EGU General Assembly 2024

EGU ANNUAL MEETING 2024, Vienna, Austria

EGU24-479 - Session NH5.1 -Tsunamis: modelling, hazard assessment, forecasting and warning

Sharing is encouraged

Improving Rapid Earthquake Characterization for Tsunami Early Warning for Aotearoa New Zealand and the Southwest Pacific

Luce Lacoua, Bill Fry, Andrew Gorman, Yi-Wun Mika Liao, Laetitia Foundotos, Chris Zweck, and Anthony Jamelot, 15th March 2024

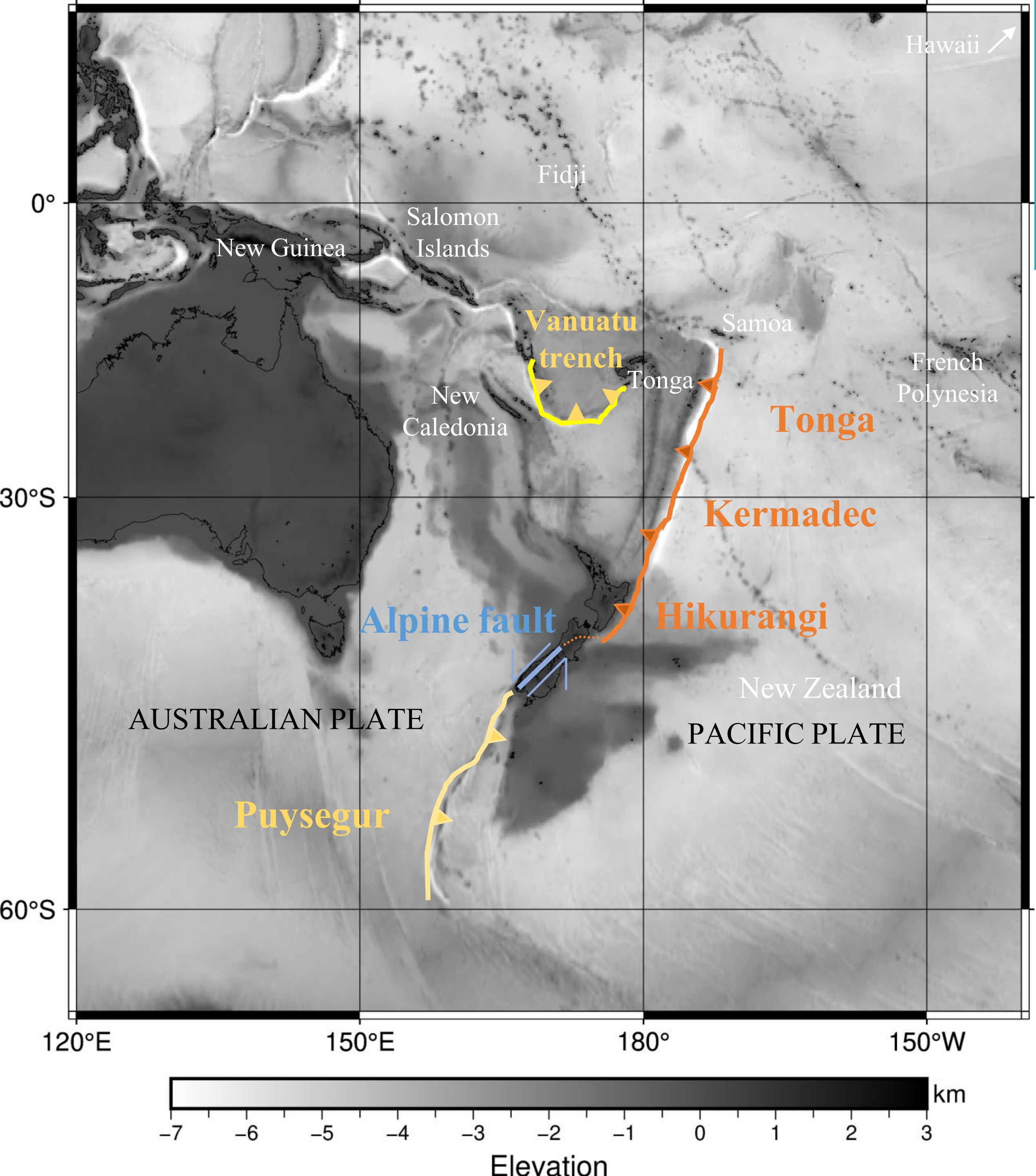
In collaboration with:

University of Otago
ŌTĀKOU WHAKAIHU WAKA

GNS SCIENCE
TE PŪ AO

cea

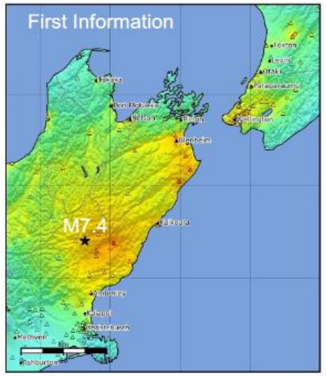
The southwest Pacific, vulnerable to tsunamis

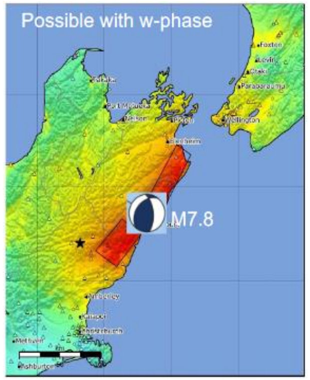


- Subduction zones Hikurangi-Kermadec-Tonga
- Earthquakes of magnitude > 6 recorded
- Potential tsunamigenic earthquake = big magnitude + big vertical displacement
- Many cities by coastlines

A Tsunami Early Warning (TEW) workflow

1. Earthquake characterization





TARGET TIME
15-20 min

t = 0 min — An earthquake is detected in the Pacific Ocean

t = 5 min — Hypocenter & magnitude

15-20 min — Centroid, magnitude & focal mechanism

Te Whakaahuatanga Tere o ngā Rū Whenua me ngā Parawhenua
R-CET Rapid Characterisation of Earthquakes and Tsunamis
A GNS Science Led Research Programme

