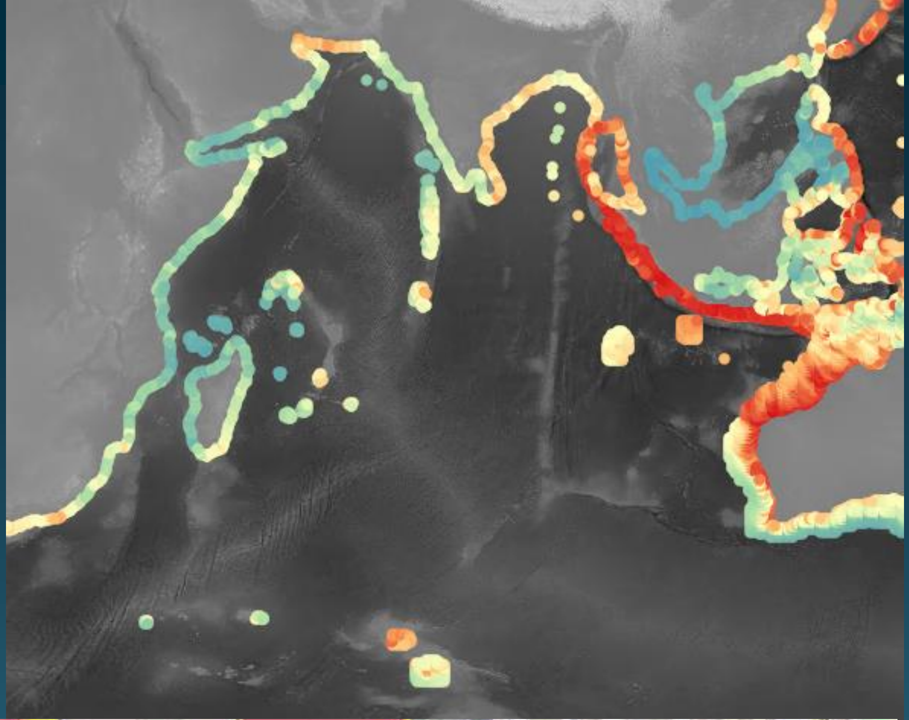
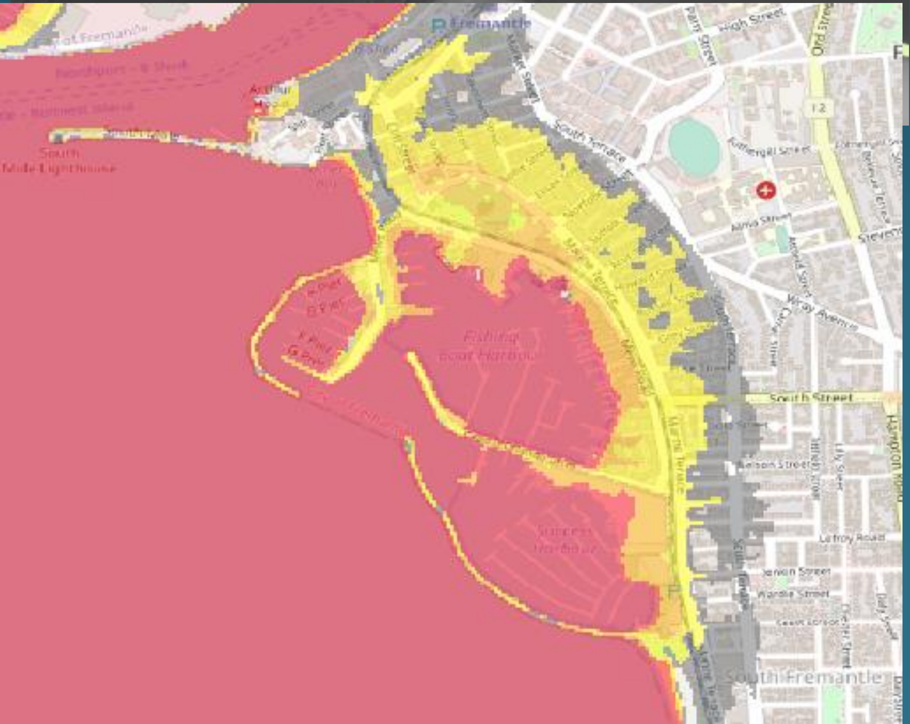
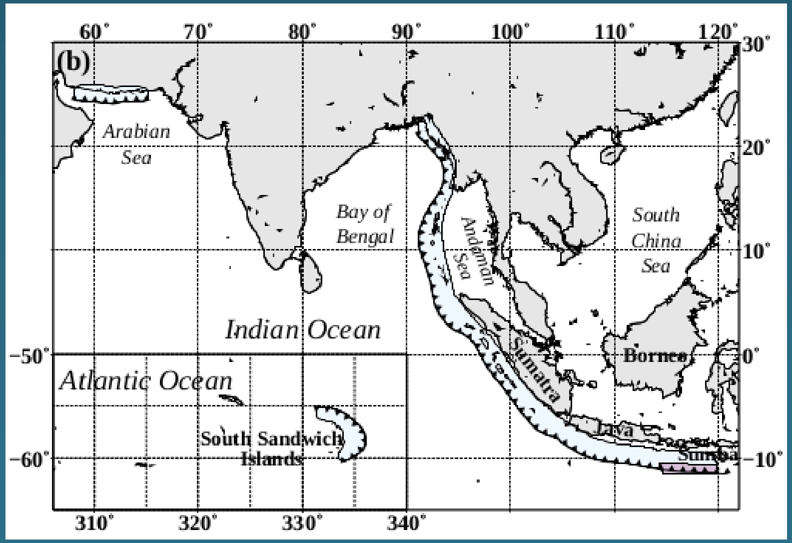
Australian Government
Geoscience Australia

