Assessing the use of tsunami simulations as a tool to predict source magnitudes and locations of paleoearthquakes in Chile

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Project Goals

A long-term goal of paleotsunami studies is the ability to predict paleo-earthquake parameters based on tsunami deposits found on land.

Using modern tsunami modeling techniques, I aim to determine if unknown rupture parameters from past earthquakes in Chile can be refined if on-land observations are used as a guide.

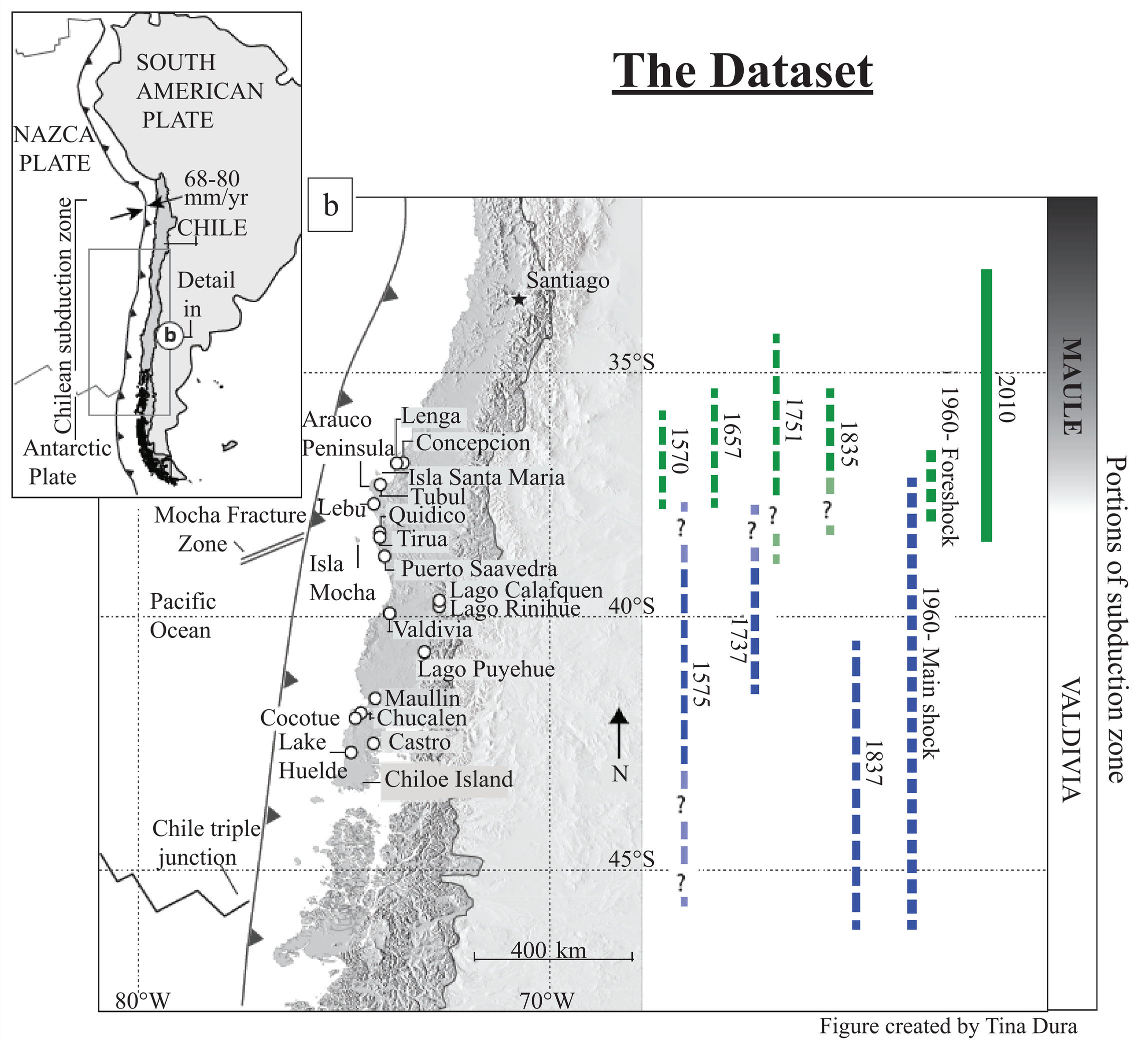
South-central Chile provides an exemplary location for testing methodologies because the historical record includes ~20 tsunamigenic earthquakes dating as far back as 1570 AD, and paleotsunami deposits are well-studied in the region (Lomnitz, 2004).

