arrival times**



**Inundated area**

# TSUNAMI EVACUATION CASE STUDY IN THE CITY OF IQUIQUE

- **Commercial ZOFRI area is highly exposed**
- **Nearly 10.000 persons at peak hours**
- **Less than 20 minutes for evacuation**
- **Narrow ramps for pedestrian evacuation**



# TSUNAMI EVACUATION CASE STUDY IN THE CITY OF IQUIQUE

- **Observation of the evacuation drill that took place in August 8th 2013**
- **National evacuation drill program led by ONEMI since 2011**
- **Nearly 70.000 persons participated in the evacuation drill in Iquique**
- **CIGIDEN and SATREPS researchers conducted a field work during the drill**
  - **Observations**
  - **Questionnaires**
  - **Interviews**



# TSUNAMI EVACUATION CASE STUDY IN THE CITY OF IQUIQUE

## Items evaluated during the drill

- Required time for evacuation
- Evacuation routes
- Congestion and bottlenecks
- Community awareness about the evacuation process
- Time perception during evacuation

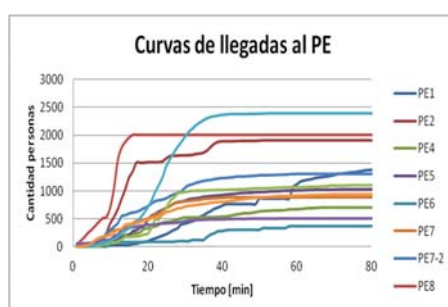


# TSUNAMI EVACUATION CASE STUDY IN THE CITY OF IQUIQUE

## Evacuation times

Mean : 17.35 min      SD : 13.08 min

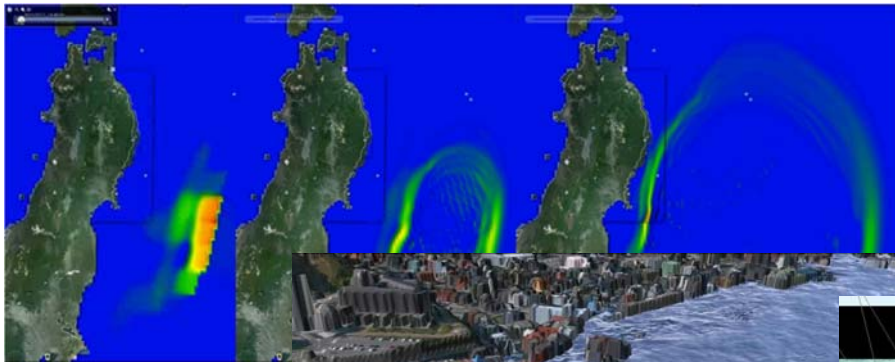
TIME	PERCENTAGE
5 min or less	19.5%
10 min	27.9%
15 min	28.8%
More than 15 min	23.9%





# TSUNAMI EVACUATION CASE STUDY IN THE CITY OF IQUIQUE

- **Agent based modeling for tsunami evacuation in collaboration with PARI (CADMAS-AGENT)**



Now under development



Arikawa, Tomita, Abe  
and Koshimura (2013)



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## RESEARCH ADVANCEMENTS

TSUNAMI MODELING

TSUNAMI EVACUATION

TSUNAMI EARLY WARNING SYSTEM

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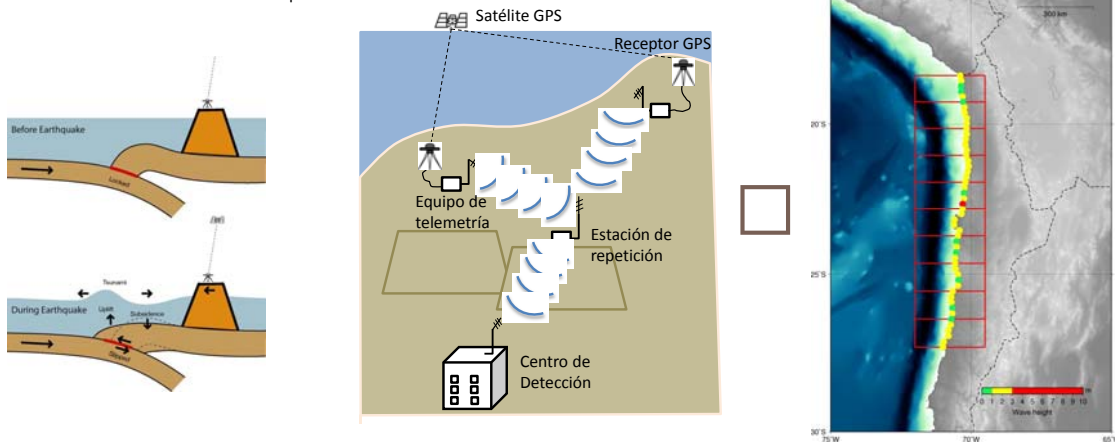
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# TSUNAMI EARLY WARNING SYSTEM