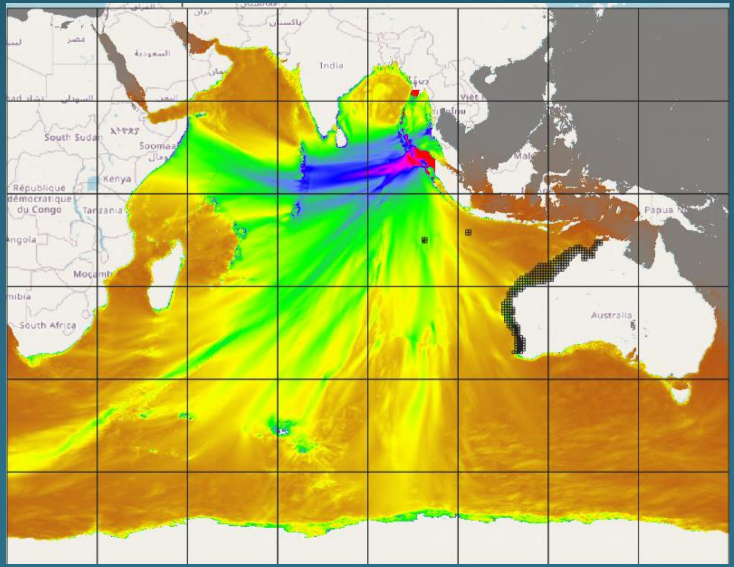


Probabilistic Tsunami Hazard Assessment for the Indian Ocean Region

Gareth Davies | Geoscience Australia







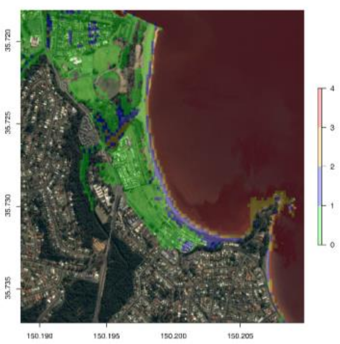
Earth sciences for Australia's future | ga.gov.au

What is Probabilistic Tsunami Hazard Assessment (PTHA)?

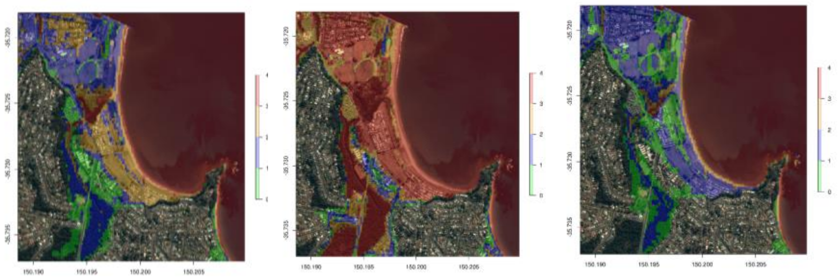
Approaches to tsunami inundation hazard assessment

Deterministic

- **Single scenario**

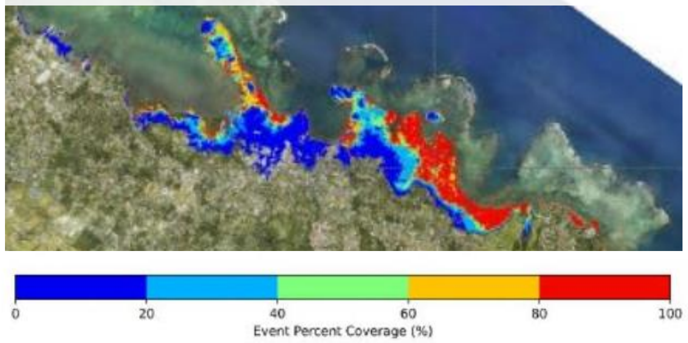


- **Set of scenarios**



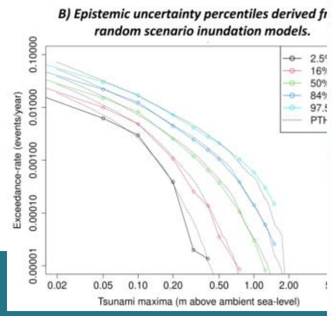
- **Set of scenarios informed by probabilistic analyses**
  - **Nominal average return period**, e.g.
    - 1/2500 wave height exceedance-rate at an offshore site
  - **Epistemic uncertainty**, e.g.
    - Likelihood that scenario is even possible (given M_w etc.)

7 scenarios with 1/1000 year offshore wave height: Giblin et al. 2022

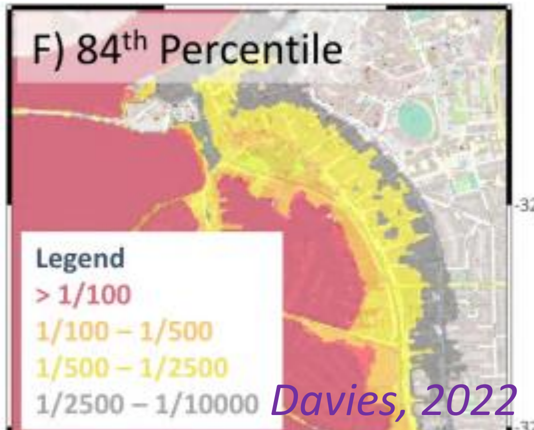


Probabilistic

- **Probabilistic tsunami inundation hazard assessment**
  - Integration over model of *all plausible scenarios & frequencies*
    - Tsunami intensity vs exceedance-rate [everywhere]
    - With epistemic uncertainty
  - Common for <u>offshore PTHA</u> from earthquakes
  - Increasingly possible for inundation hazard



Inundation events/year

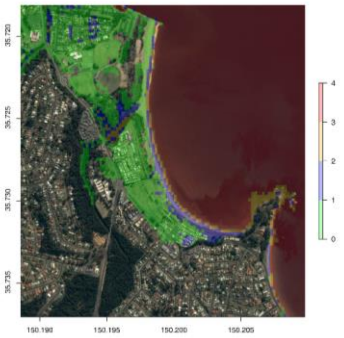


Davies, 2022

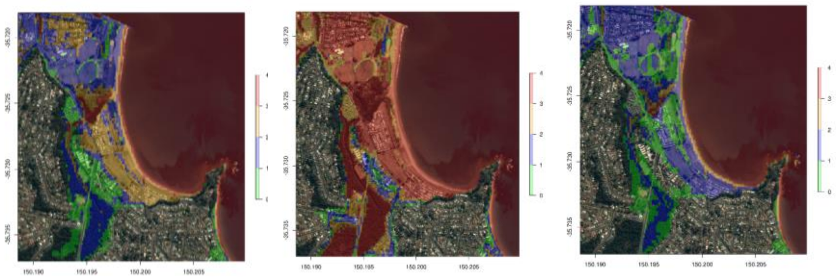
Approaches to tsunami inundation hazard assessment