2. Tsunami forecast

Multiple scenarios : ensemble forecast

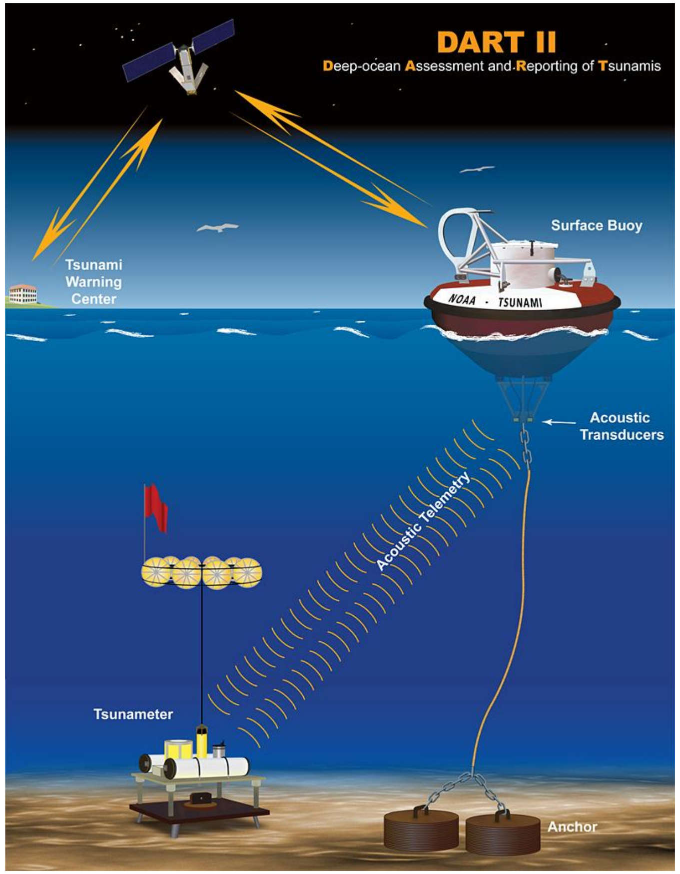
t= 25 min — Tsunami simulations from the different scenarios

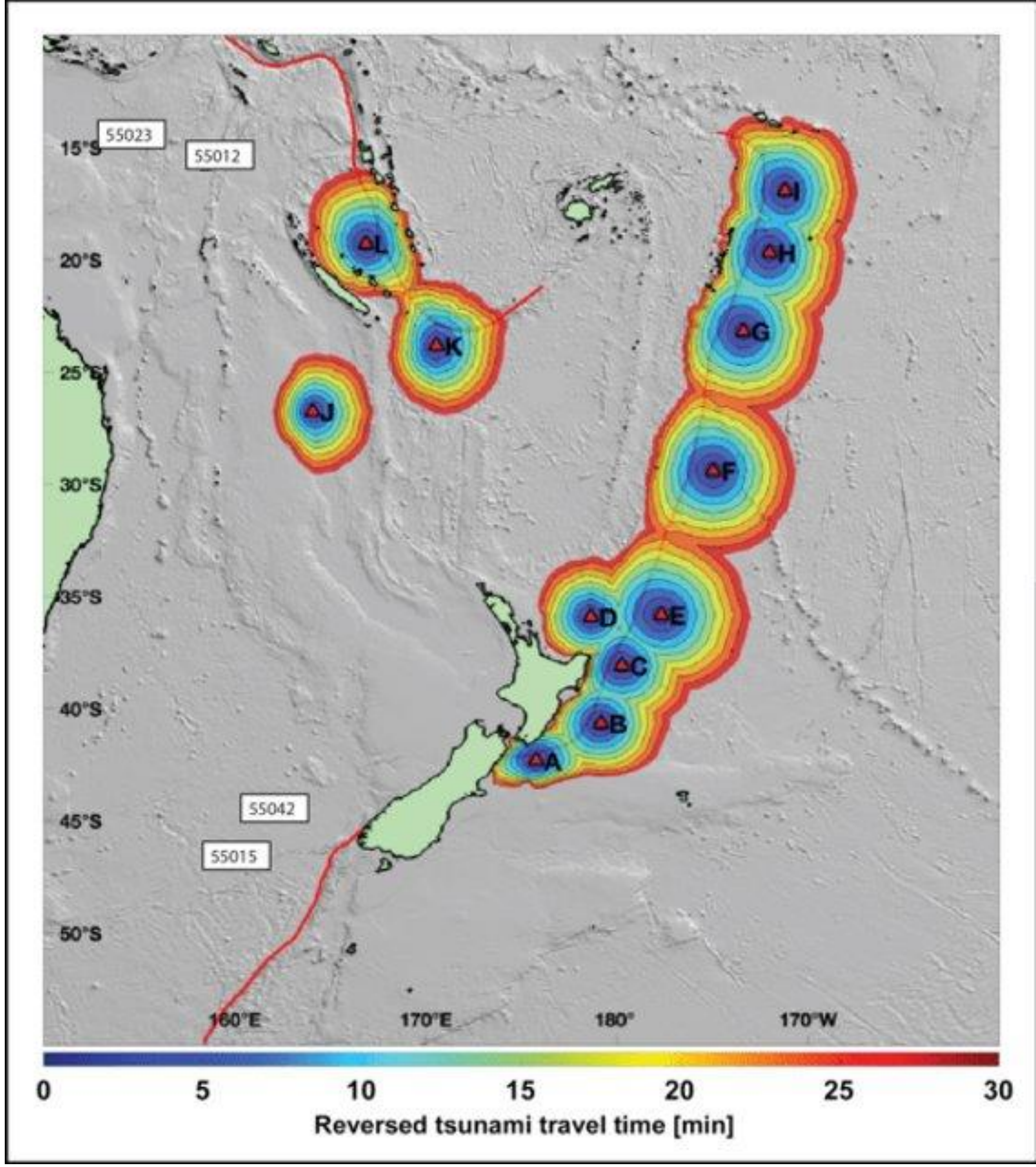
t= 30 min — Tsunami forecast sent to emergency management institution

Emergency response

What do we need to start a tsunami forecast?

1. **DART data**
    - Measure the pressure of the water column
    - Strong change of pressure = TSUNAMI
2. **Rapid earthquake characterization**





Fry, B., S.-J. McCurrach, K. Gledhill, W. Power, M. Williams, M. Angove, D. Arcas, and C. Moore (2020), Sensor network warns of stealth tsunamis

What do we need to start a tsunami forecast?

MORE PRECISE AND FASTER CHARACTERIZATION OF EARTHQUAKES

1. **DART warnings**

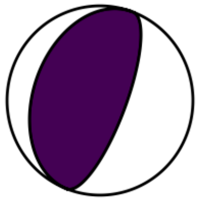
2. **Rapid earthquake characterization**

CURRENT EARTHQUAKE CHARACTERIZATION FOR TEW
From Strong Motions, GNSS, SMART cable

- Local magnitude
- Epicenter

W PHASE CHARACTERIZATION OF AN EARTHQUAKE

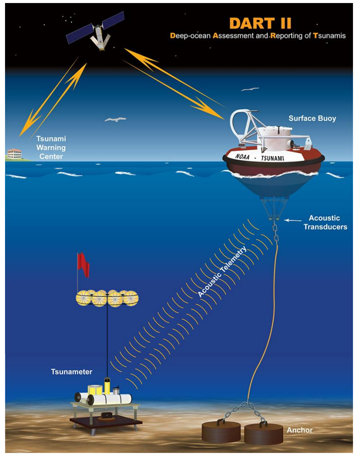
- Moment magnitude Mw
- Centroid
- Focal mechanism

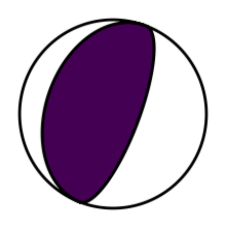


What do we need for a tsunami forecast?

