# Systematic comparison of different numerical approaches for tsunami simulations at the Chilean coast as part of the RIESGOS project

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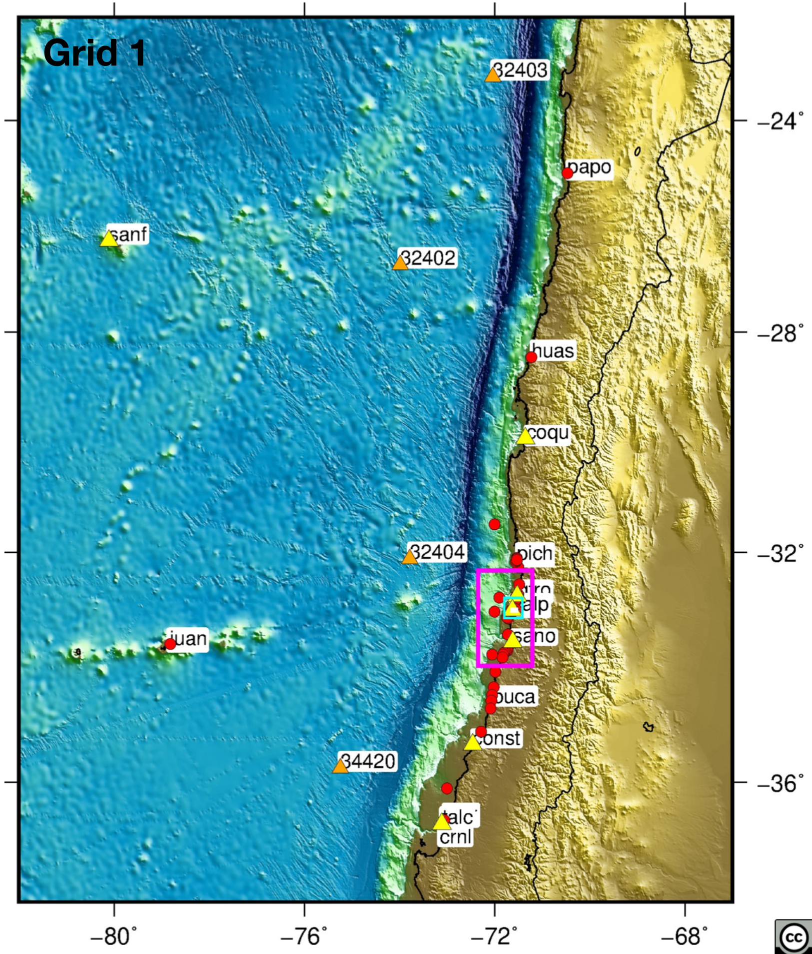
Session NH5.1 Tsunamis EGU2020-6764
European Geoscience Union
Wednesday May 6th, 2020

# I. Introduction

**Aim of the study**. To conduct a systematic comparison of three tsunami numerical codes. We investigate the performance of three models (TsunAWI, HySEA, COMCOT) in the oceanic region offshore central and northern Chile with inundation studies in Valparaíso and Viña del Mar. The investigation forms part of the tsunami component in the RIESGOS project dealing more general with multi hazard assessments in the Andes region (see [www.riesgos.de](http://www.riesgos.de)).

Valparaíso region is one of the pilot areas of the project (besides Metropolitan Lima and Callao in Perú and Quito/Cotopaxi region in Ecuador) and in this study we investigate the tsunami modeling approaches conducted by the project partners.

Figure 1 shows the extent of the coarser grid, level 1 in the nested grids. Selected virtual tide gauges and DARTs.



# II. Methods

The numerical implementation of the models include both a finite element approach with triangular meshes of variable resolution (TsunAWI code) as well as finite volume and finite difference implementations with nested grids for the coastal area (HySEA and COMCOT). In Table 1 we show the parameters used in the numerical simulations.

We investigate the consistency of the models based on different numerical approaches (nested grids and unstructured meshes) with respect to

- Virtual tide gauges in various water depths as well as reference locations on land.
- Tide gauge locations and records where available.
- Flow depth on land and runup height.

as well as the sensitivities of the models with respect to model parameters like

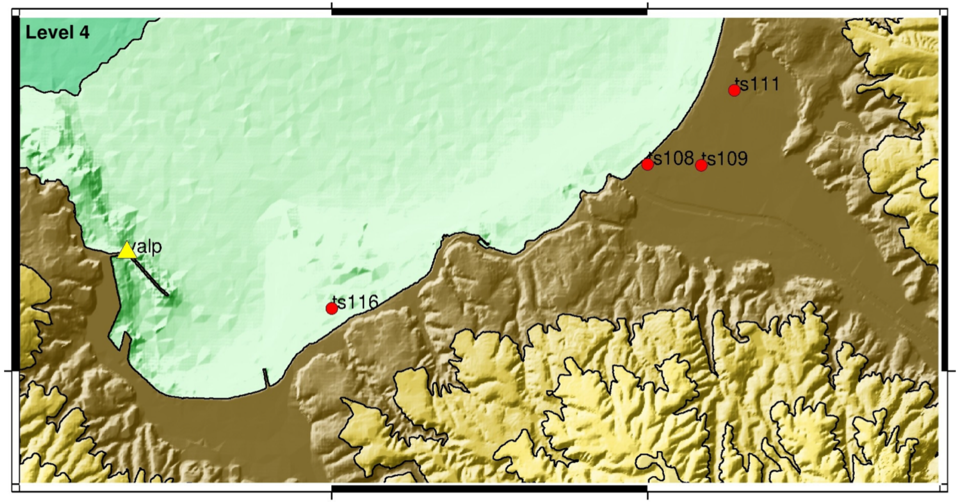
- Mesh resolution and bathymetry representation in the varying mesh geometries.
- Bottom friction (Manning implementation).