Deterministic

- **Single scenario**



- **Set of scenarios**



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Probabilistic

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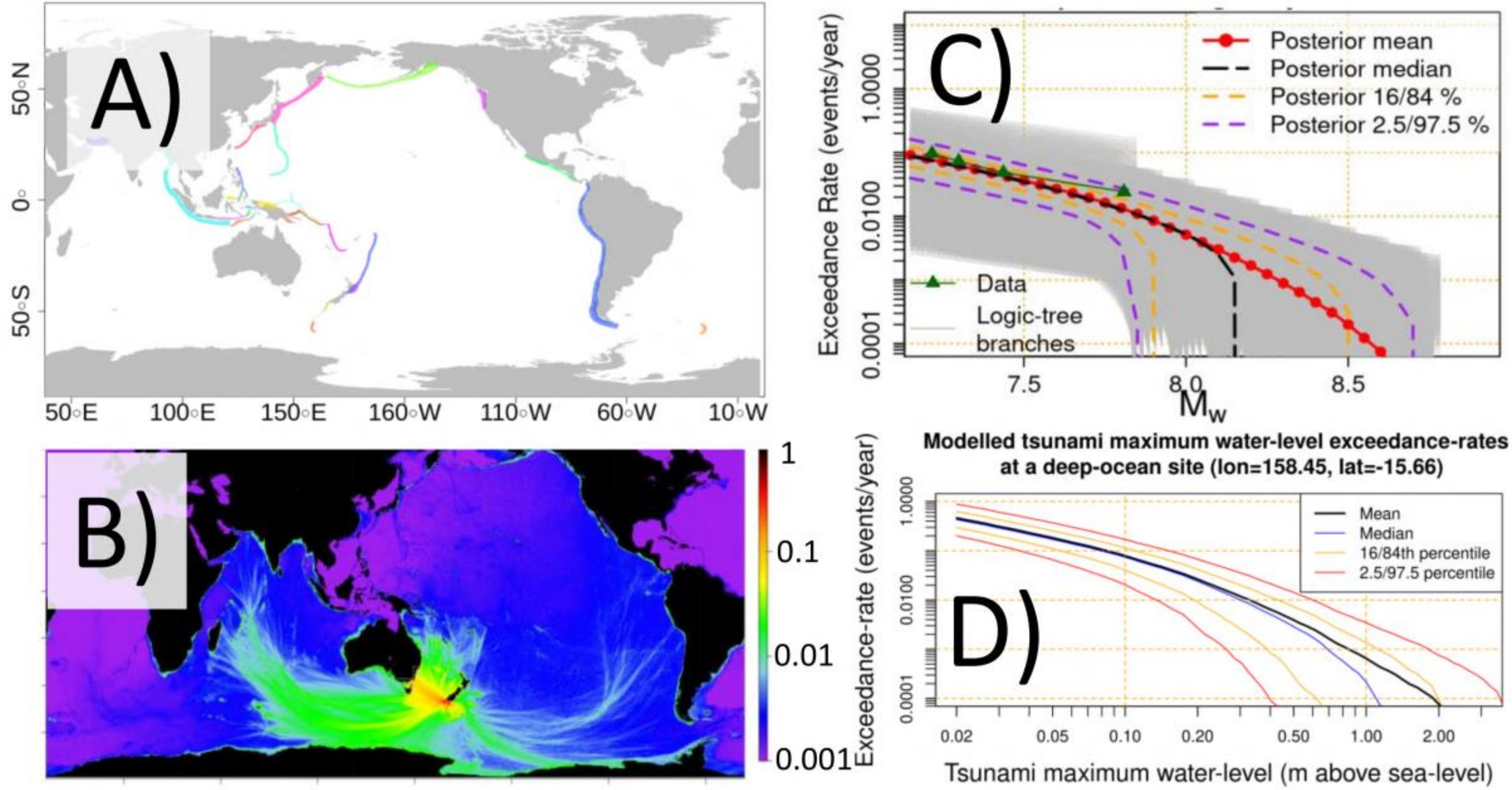
  - Increasingly possible for inundation hazard

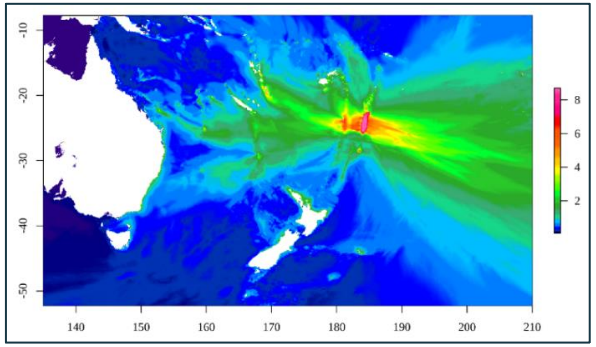
Leverage an Offshore Probabilistic Tsunami Hazard Assessment?

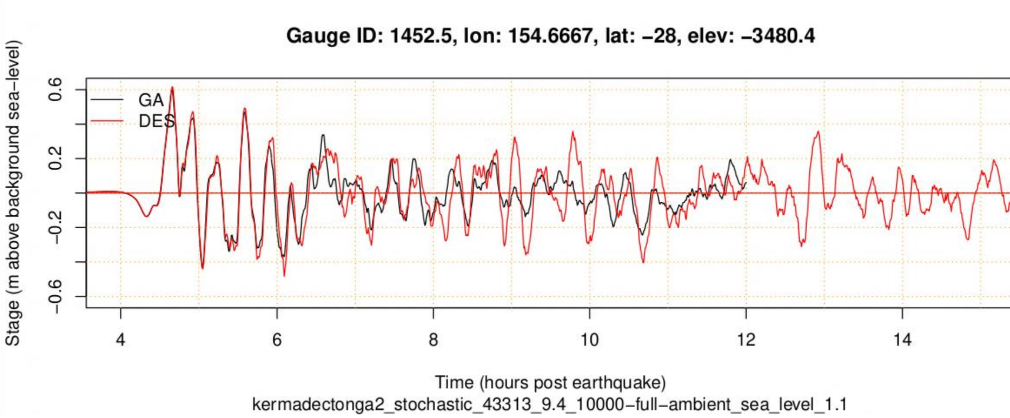
Offshore Probabilistic Tsunami Hazard Assessment: The basic idea