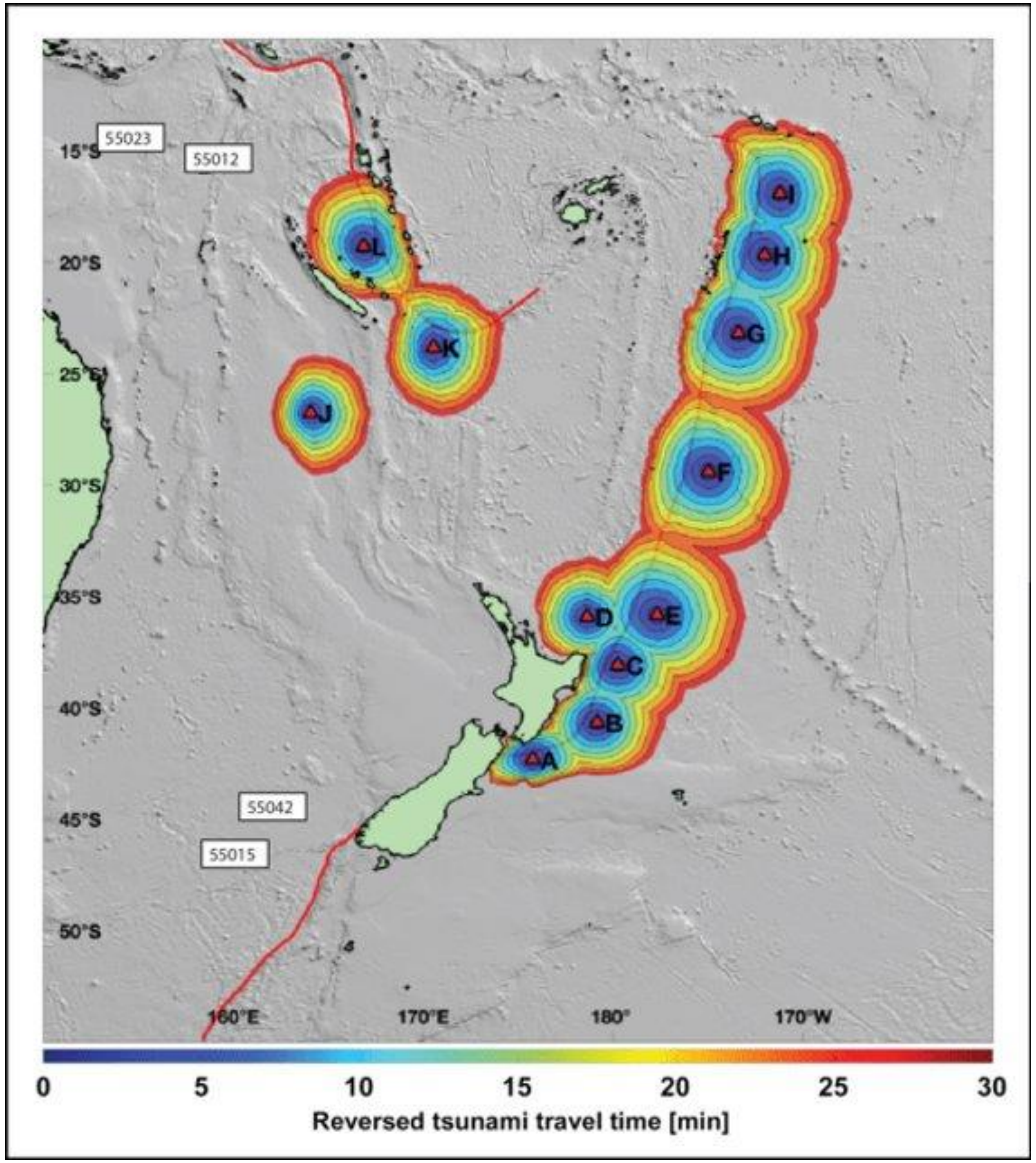
To start the tsunami forecast simulations, we can use:

2 DART warnings OR **1 DART warning + W-phase solution**





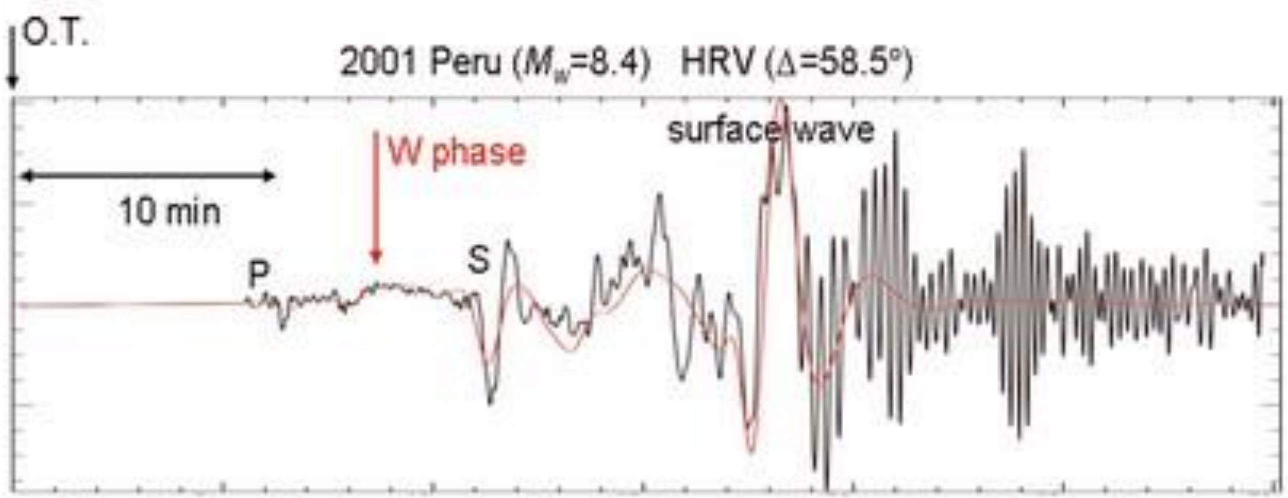
FASTER!



Fry, B., S.-J. McCurrach, K. Gledhill, W. Power, M. Williams, M. Angove, D. Arcas, and C. Moore (2020), Sensor network warns of stealth tsunamis

The W-phase

- Arrives between the P and S arrival → rapid
- Long period → energy propagate through the mantle
- Very low amplitude → does not saturate for strong magnitude



W phase from the 2001 Peruvian earthquake (Mw = 8.4) recorded at HRV, and the synthetic W phase computed by mode summation using the Global CMT solution.