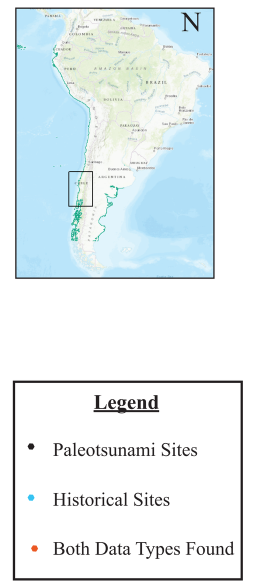
Main Objectives:

Model 9 hypothetical megathrust earthquakes that are based on actual past events (*Mw* 8.6, 8.8, and 9.0 at locations within the field area: N, C, and S sites).

Compare sites-- Is it possible to distinguish models within each site and latitudinally along the coast?

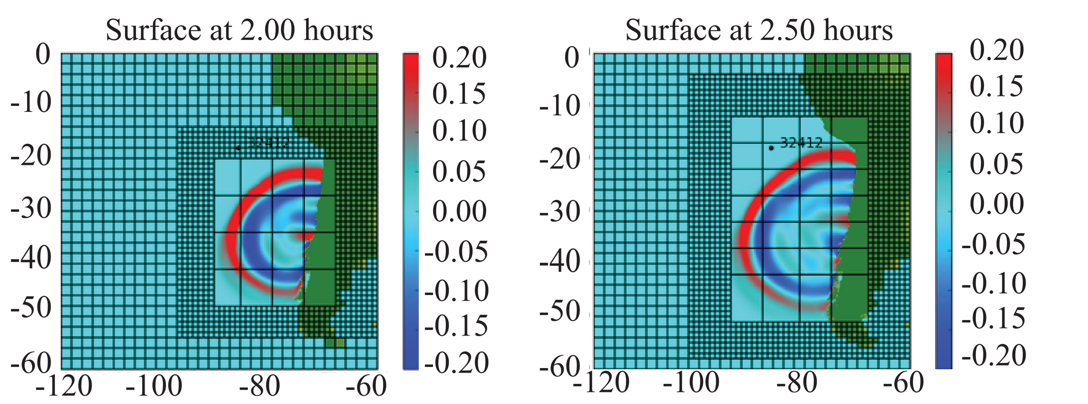
The Dataset





- 12 historical observations
- 24 paleotsunami locations
- 6 historical earthquakes recorded

Methodology



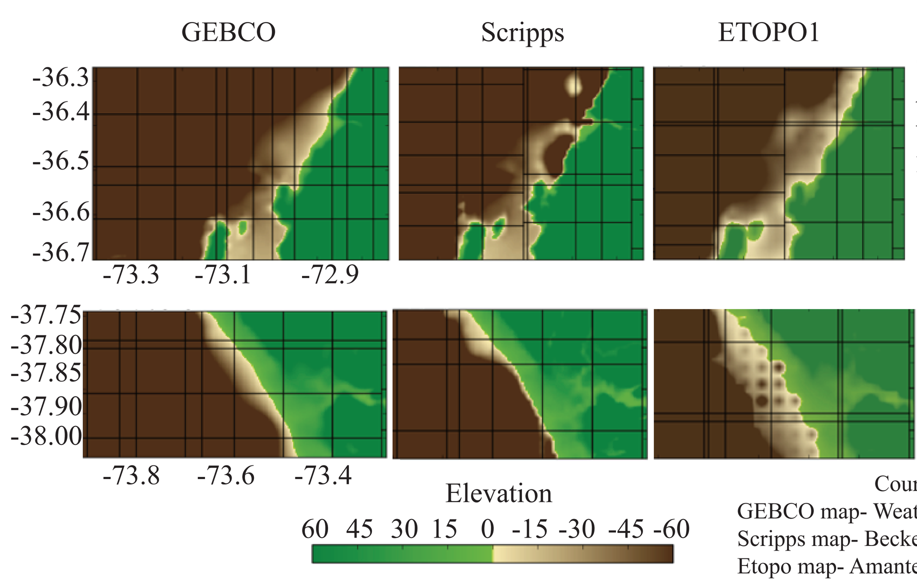
Using the tsunami model GeoClaw, tsunami runup and inundation can be produced onto coastal areas of south-central Chile. The above image is the wave propogation for the 2010 tsunami in Maule, Chile. GeoClaw is a finite-difference model based on nonlinear shallow-water wave equations (LeVeque et al., 2011).