Offshore Probabilistic Tsunami Hazard Assessment: The basic idea

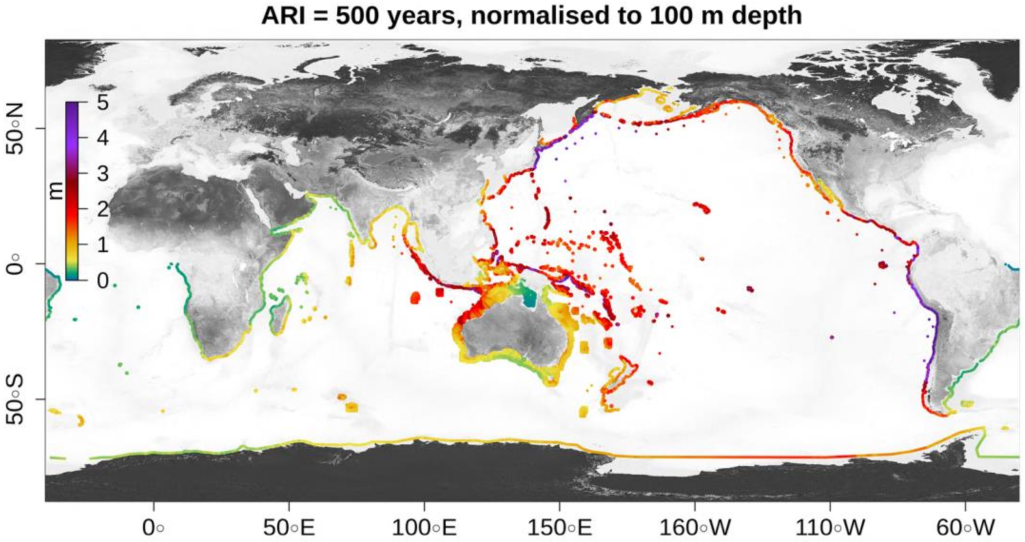
- *Earthquake scenario database for forcing **your own site-specific inundation model***
  - *Tsunami initial conditions*
  - *Linear wave time series*