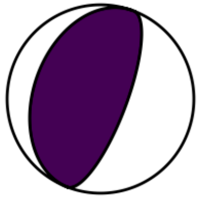
From Kanamori, H., & Rivera, L. (2008). Source inversion of W phase: Speeding up seismic tsunami warning. Geophysical Journal International

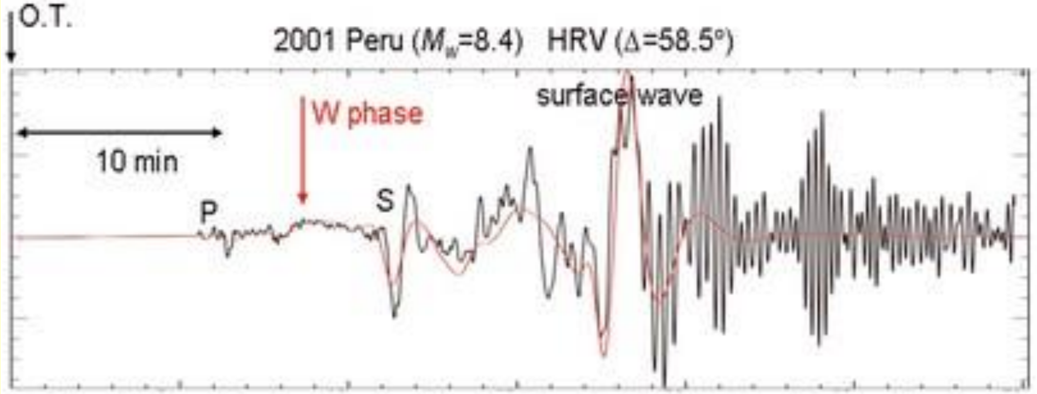
The W-phase

Already used on a **global** scale for large events.

CHALLENGES OF A **REGIONAL** W PHASE FOR THE SOUTHEST PACIFIC :

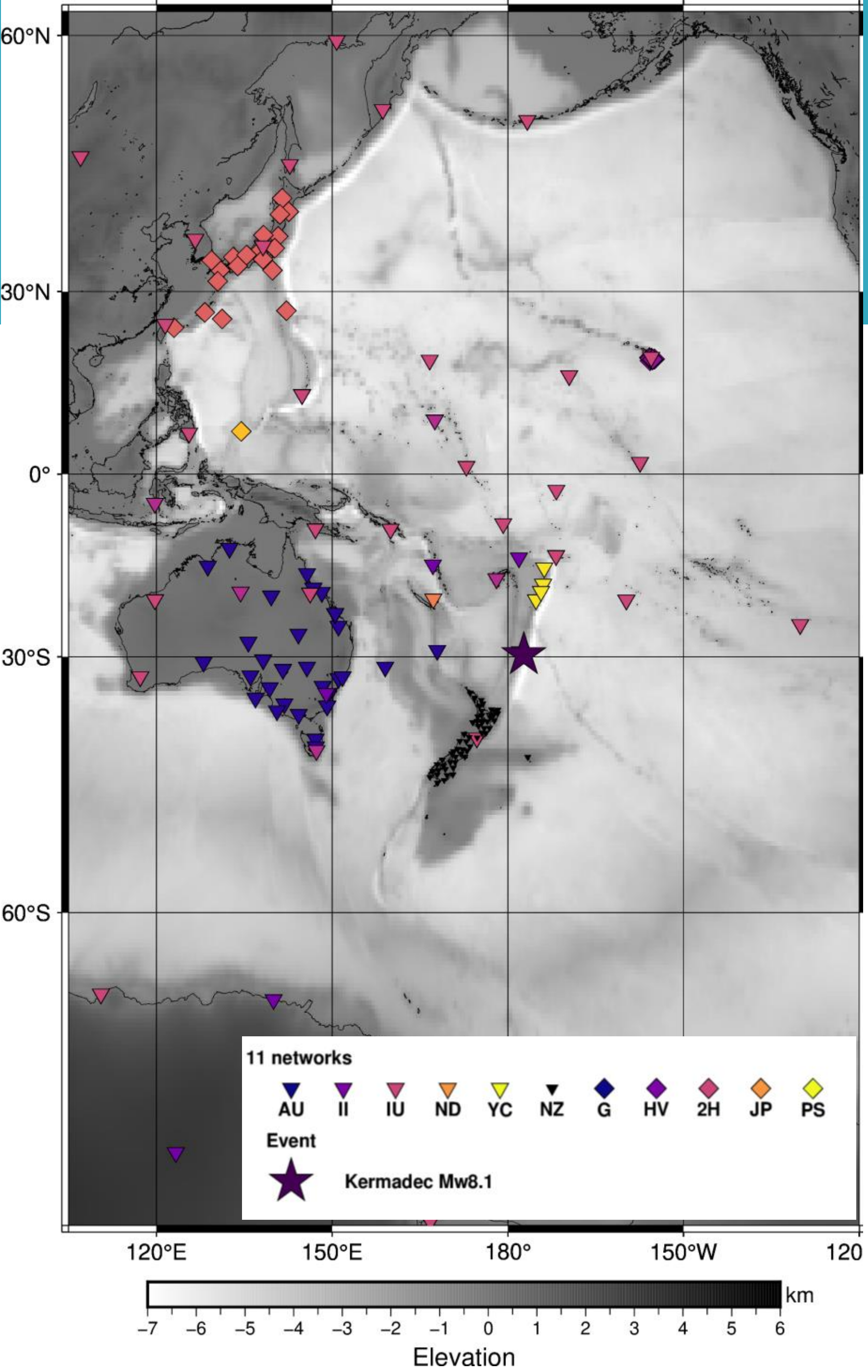
- Regional scale : smaller distances → what is the minimal source – station distance ? What is the minimal magnitude ?
- Do we have a good enough station coverage ?





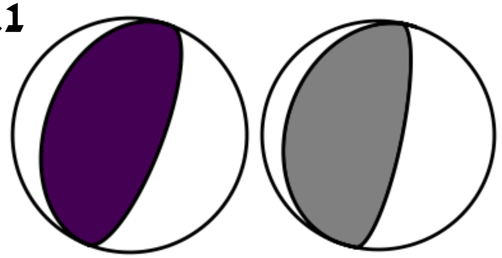
W phase from the 2001 Peruvian earthquake (Mw = 8.4) recorded at HRV, and the synthetic W phase computed by mode summation using the Global CMT solution.

An example on the recent event of Kermadec Mw8.1, March 2021



Kermadec Mw= 8.1

Mww = 7.92



Tools to quantify our results:

- Magnitudes difference
- Kagan angle
- Centroid difference

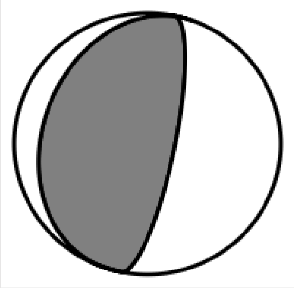
What next ?

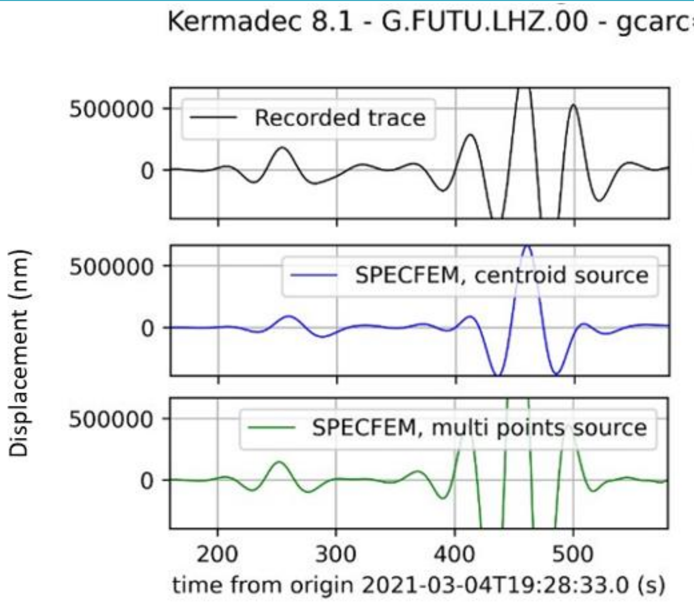
To estimate the limits of a regional W-phase solution, we will use a catalogue of synthetic earthquakes adapted to the Southwest Pacific context

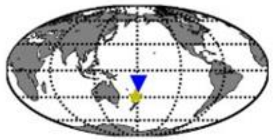
What source complexity is captured by the W-phase ?