Inputs include: the seismic motion initiating the tsunami and bathymetry with onshore topography. ▼

My Rupture Scenarios

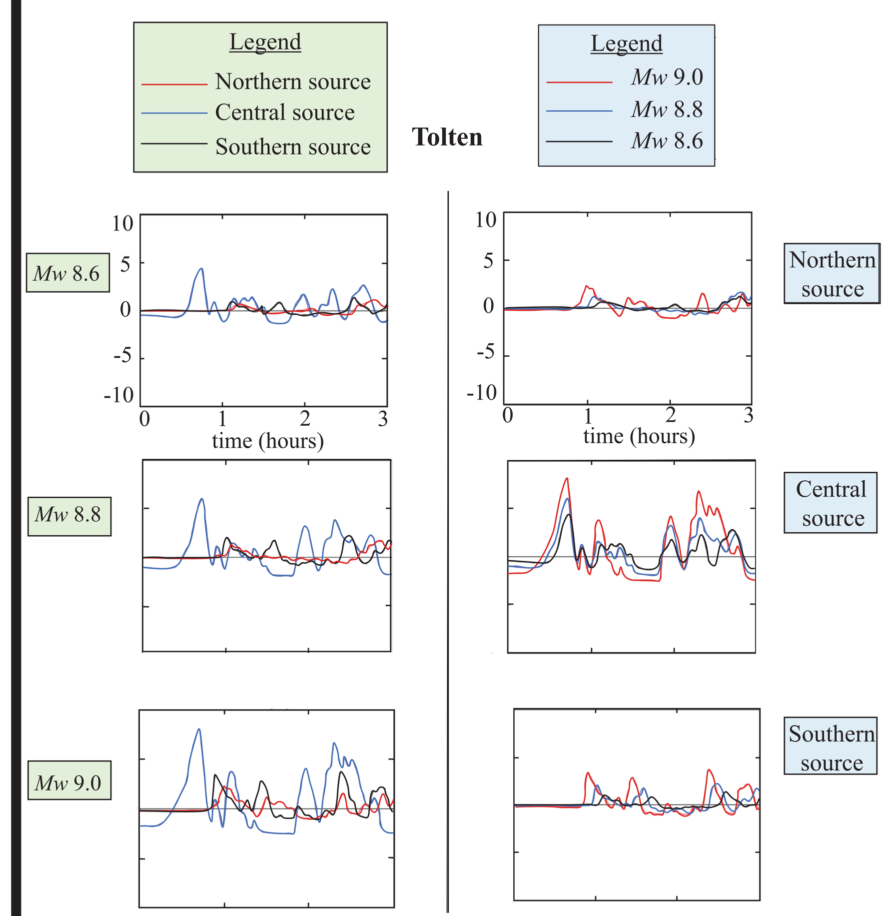
	Mw 8.6	*Mw* 8.8	*Mw* 9.0
Length (km)	400	500	600
Width (km)	110	120	130
Slip (m)	5	8	12

The Problem: Coarse Bathymetry



See examples of high-resolution inundation maps. ▶

Results



As expected, increasing earthquake magnitude produces larger tsunami wave heights, generally earlier arrival times and greater values of coseismic subsidence and uplift.