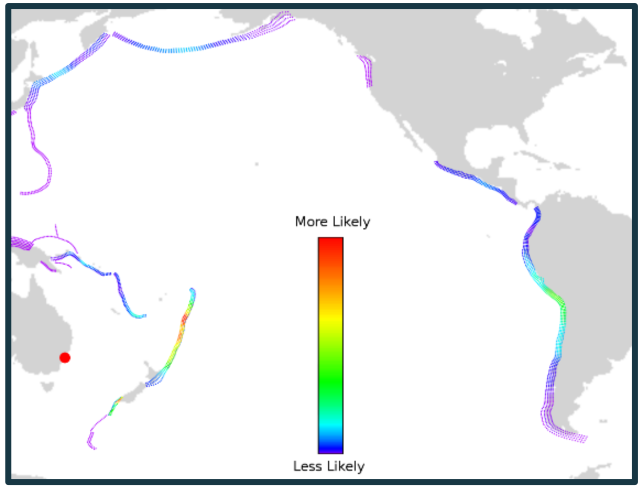




- *Exceedance-rates with epistemic uncertainty*
  - *Mw*
  - *Wave size*

- *Hazard deaggregation*



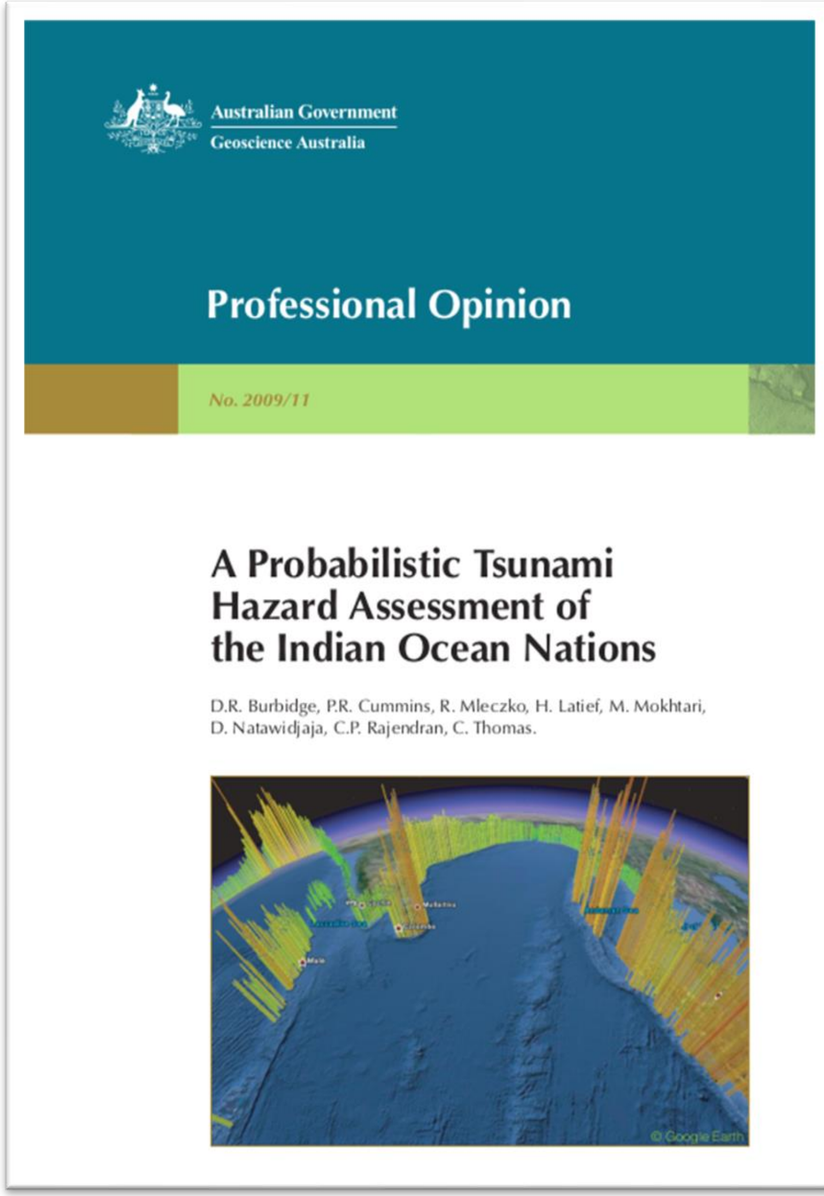


https://github.com/GeoscienceAustralia/ptha/tree/master/ptha_access

Offshore PTHAs for the Indian Ocean Region

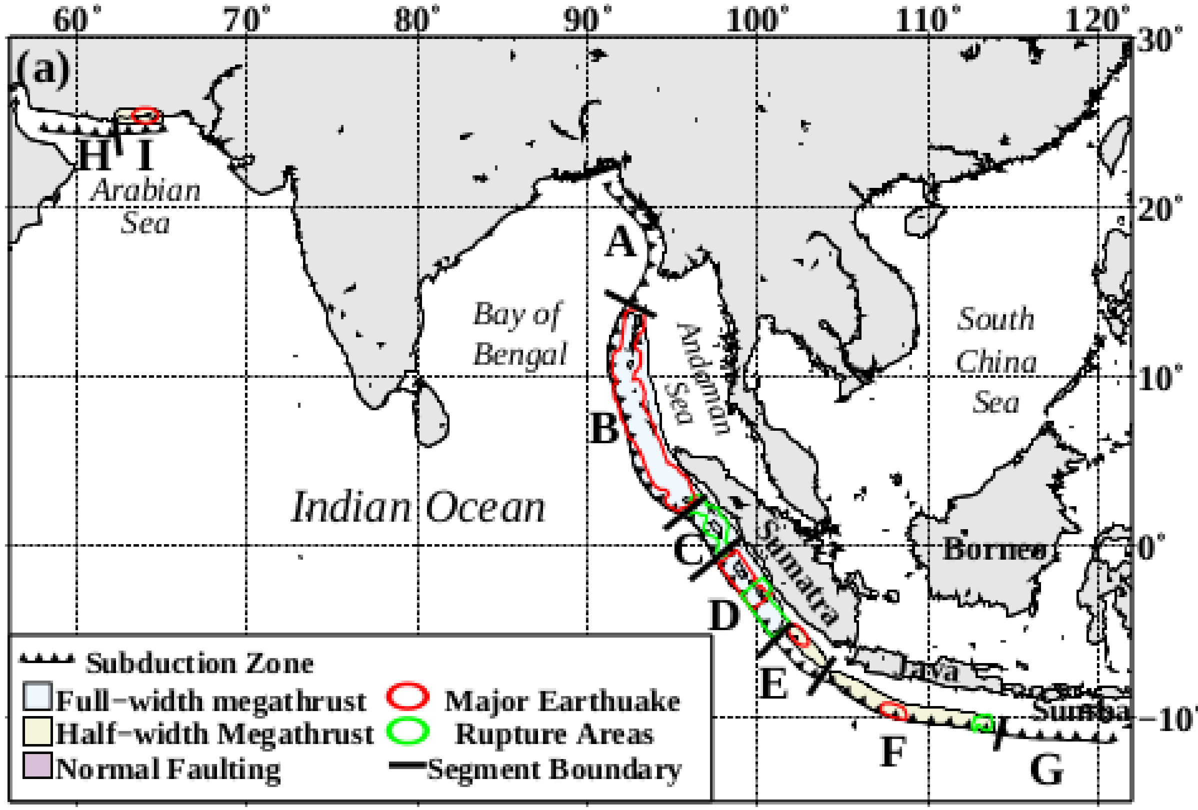
2009 PTHA for the Indian Ocean

- **Collaboratively developed by scientists from IO nations**
  - Australia, Indonesia, India, Iran
- **In use for many years since**
  - e.g. June 2018 Hyderabad tsunami modelling workshop
- **Accounted for expert disagreement on earthquake source uncertainty using alternative models**
  - Degree of segmentation
  - Maximum Magnitude