SIMPLE SOURCE

CENTROID SOURCE
From Global CMT

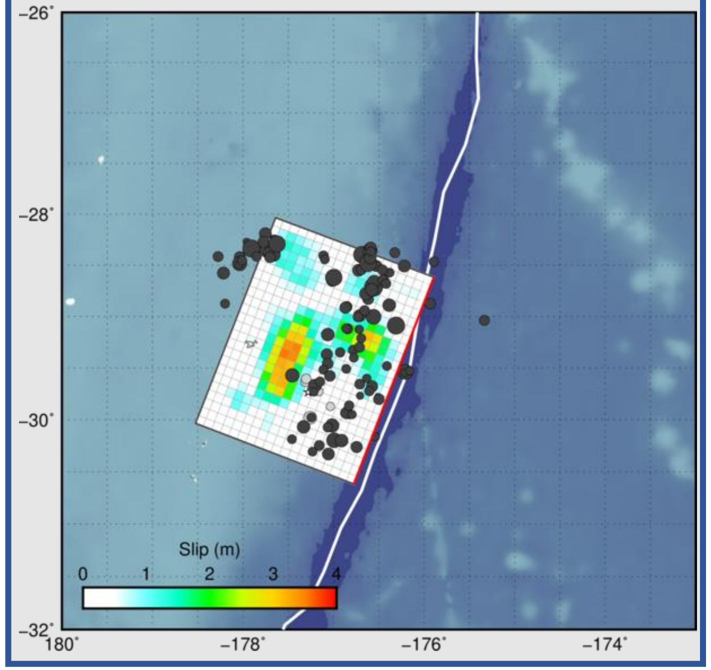






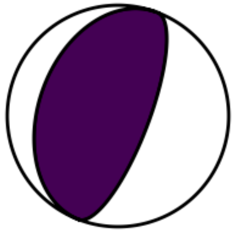
COMPLEX SOURCE

MULTIPLE POINTS (TILED) SOURCE
From USGS finite fault model, 283 patches



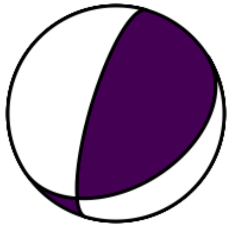
W-phase solution

Mww = 8.08



W-phase solution

Mww = 8.04



Take home messages

- The W-phase characterization allow us to have a faster and more precise characterization of potential tsunamigenic earthquakes

- A regional W-phase solution brings challenges in terms of **minimum magnitude, smallest source-station distance** we can get a robust W-phase solution for (= how soon)

- By testing a catalogue of synthetic events, we will be able to assess the limits of a regional W-phase

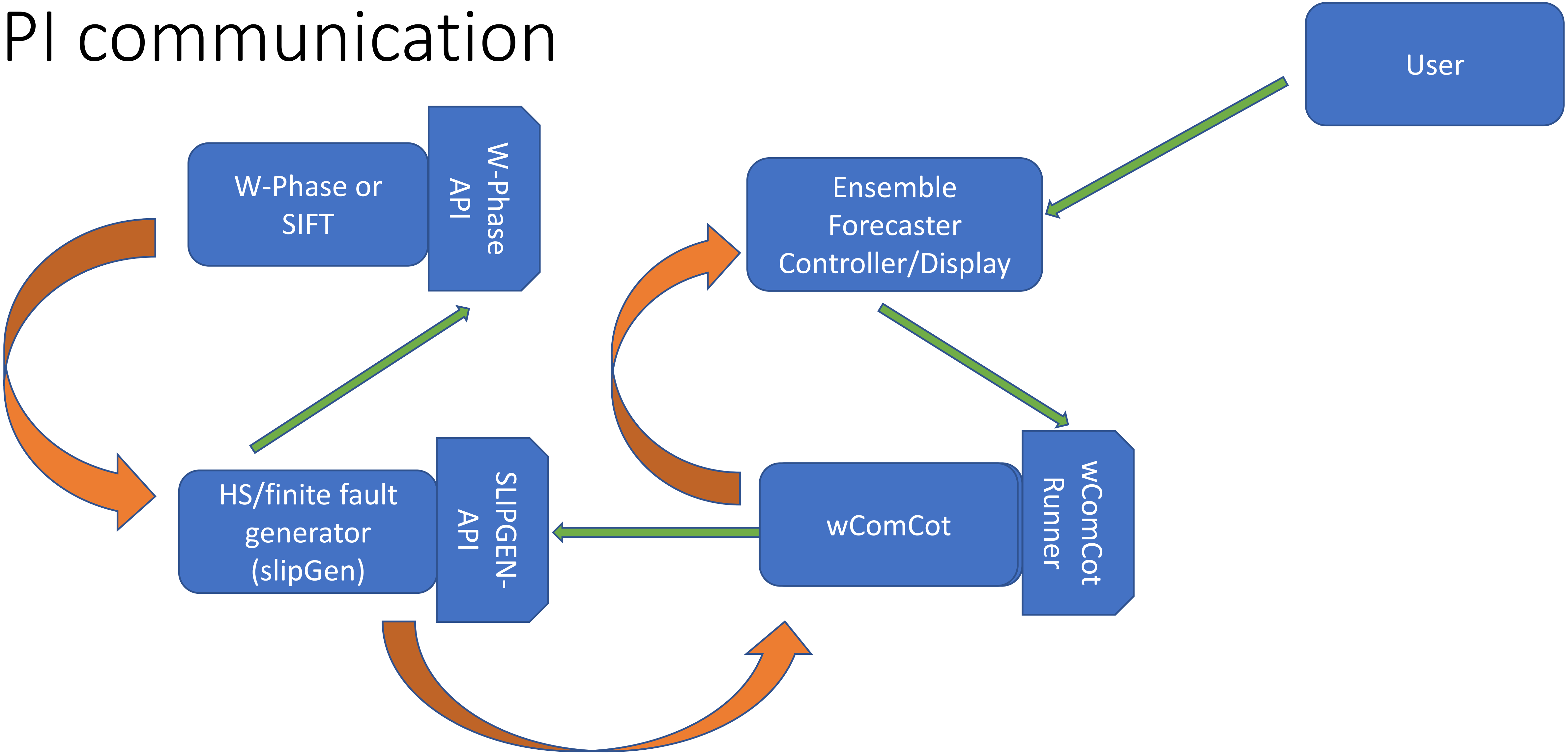
Thank you!
Any suggestions or questions?

luce.lacoua@postgrad.otago.ac.nz

For more information about time dependent forecast and emergency response, go check Emeline's poster tomorrow !