Table 1. Set-up for numerical simulations

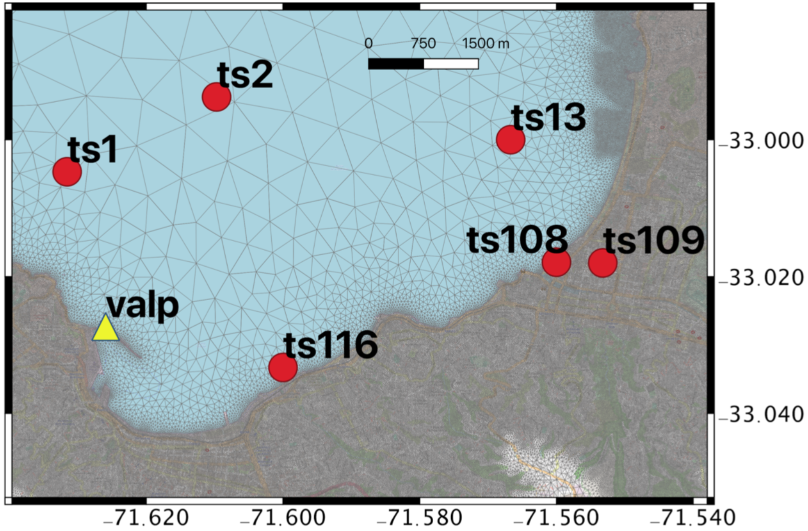
| Model | HySEA | TsunAWI | COMCOT |
|---|---|---|---|
| Spatial discretization | 4 nested grids (res. 925, 231, 57, 7.25 m) | Triangular, resolution 10km-20m | 4 nested grids (res. 925, 231, 57, 7.25 m) |
| Time stepping | Leap frog and 2nd order TVD - WAF flux limiter scheme 0.5 sec | Leap frog 0.2 sec glob. | Leap frog 1.0 sec, automatically adjust to satisfy Courant condition |
| Numerical approach | Finite Volume | Finite Elements | Finite Differences |
| Inundation scheme | TVD-weighted averaged flux (WAF) flux-limiter | Extrapolation scheme | Moving boundary |

# III. Digital elevation models (nested grids and triangular mesh)

High resolution grid, level 4 for HySEA and Comcot




Triangular mesh for TsunAWI




Nested grids were created based on the General Bathymetric Chart of the Oceans GEBCO (Becker2009), SHOA nautical charts, local cartography and ALOS World 3D - 30m (AW3D30) (Tadono2014).

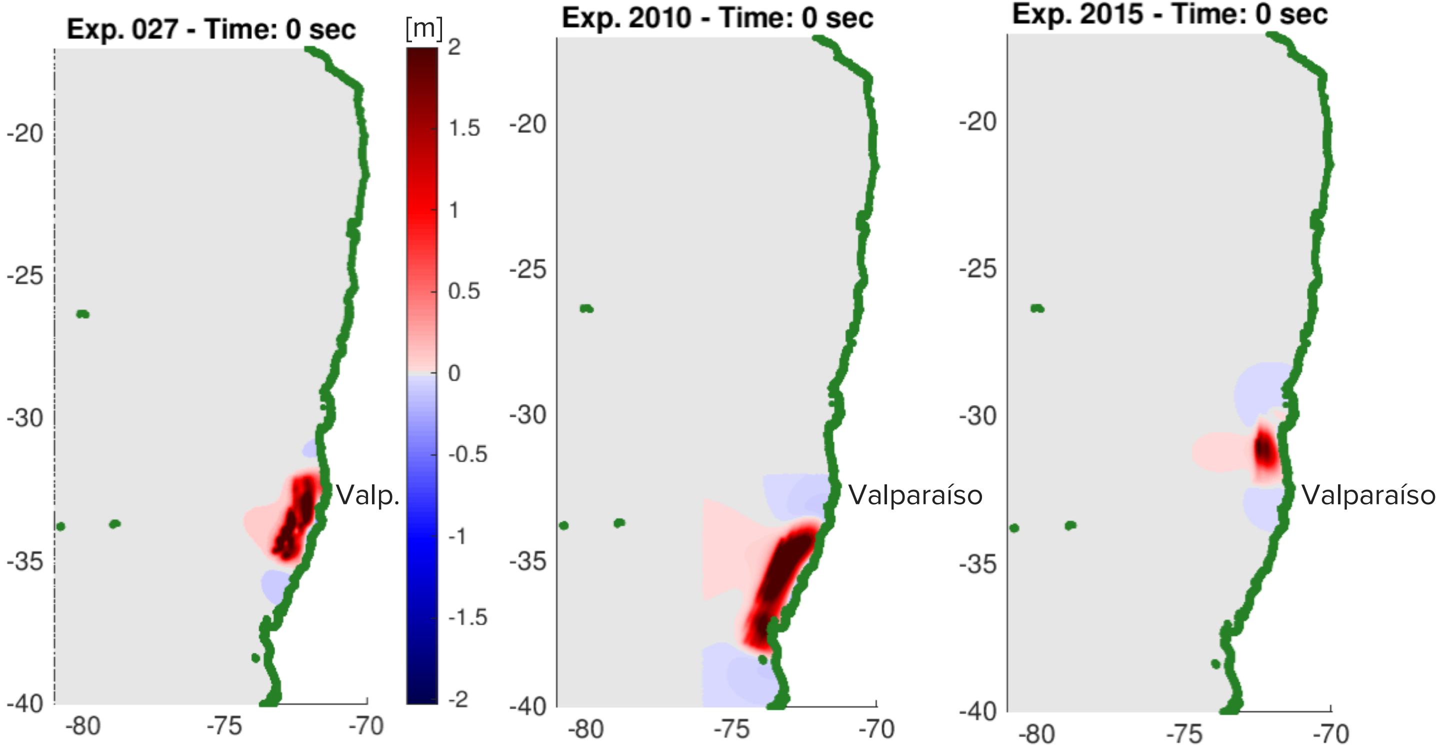
# IV. The source models

The tsunami sources are identical in all models and chosen from an ensemble of events used in an earlier probabilistic study of the region (Exp 027 Mw 8.7, left panel)

Additionally, two historic events are considered to validate the models against corresponding measurements (central and right panel).