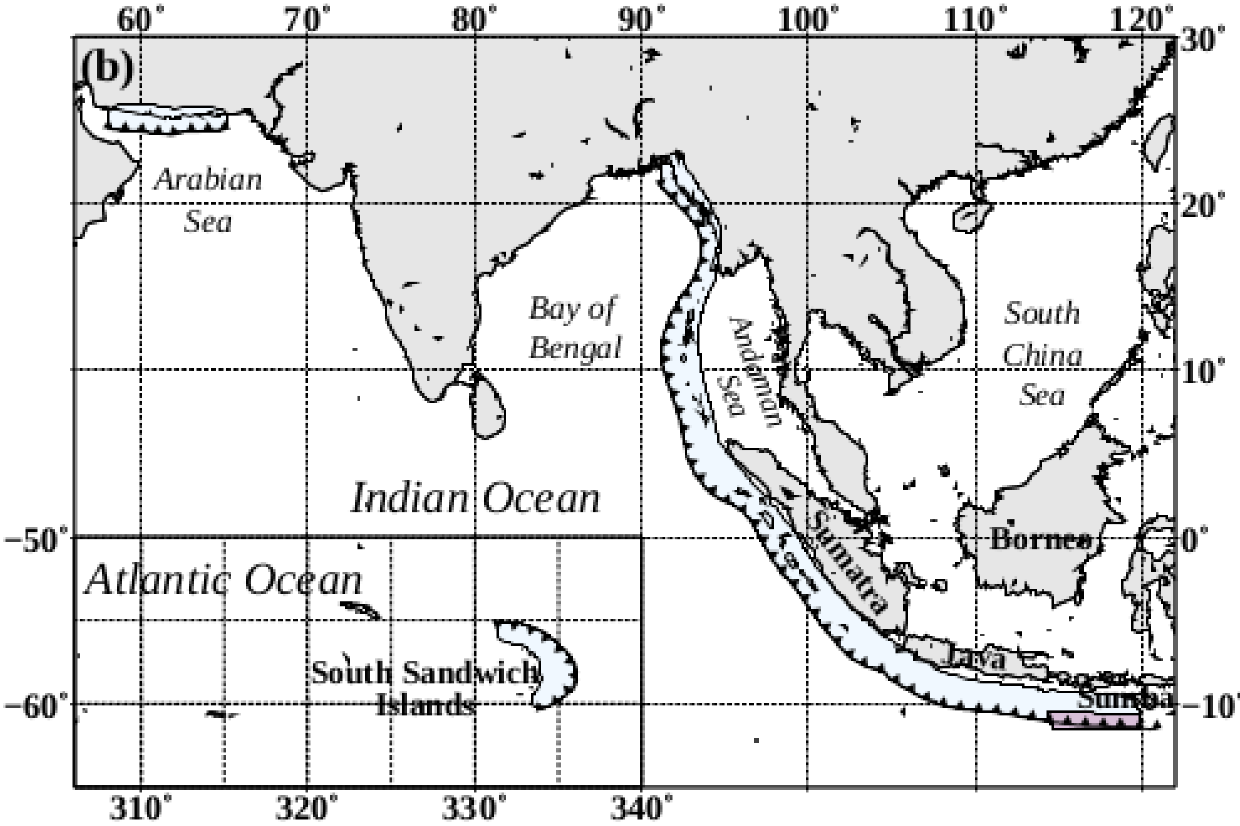


2009 PTHA for the Indian Ocean: Alternative models of segmentation

Low hazard

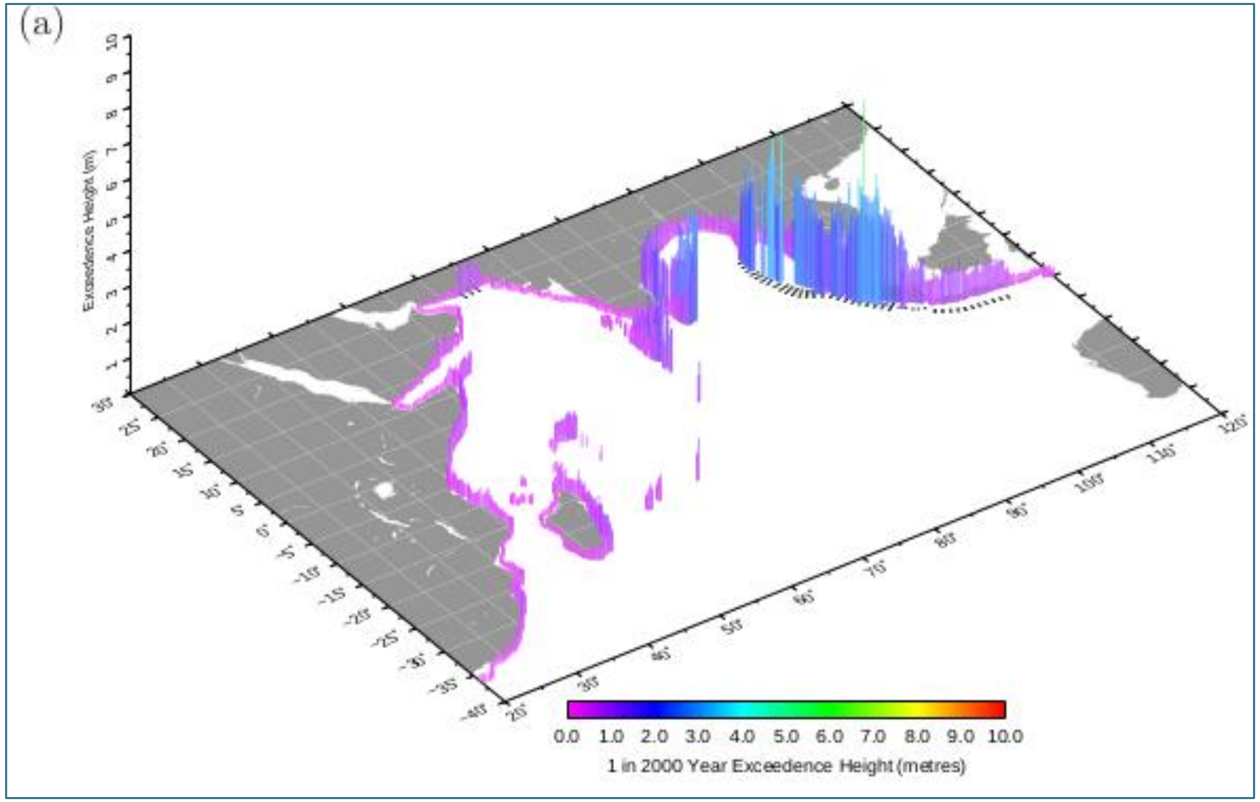


High hazard

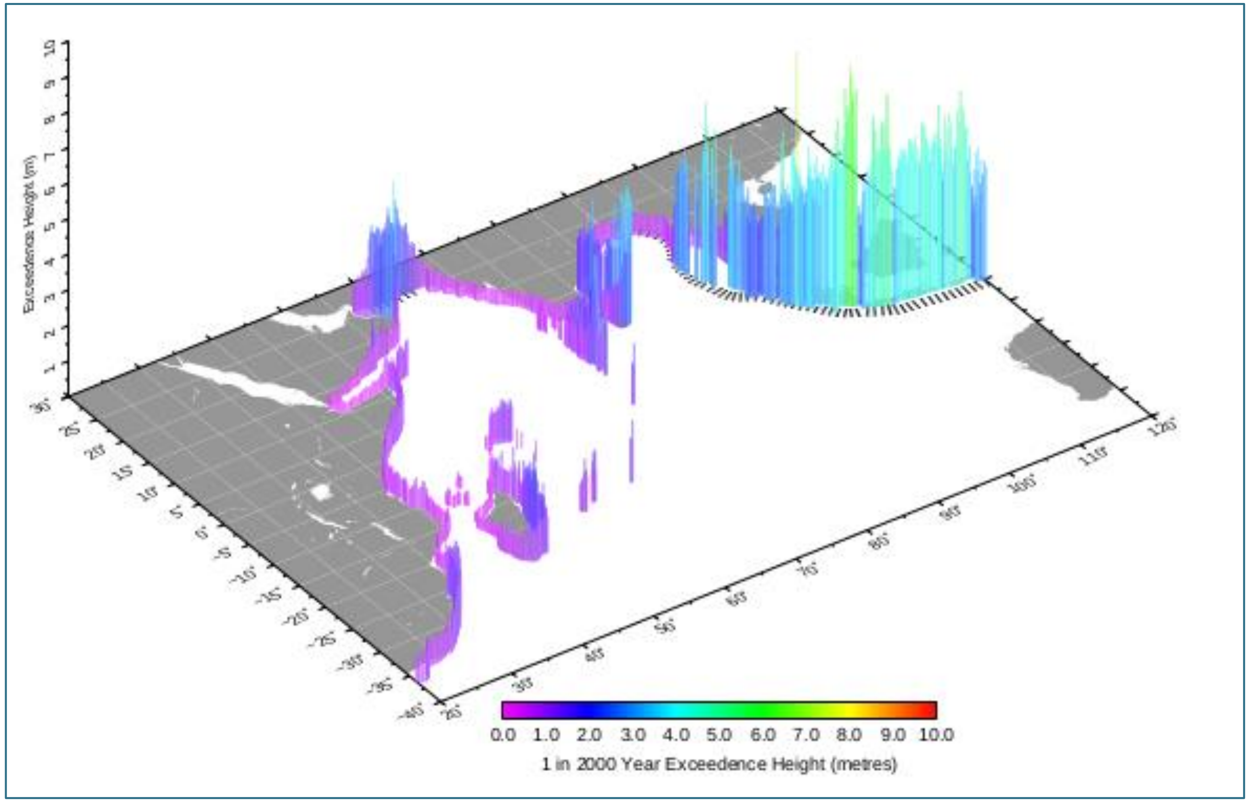


2009 PTHA for the Indian Ocean: 1/2000 yr wave height in 100m depth

Low hazard

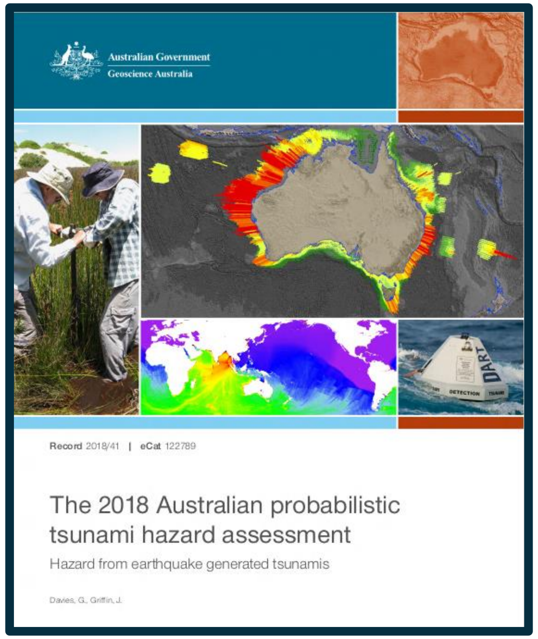


High hazard



2018 Australian Probabilistic Tsunami Hazard Assessment

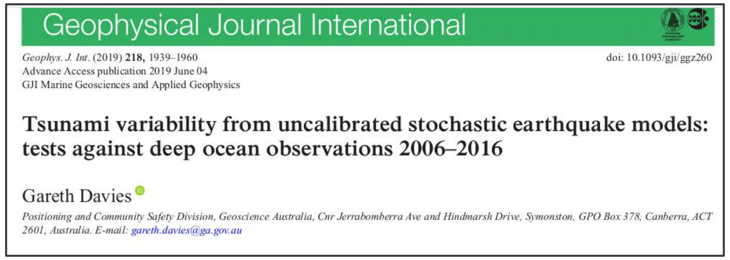
- **Includes outputs globally**
  - Not just Australia
- **Major IO source zones**
  - Sunda Arc [megathrust + outer-rise]
    - 50:50 segmented vs unsegmented
  - Makran
  - South Sandwich
- **~750,000 scenarios**
  - Random slip & area
  - Tested vs 18 real tsunamis
    - Deep ocean DART buoys
- **Scenario frequencies**
  - With uncertainty


Australian Government
Geoscience Australia

Record 2018/41 | eCat 122789

The 2018 Australian probabilistic tsunami hazard assessment
Hazard from earthquake generated tsunamis

