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Numerical modelling of the 1771 Meiwa tsunami to better understand tsunami-reef interactions

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Plan

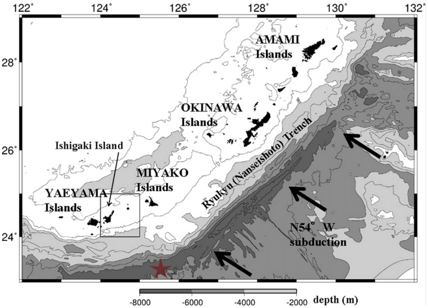
Ishigaki Island

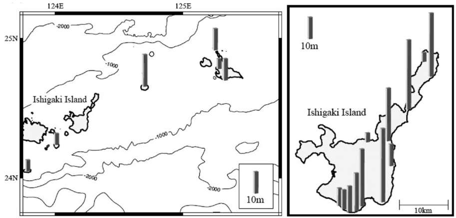
1. Introduction and context
   - The 1771 Meiwa tsunami
   - Reef - tsunami interaction
2. Methodology
3. Main results
4. Conclusions

The 1771 Meiw tsunami

Description of the event

- Date : 24 April 1771
- Boulders along the coasts
- Run ups estimated up to 30*m*
- * Casualties : $\sim$ 12000 (48% of the population of Ishigaki Islands)





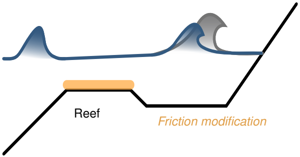
Both maps issued from Matsumoto *et al.* 2009.

Reef - tsunami interactions

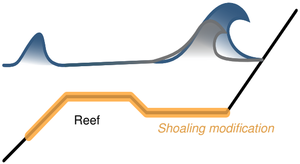
For regular flooding (non-tsunami) it has been shown that reefs can absorb 80% of the wave energy (Ferrario 2014).
For tsunami flooding, the influence of the reef is less clear.

The reef influence on waves is twofold:

- it modifies of the bottom friction (usually by increasing it), which **attenuates** in-coming surface waves,



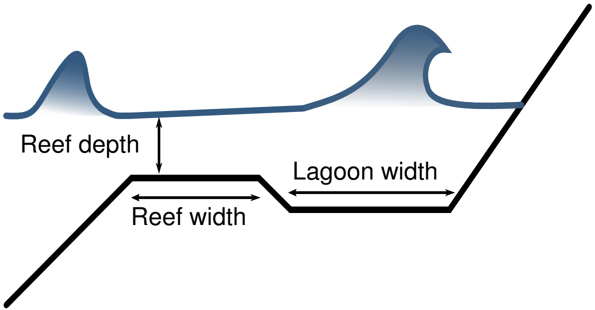
- its structure impacts the shoaling, resonance and refractive effects, that can **amplify** inundations.



? How did the Ishigaki reef influence the 1771 tsunami flooding ?

Reef - tsunami interactions

From previous idealized studies, the main reef parameters influencing the process are the reef depth, reef width and lagoon width.



In this presentation, we will focus on the reef as an whole and quantify the impact of its presence by using numerical modelling.

Method

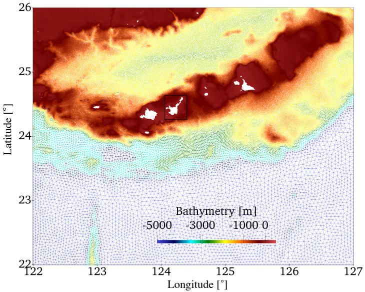
Hypothesis:

- NLSWE is sufficient to represent the coastal processes,
- The bottom friction coefficient can be represented as spatially homogeneous.

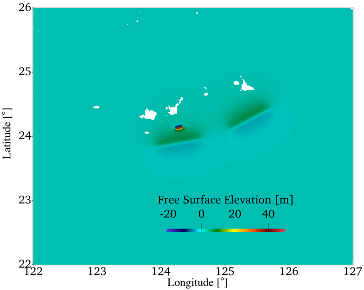
Model:

- 2D Numerical Modelling solving the NLSWE: Telemac2D (Hervouet 2007).
- Grid resolution up to 10m at the coast.
- 3 models: real reef model, no reef model (Numerical smoothing), no channel model.

Numerical mesh



Initial condition Miyazawa (2012)



Protocol

1. Building a reference calibrated numerical model representing the real scenario

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2. Building modified reef models

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3. Quantifying the impact of the modifications with :

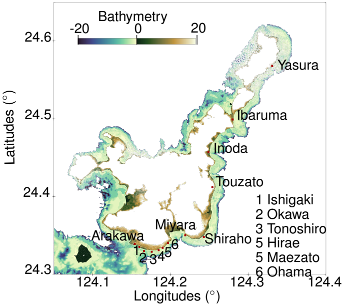
$$\textbf{RIF} = \left(\frac{(\text{MWD modified model})}{(\text{MWD reference model})} - 1.0 \right) \times 100$$