Colorbar is the same for the three sources.

Vertical displacement - initial sea surface elevation




Mw 8.7 scenario (member of a probabilistic study along the chilean coast)

Tsunami on 27 Feb. 2010 Source based on Moreno et al. (2010).

Tsunami on 16 Sep. 2015 Source based on Shivarasta et al (2015)



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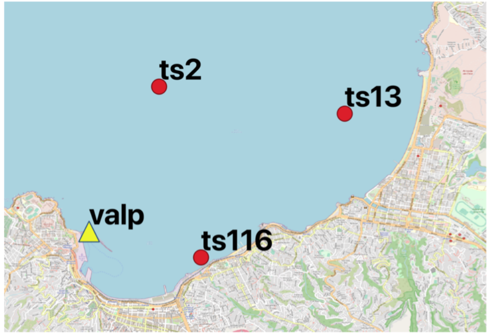
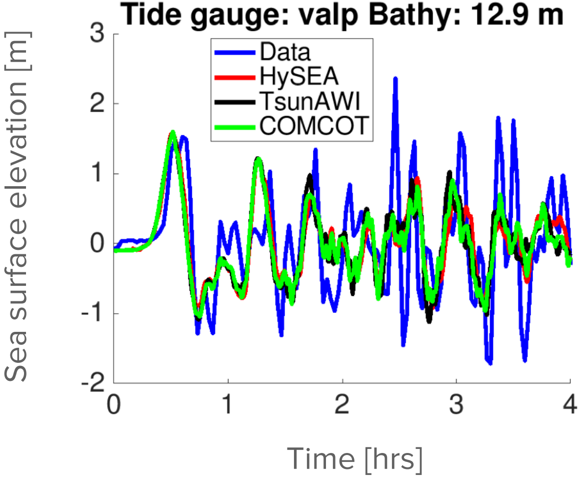
# V. Results

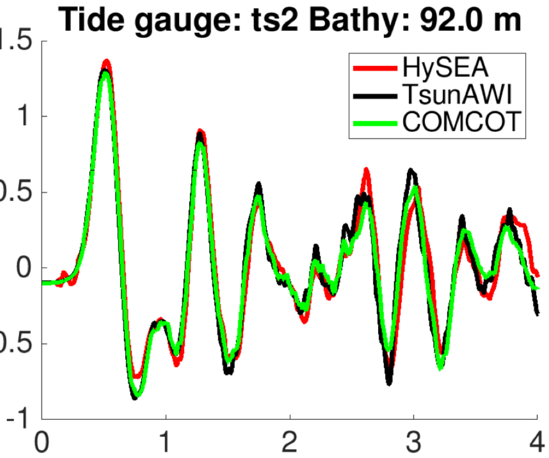
**Experiment 2010:**

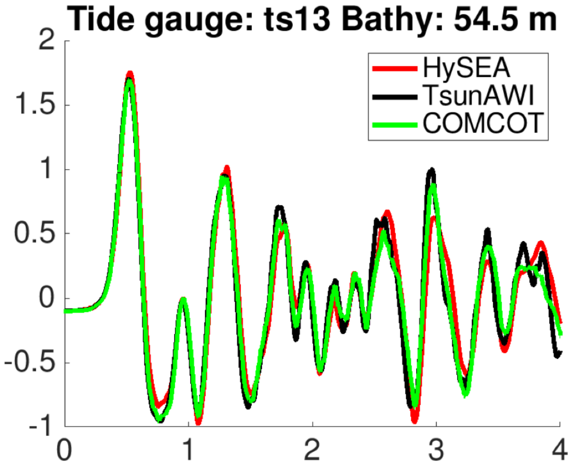
Model comparison in tide gauges

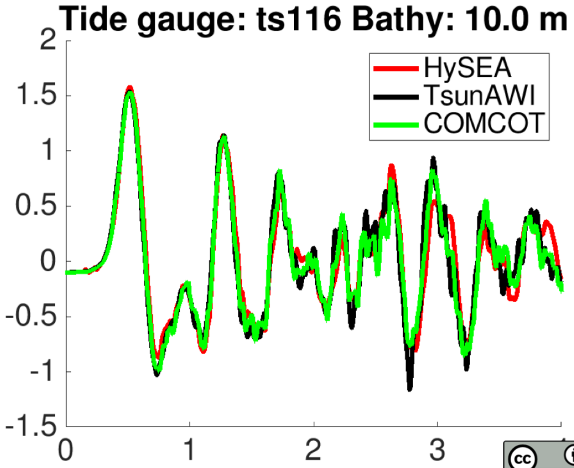
Setup all models as in Table 1
Manning: n=0.02