X4.70 – EGU24-799 – NH5.1: Exploration of a Time-dependent Forecast for Tsunami in New Zealand, *Emeline Wavelet et al.*

Containerized software system with API communication

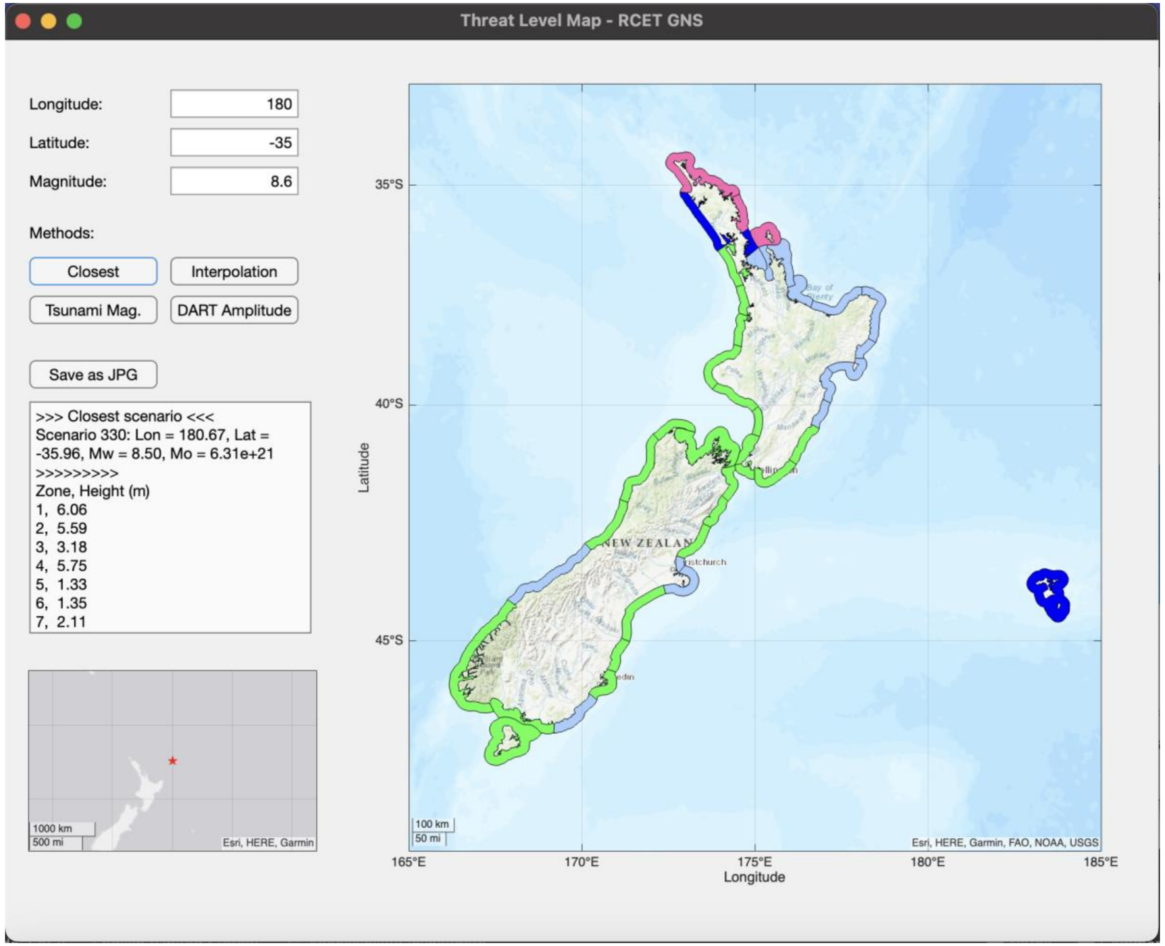


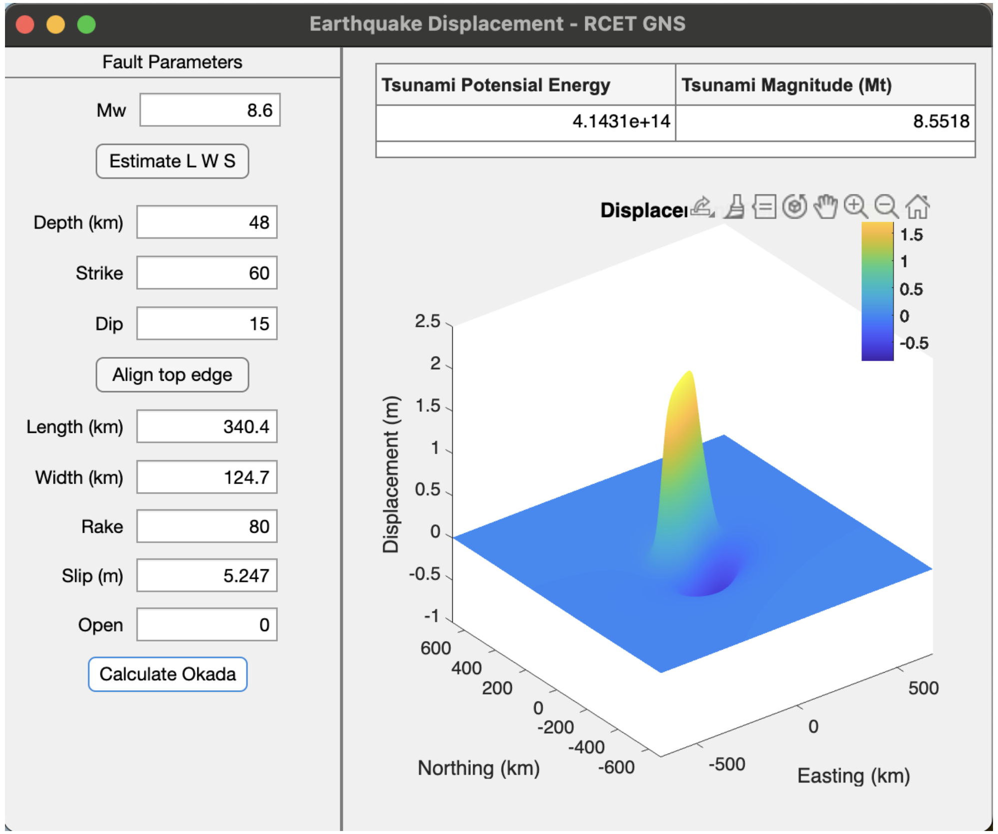
Mww role in threat maps

Methods:

1. Closest scenario – current NGMC practice
2. Interpolation based on Mw and location
3. Interpolation based on Mt and location

Tsunami magnitude calculator based on earthquake fault parameters and Okada formula





Action map VS forecast map

Figure 4: Initial Advice Land Threat Map issued for the Kermadec Island earthquake (2) at 0845 am on 5 March 2021.