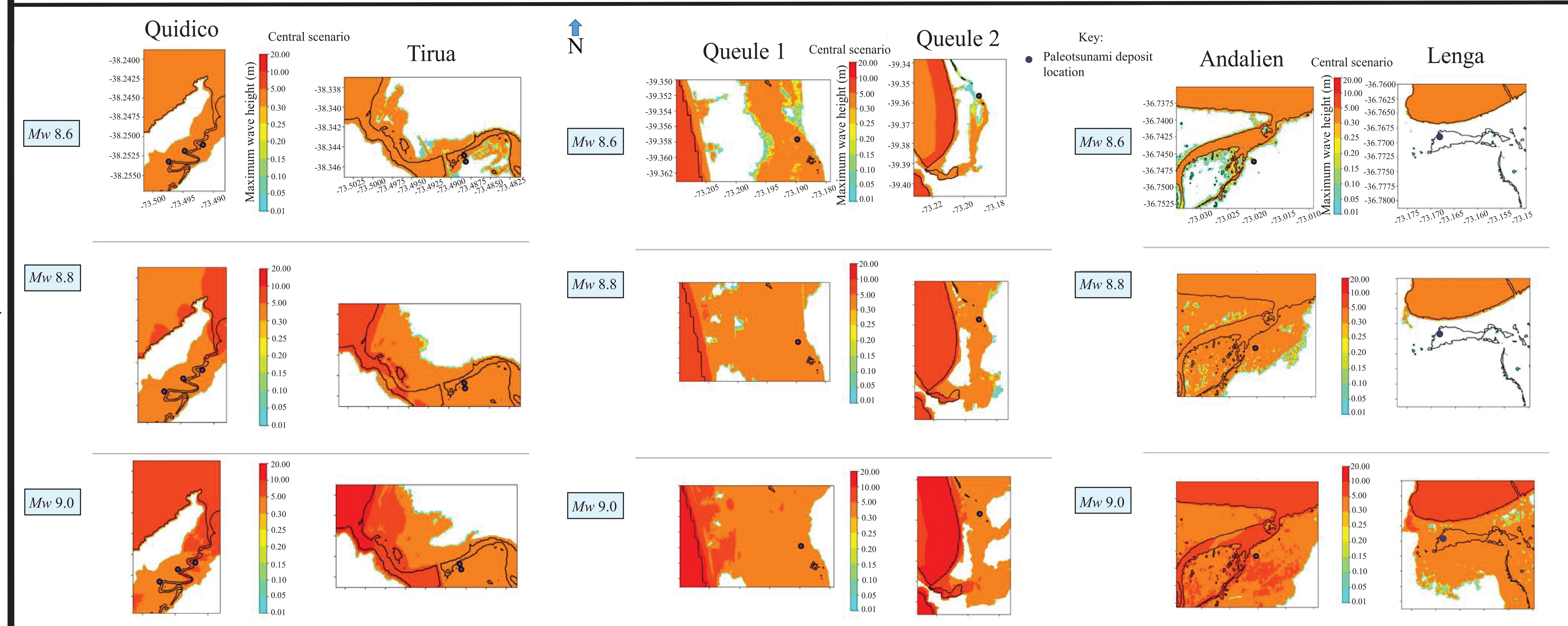
Simulations showed tsunamis from *Mw* 9.0 earthquakes can inundate coastal plains from nearfield sources, but not exclusively as *Mw* 8.6 and *Mw* 8.8 earthquake tsunamis can produce wave heights over 5 m at some sites.

At paleotsunami deposit locations, at least one of the three earthquake epicenter locations can be ruled out as a possible source area.

◀ e.g., see figure on left: earthquake from a central source area if wave heights observed are over 5 m.

Tsunami sensitivities such as wave heights or inundation maps are used to better understand source characteristics, such as magnitude.