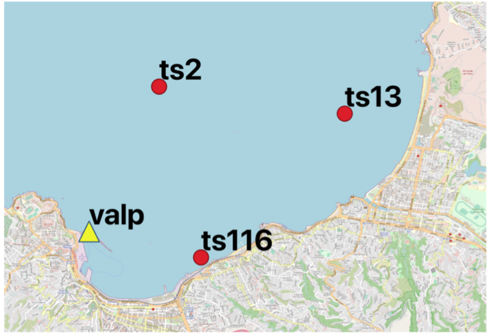



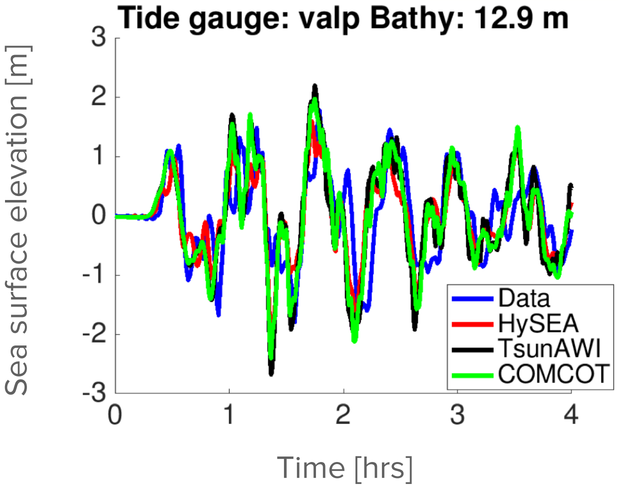
# V. Results

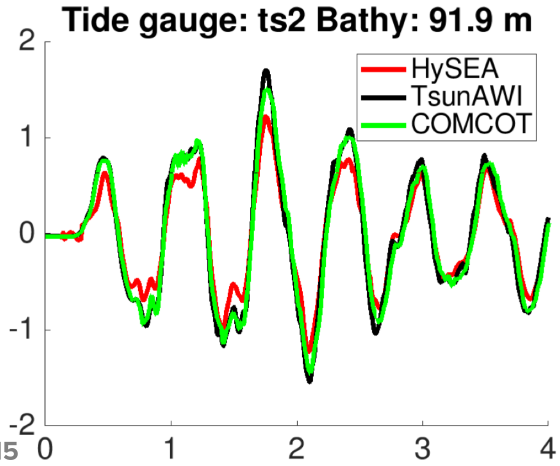
**Experiment 2015:**

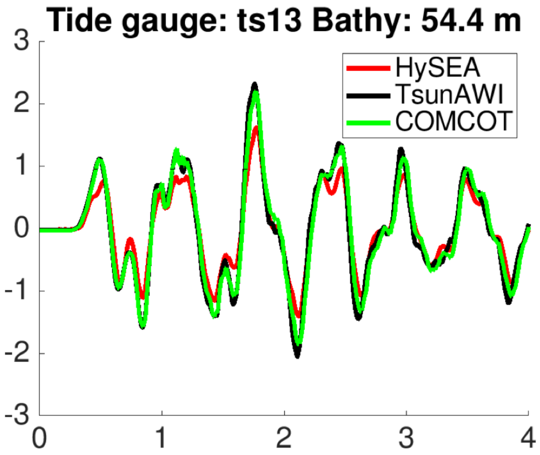
Model comparison in tide gauges

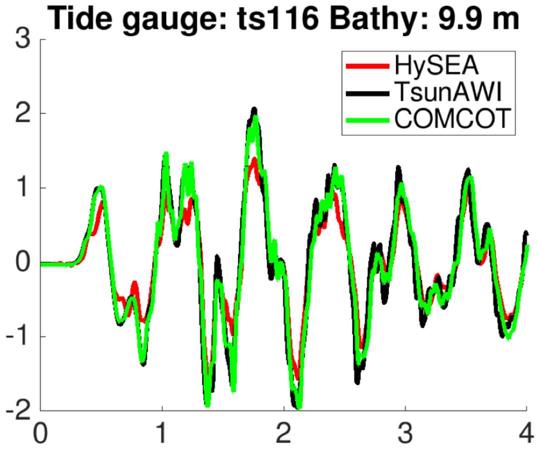
Setup all models as in Table 1
Manning: n=0.02