- Development of a pre-tsunami modeled scenario database
- Instrumentation analysis

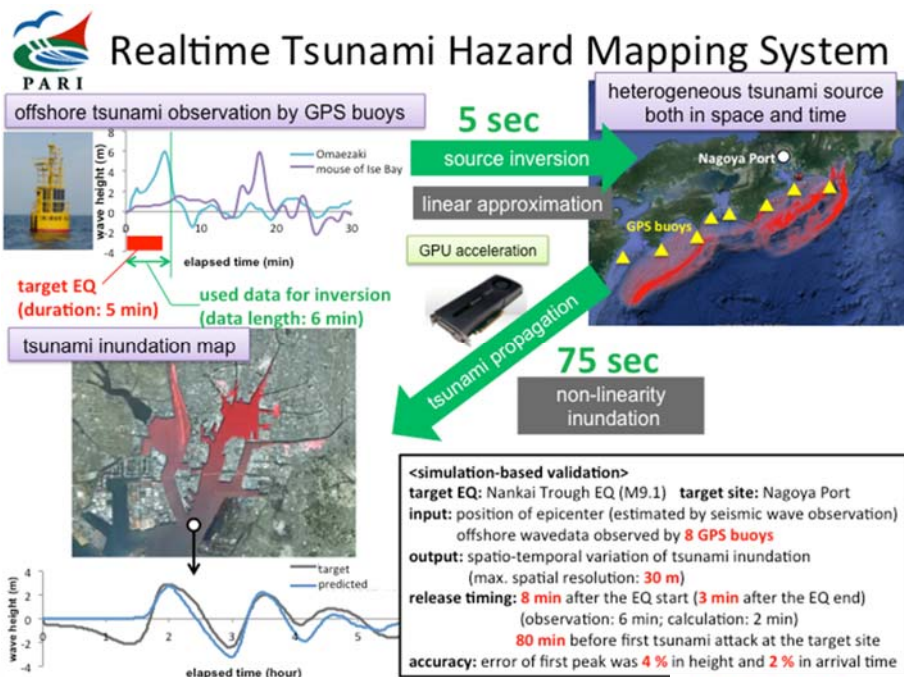
Pre-modeled tsunami scenarios (Fondef project)



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# TSUNAMI EARLY WARNING SYSTEM



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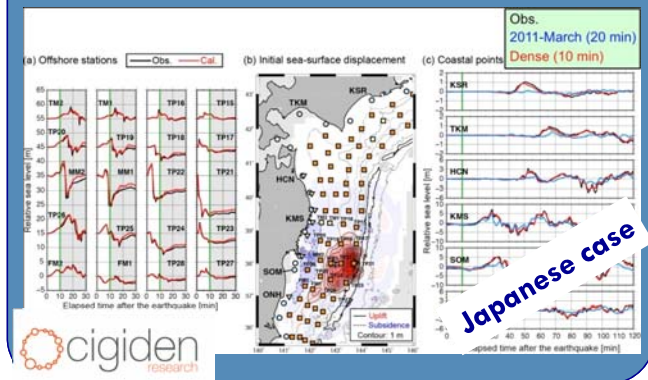
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# TSUNAMI EARLY WARNING SYSTEM

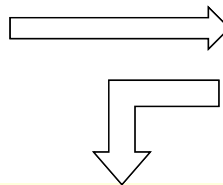
Investigation of what array configuration of offshore-tsunami stations is effective for near-field tsunami prediction in the Chilean coasts

Synthetic test of tsunami prediction assuming several array configurations

Investigation using tFISH algorithm  
Effect of offshore tsunami station array configuration on tFISH forecast in Japan



Application to Chilean case



Information: effective array configuration  
→ Possibility to contribute to planning future tsunami observatories in Chile

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## WG4a, Education

### □ LINES OF ACTION

- Formal education
- Non-Formal Education
- Information Systems
- Evacuation

### □ Pilots Course under development

- Diploma for municipal officials from Talcahuano.
- Elective management course in DRR for students who will be teachers at the school system.
- Elaboration of series of Elective courses in DRR and CCA for all students of the University.

### □ Introducing Project in School Education for Disaster Risk Reduction to Government of BIOBIO Region.

# Summary

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- Project has been successful in advancing in state-of-the-art tsunami research in both Chile and Japan
- Improved understanding of physical, technological and societal aspects
- Good record of capacity building in Chile
- Challenges ahead: Transferring advancements to measures at local level (e.g. Municipalities)

# Thank you!

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