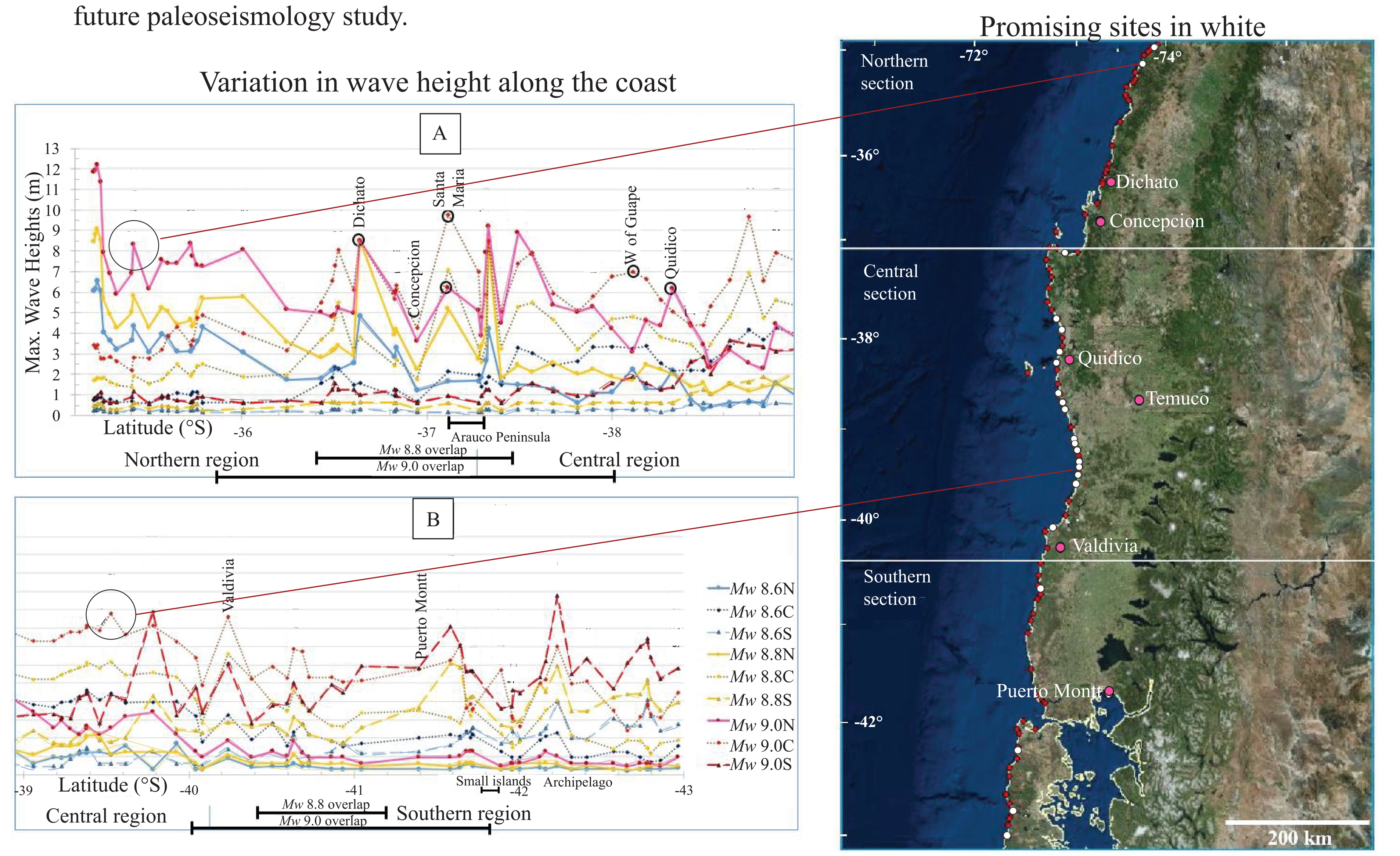
▼ Inundation maps provided below are useful for distinguishing models at a particular site.



Promising Sites

Definition: A site onshore that magnifies differences between tsunami wave heights AND a site that is capable of tsunami inundation.

These sites are promising to look for past records to determine pre-instrumental earthquake size and location for future paleoseismology study.



Between all *Mw* 8.6, 8.8, 9.0 scenarios, each section shows distinguishable wave heights. Small circles indicate anomalous tsunami wave heights typically due to shoreline geometry amplifying waves.

Conclusions

Tsunami simulations can be used as a tool to determine poorly constrained characteristics of pre-instrumental earthquakes, as they are capable of matching historical observations and paleotsunami deposit records.

My nine scenarios showed that more extensive comparisons of possible paleoearthquake parameters with on-land observations is an effective and promising approach to defining characteristics of historical and prehistoric events.

What Lies in the Future?

Big Picture Question: What are possible source magnitudes and locations of pre-instrumental earthquakes in South-central Chile?

Going forward, tsunami modelers are able to:

- Constrain best-fit characteristics (i.e., source magnitudes and locations) of pre-instrumental earthquakes from tsunami simulations
- Produce simulations for hundreds of earthquakes to calibrate with paleotsunami deposits of a specific site
- Associate location with a possible range of source earthquake magnitudes (e.g., *Mw* 8.0-8.5) using tsunami simulations and historical observation data
- Associate source parameters from prehistoric earthquakes at a particular location with on-land observations

References

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