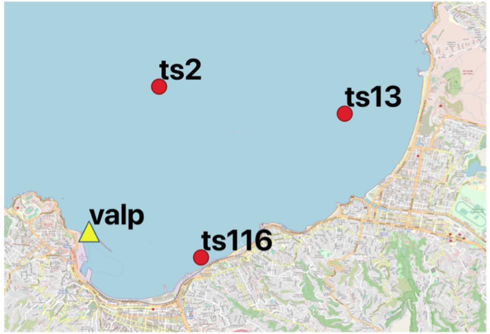



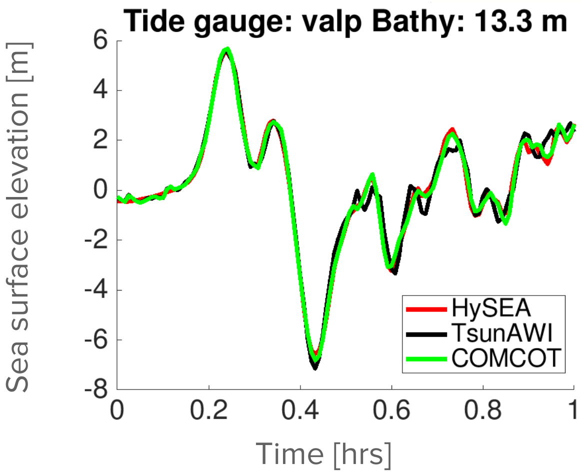
# V. Results

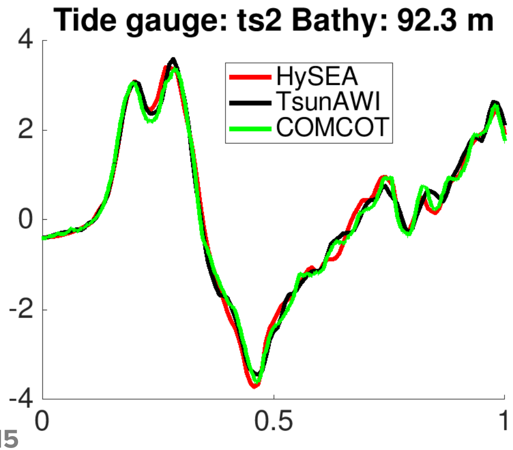
**Experiment 027:**

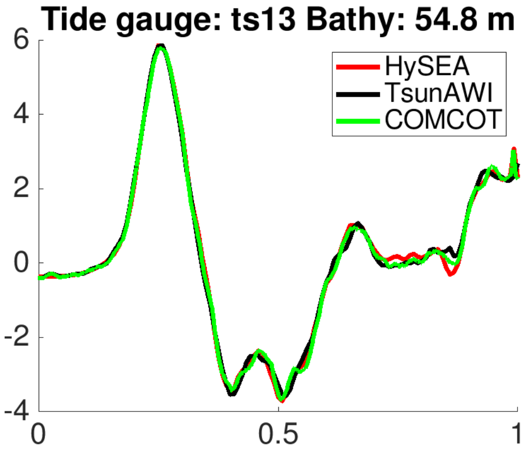
Model comparison in tide gauges

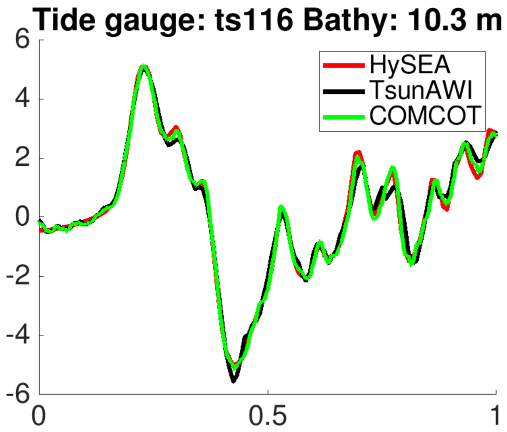
Setup all models as in Table 1
Manning: n=0.02