Davies, G., Griffin, J.

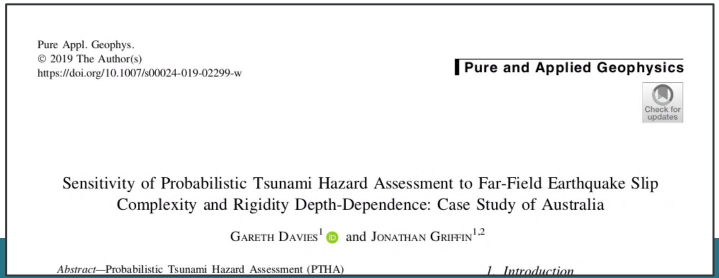

Geophysical Journal International

Geophys. J. Int. (2019) 218, 1939–1960
Advance Access publication 2019 June 04
GJI Marine Geosciences and Applied Geophysics
doi: 10.1093/gji/ggz260

Tsunami variability from uncalibrated stochastic earthquake models: tests against deep ocean observations 2006–2016

Gareth Davies

Positioning and Community Safety Division, Geoscience Australia, Cnr Jerrabomberra Ave and Hindmarsh Drive, Symonston, GPO Box 378, Canberra, ACT 2601, Australia. E-mail: gareth.davies@ga.gov.au


Pure Appl. Geophys.
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https://doi.org/10.1007/s00024-019-02299-w

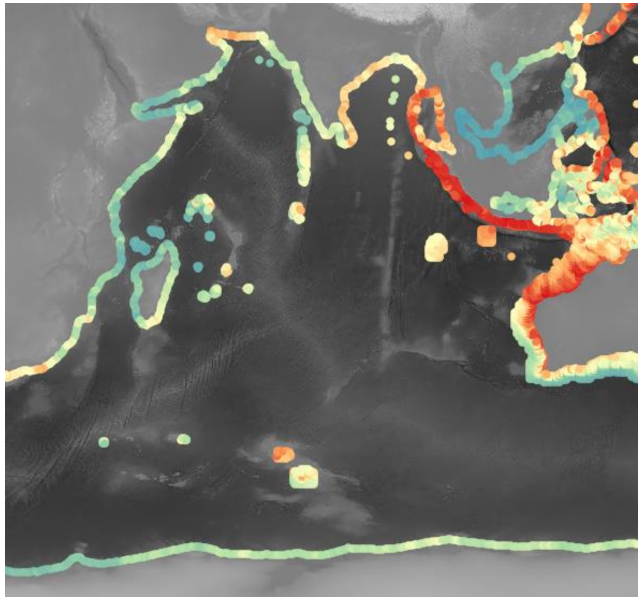
Pure and Applied Geophysics

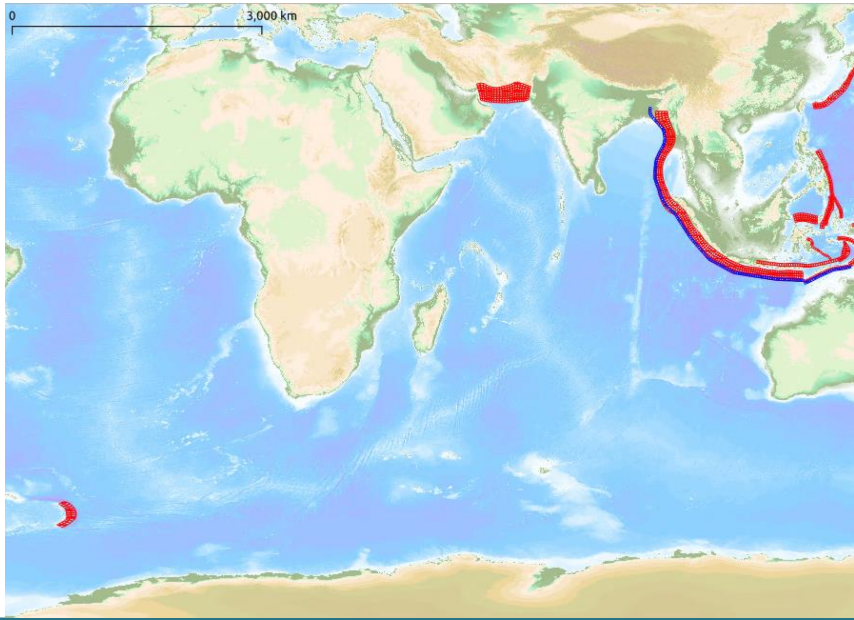
Sensitivity of Probabilistic Tsunami Hazard Assessment to Far-Field Earthquake Slip Complexity and Rigidity Depth-Dependence: Case Study of Australia