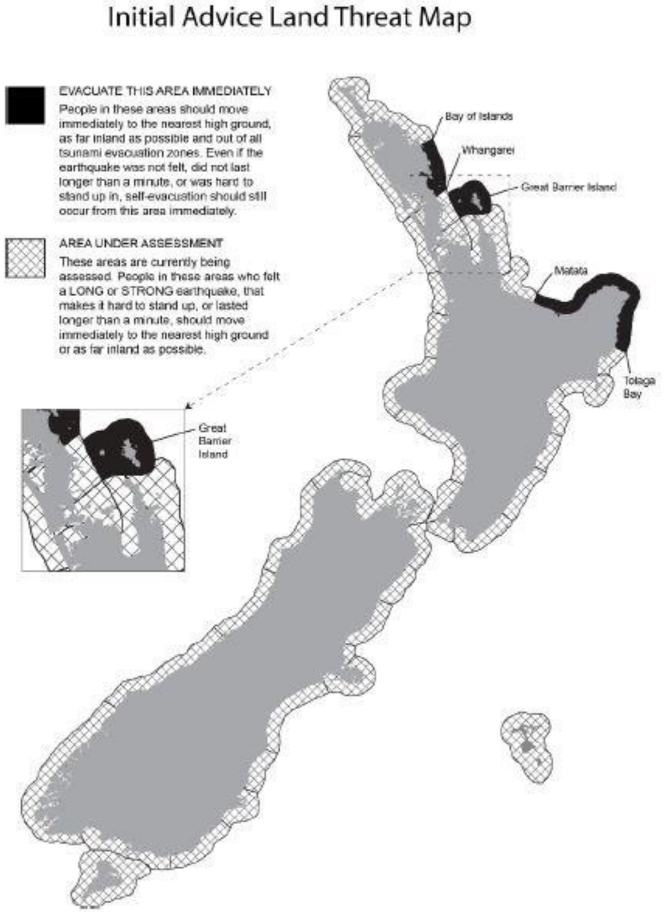
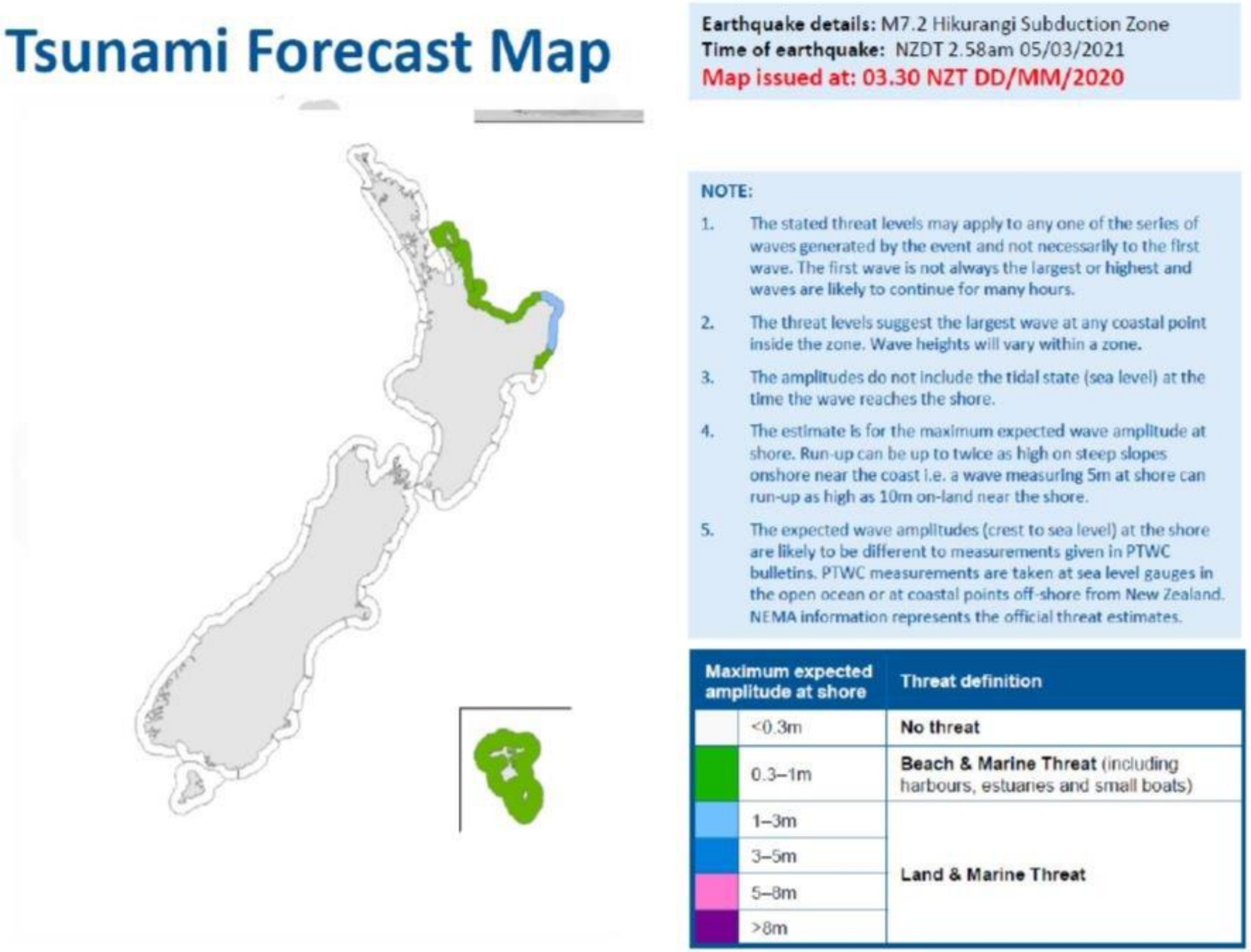
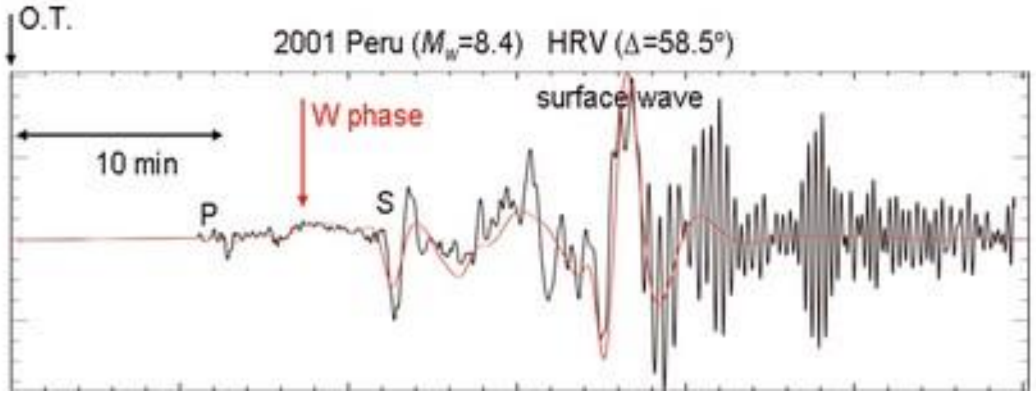


Figure 3: Tsunami Forecast Map issued for the Hikurangi earthquake (Event 1) at 0330 AM on 5 March 2021.