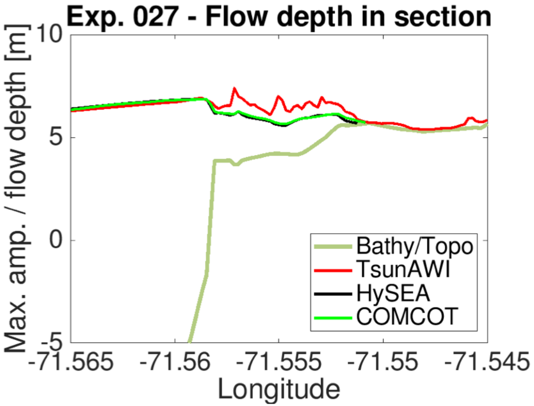



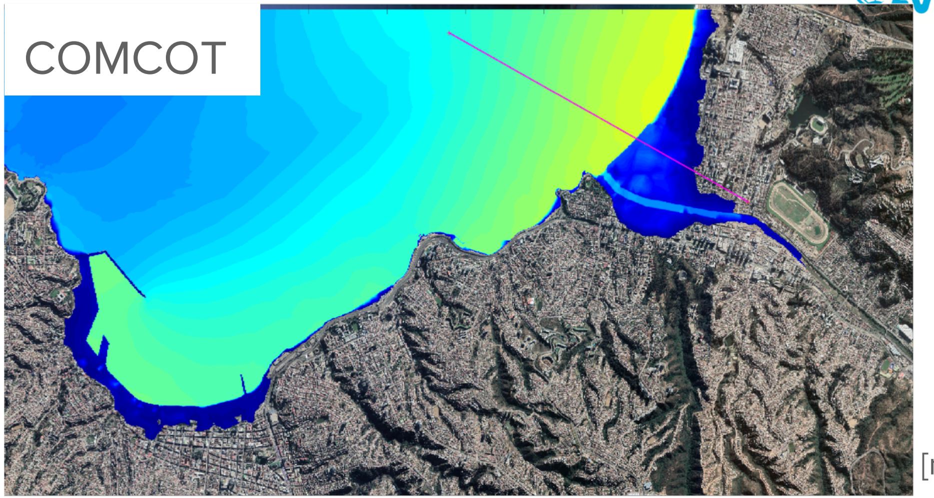



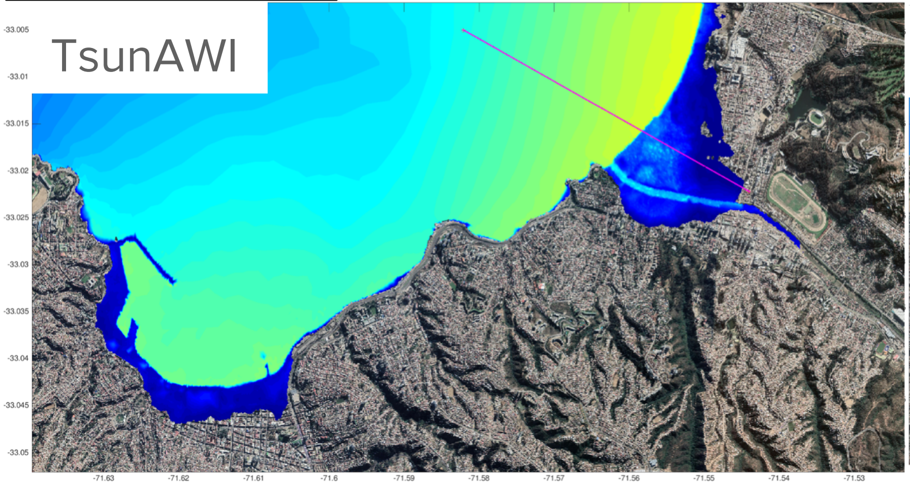
V. Results

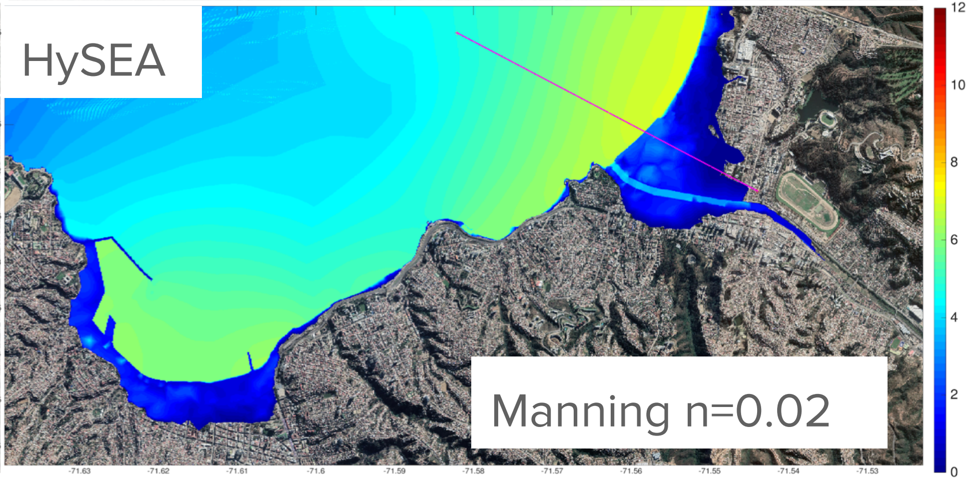
**Exp. 027**:
Inundation

The section stretches to 70m water depth. The models differ only in the near- and onshore part.