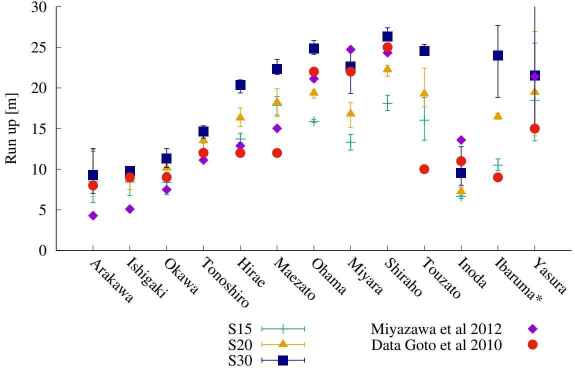
**RIF = Reef Impact Factor*

MWD = Maximal Water Depth at the shore

1. Reference model and calibration

A sensitivity test on the friction coefficient (Strickler law) is performed.
Result is compared to estimated run-up data from Goto (2010).



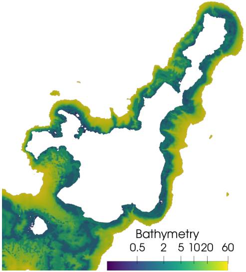


The model with the Strickler coefficient $S = 30m^{1/3}.s{-}1$ fits the highest run-ups.
This model is kept as the reference model.

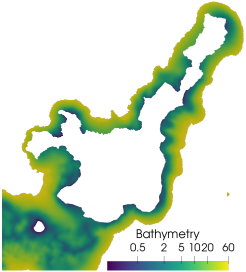
2. Modified reef models

- The no reef model is created by numerically smoothing the reef area.
- The no channel model is created by artificially filling the channel areas to obtain a reef depth similar to adjacent sections.

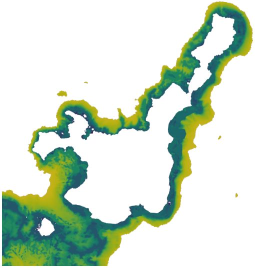
Reference reef model

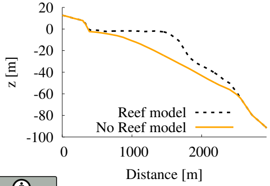


No reef model

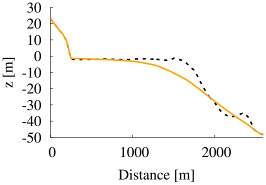


No channel model

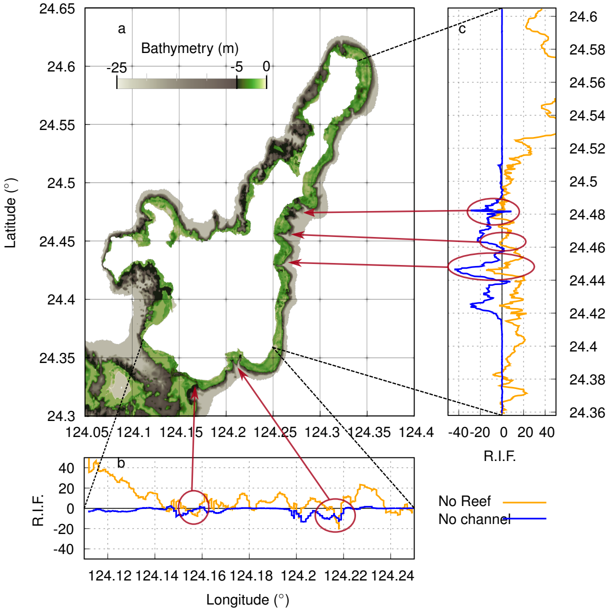




Comparison of Cross-section of the reef in the reference and no reef models.



3. Main results and RIF estimation



Conclusions and perspectives

How did the reef influence on the tsunami wave(s) and on the inundation ?

- RIF fluctuates significantly along the coast:
  - Dependence of the 2D shore geometry,
  - Importance of the wave parameters as the reef geometry does not drastically change (see Lynett 2007).
- On average, the reef **protected** the coasts: 12.5% reduction of the MWD, which is much smaller than for regular-flooding.
- BUT:
  - Channels **amplified** the nearby inundation: up to 40% decrease of the MWD without channel, which is more important than estimated for idealized channels but matching the impact of embayments by Gelfembaum *et al.* (2014).
  - For adjacent coasts, **reef channels are more harmful than no reef**,

Perspectives

- There are some isolated negative RIF not due to channels: resonance effect ?
- A deeper analysis of the relationship between RIF and specific reef morphologies can be performed as by Costa *et al.* (2016),
- Can dispersion process influence this result ? Boussinesq model ?

References

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- Ferrario, F., et al. "The effectiveness of coral reefs for coastal hazard risk reduction and adaptation. Nat Commun." (2014): 3794.
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- Matsumoto, T., et al. "Did the Submarine, Across-Arc Normal Fault System in the Southwest Ryukyu Arc Trigger the 1771 Tsunami? Field Evidence from Multibeam Survey and In-Situ Observation." Polish Journal of Environmental Studies 18.1 (2009).

Thank you for your time.

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