W-phase

W phase can be interpreted as superposition of the fundamental mode, first, second and third overtones of spheroidal modes at long period (i.e. Rayleigh waves) indicated by the two horizontal red lines in Fig. 2 which displays the group velocity dispersion curves of these modes computed for the Preliminary Reference Earth Model (PREM, Dziewonski & Anderson 1981). The group velocity of W phase ranges from 4.5 to 9 kms−1 over a period range from 100 to 1000 s



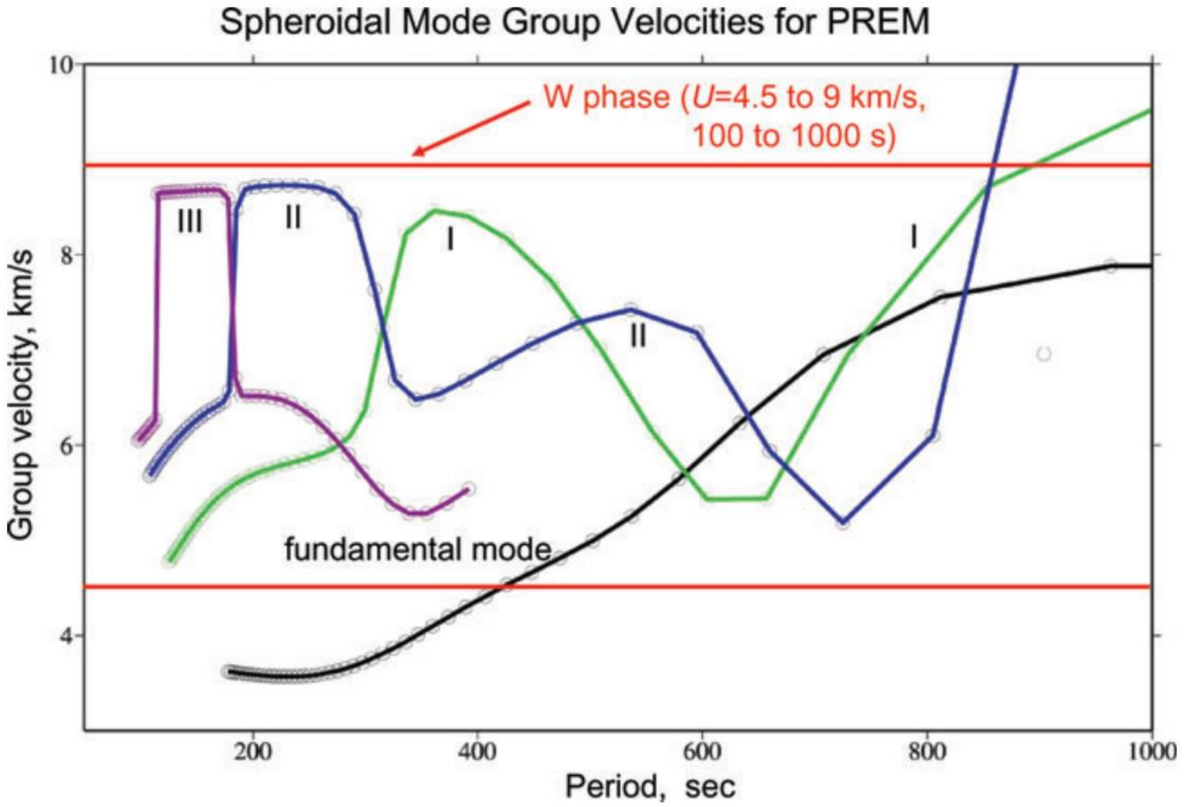
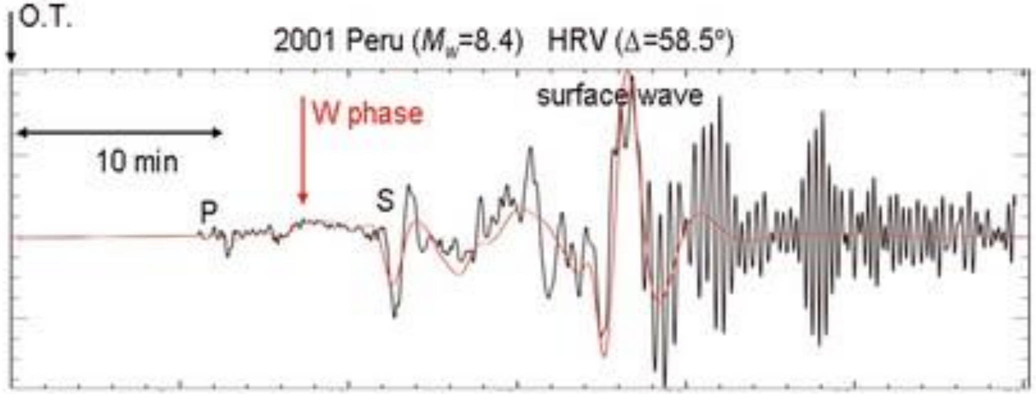


Figure 2. Group velocity dispersion curves of spheroidal modes computed for PREM. Dispersion curves for the fundamental mode (black), the first overtone (green), the second overtone (blue) and the third overtone (magenta) are shown. The horizontal red lines bound the group velocity of W phase.

From Kanamori, H. (1993). W phase. Geophysical Research Letters

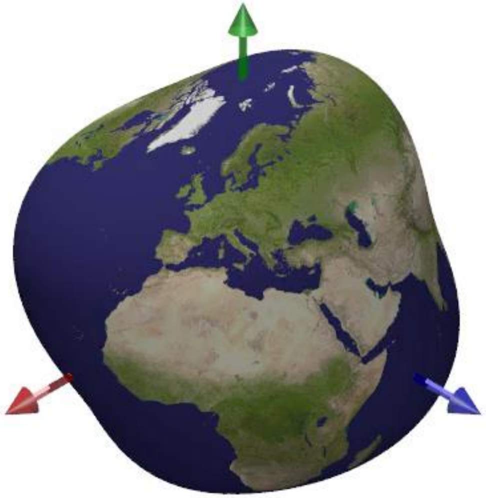
The W-phase

- Arrives between the P and S arrival → rapid
- Long period → energy propagate through the mantle
- Very low amplitude → does not saturate for strong magnitude



W phase from the 2001 Peruvian earthquake (Mw = 8.4) recorded at HRV, and the synthetic W phase computed by mode summation using the Global CMT solution.

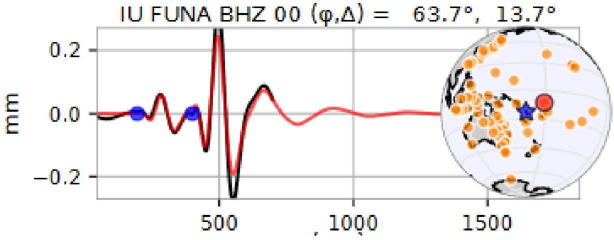
From Kanamori, H., & Rivera, L. (2008). Source inversion of W phase: Speeding up seismic tsunami warning. Geophysical Journal International



- Centroid location
- Magnitude
- Moment tensor

Green's functions →

← Source inversion



From Anthony Jamelot (LDG, CEA)