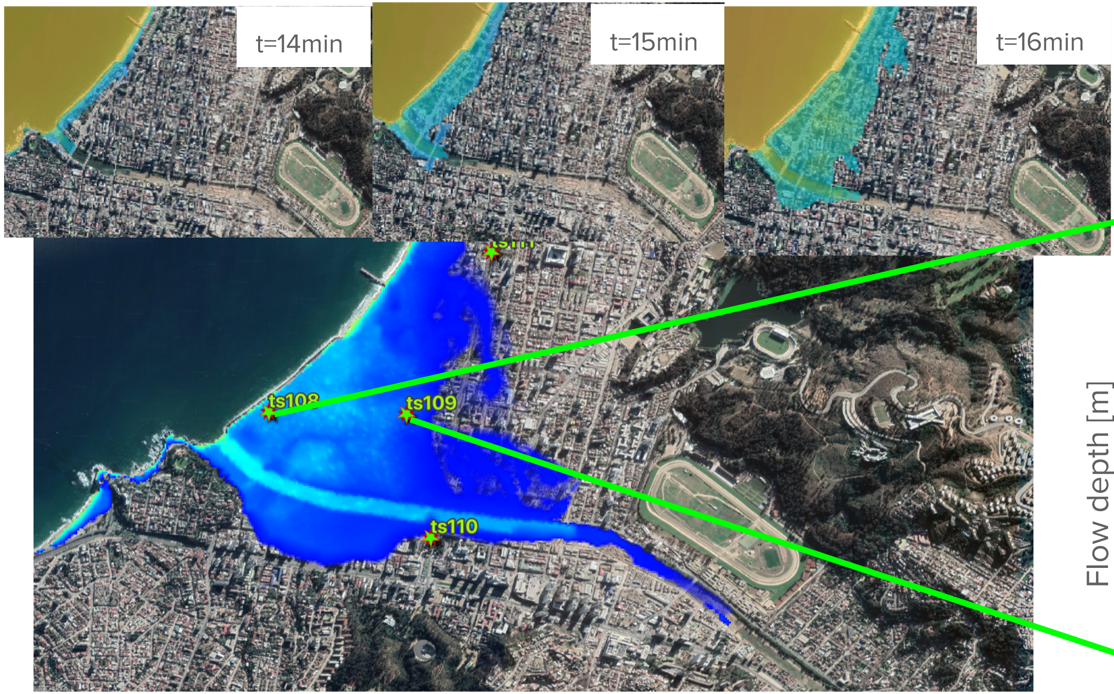



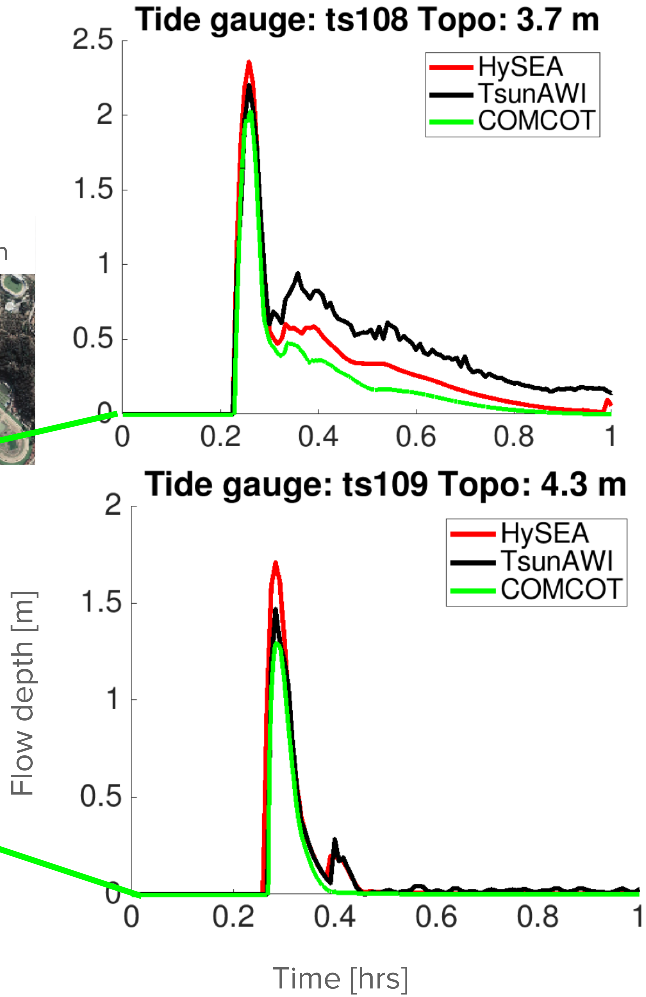




 Max. tsunami amplitude in sea and max flow depth [m] on land. (Areas with flow depth of more than 1 cm are shown)

# V. Results

## **Exp. 027**: Temporal evolution of the runup

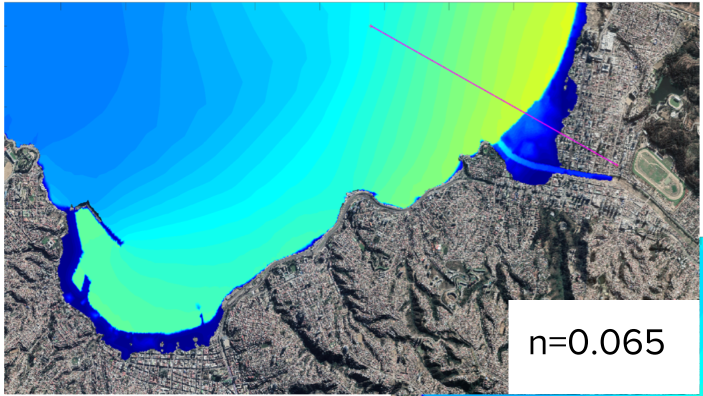


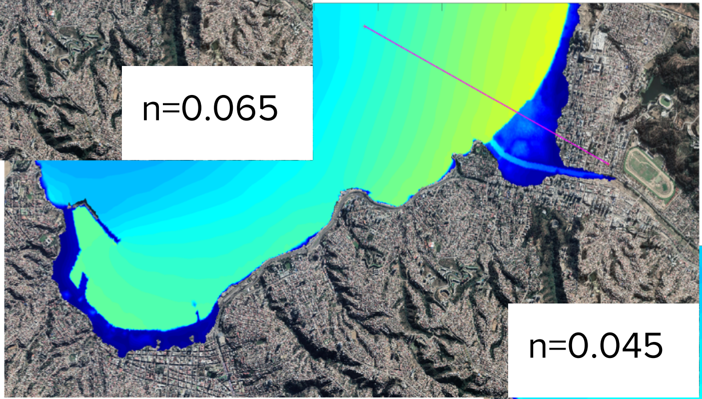



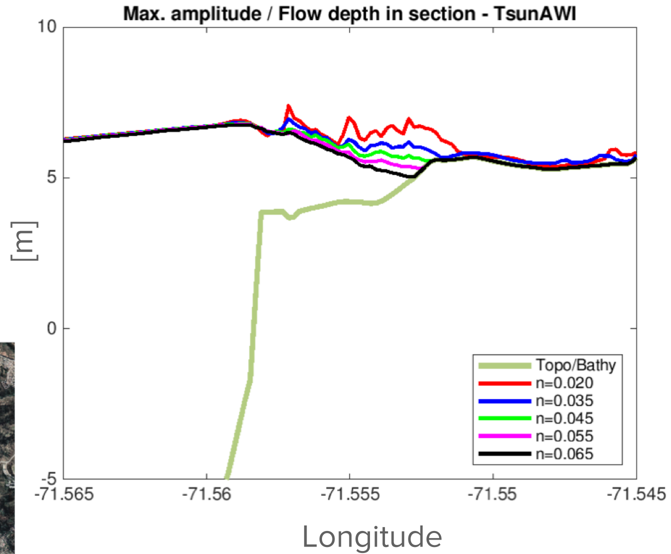

Manning n=0.02

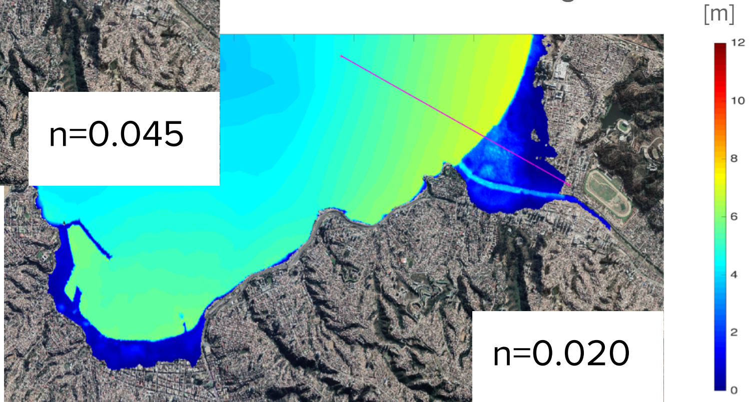
## V. Results

### **Exp. 027**: Sensitivity to Manning



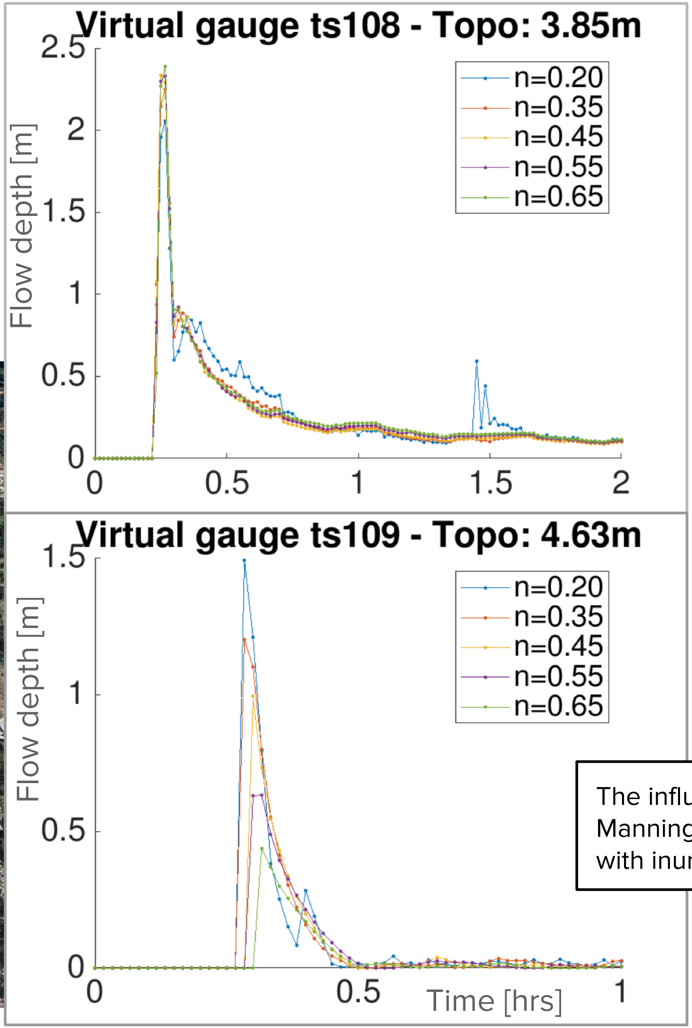




Model: TsunAWI

# V. Results

## **Exp. 027**: Sensitivity to Manning

Model: TsunAWI


The influence of larger Manning values grows with inundation depth.

# VI. Final remarks

The study is ongoing, so far we observed:

- Good agreement in virtual gauges offshore regardless the differences in resolution and mesh structure.
- Differences in the flooded area on land grow with inundation depth due to the effect of bottom roughness.
- Differences in offshore gauges occur after several hours when reflections from the coast become more important.

Next steps:

- Extension of the comparison to mesh resolution and variable roughness parameterization.
- Inclusion of flow velocity into the comparisons.
- Some instabilities were found in our Comcot set up, and we will further check the possible sources of this.

# Acknowledgements

Thanks to the partners in the RIESGOS project!

The RIESGOS project is funded by the German Federal Ministry of Education and Research

Research Center for Integrated Disaster Risk Management (CIGIDEN), ANID/FONDAP/15110017

The Servicio Hidrográfico y Oceanográfico de la Armada de Chile (SHOA) provided high resolution bathymetry data via the CENDHOC: (Centro Nacional de Datos Hidrográficos y Oceanográficos de Chile) program.

EDANYA Group for sharing the HYSEA code, and X. Wang for sharing COMCOT code.

RIESGOS

MULTI-RISK ANALYSIS AND INFORMATION SYSTEM COMPONENTS FOR THE ANDES REGION

Bundesministerium für Bildung und Forschung

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# References


1. Becker, J., D. Sandwell, W. Smith, J. Braud, B. Binder, J. Depner, D. Fabre, J. Factor, S. Ingalls, L.-H. Kim, R. Ladner, K. Marks, S. Nelson, A. Pharaoh, R. Trimmer, J. VonRosenberg, G. Wallace, and P. Weatherall (2009). Global bathymetry and elevation data at 30 Arc Seconds Resolution: SRTM plus, Marine Geodesy 32(4), 355–371.

2. de la Asunción, M., Castro, M. J., Fernández-Nieto, E. D., Mantas, J. M., Ortega, S., & González-Vida, J. M. (2013). Efficient GPU implementation of a two waves TVD-WAF method for the two-dimensional one layer shallow water system on structured meshes. Computers & Fluids, 80, 441–452.

3. GoogleEarth Gallery. Retrieved on November 15th, 2019. Satellite Model http://www.google.cn/maps/vt?lyrs=s@189&gl=cn&x={x}&y={y}&z={z}. In: QGIS Development Team, 2019. QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.osgeo.org.

4. Macías, J., Castro, M.J., Ortega, S., Escalante, C., González-Vida, J.M. (2017). Performance benchmarking of Tsunami-HySEA model for NTHMP's inundation mapping activities. Pure and Applied Geophysics, 1-37. [doi: 10.1007/s00024-017-1583-1]

5. Rakowsky, N., Androsov, A., Fuchs, A., Harig, S., Immerz, A., Danilov, S., Hiller, W., and Schröter, J.: Operational tsunami modelling with TsunAWI – recent developments and applications, Nat. Hazards Earth Syst. Sci., 13, 1629–1642, https://doi.org/10.5194/nhess-13-1629-2013, 2013.

6. Tadono, T., H. Ishida, F. Oda, S. Naito, K. Minakawa, and H. Iwamoto (2014). Precise Global DEM Generation by ALOS PRISM, ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences II-4 (May), 71–76

7. Wang, X.; Power, W. L. 2011. Cornell Multi-grid Coupled Tsunami. COMCOT: a tsunami generation propagation and run-up model. GNS Science report ; 2011/43. 121p.