Gareth Davies[1] and Jonathan Griffin[1,2]

Abstract—Probabilistic Tsunami Hazard Assessment (PTHA)

1. Introduction

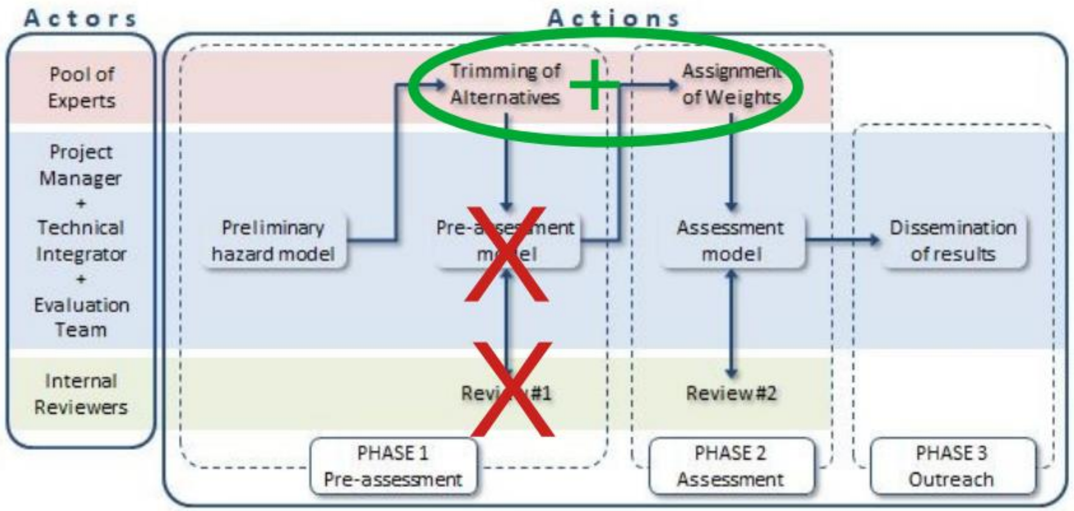




In progress PTHA for Makran

- In development by a team from the Indian Ocean and Europe
- Andrey Babeyko provided an update at the June 06 PCTWIN meeting
  - *Images on this slide are from Andrey’s presentation*
- Makran PTHA is in-development
  - Have already developed several alternative models
    - Wide variations in the hazard
  - Next steps: Consensus on weighting of alternative models.

Roadmap to consensus full PTHA



Implement alternative models	mid-Sept
Elicitation workshop (10-15 experts) on alternatives	mid-Oct
Apply weights and send PTHA to ext. Reviewers (2-3 experts)	mid-Nov
Feedback from Reviewers	Christmas
Full PTHA disseminated	Jan 2025

A. Babeyko: Roadmap from PTHA 1.0 to Consensus Model

UNESCAP TTF-31 NWIO Workshop on Tsunami Inundation Mapping, Oman, Apr 21-25, 2024

Makran PTHA v.1.0 development team

A. Babeyko, P. Kumar, S. Manneela, S. K. Srinivas, D. Saikia, S. Lorito, F. Romano, M. Volpe, A. Scala, J. Selva, M. Taroni, S. Chopra, A. Deif

Using PTHA for Inundation Hazard Assessment in Western Australia

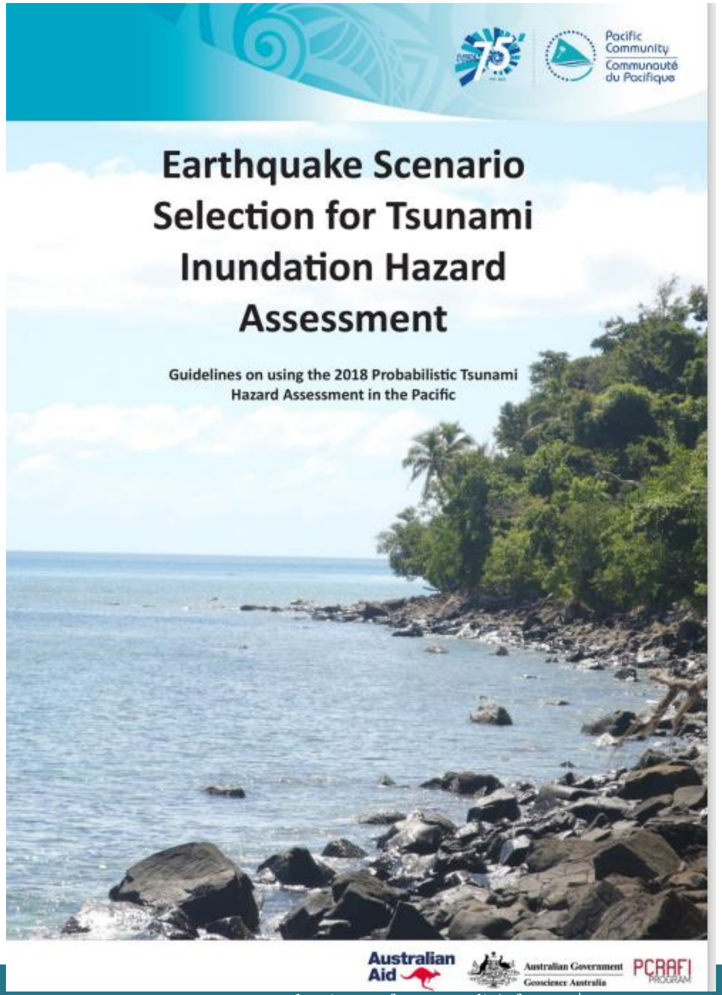
SPC & GA guidelines on using offshore PTHA for inundation hazard

Deterministic

- **Single scenario**
- **Set of scenarios**
- **Set of scenarios informed by probabilistic analyses**
- **Probabilistic tsunami inundation hazard assessment**
  - Ideal: Inundation for all offshore PTHA scenarios
    - Direct calculation of onshore hazards
  - Reality: Rigorous approximations of the ideal
    - e.g. Monte Carlo

Probabilistic

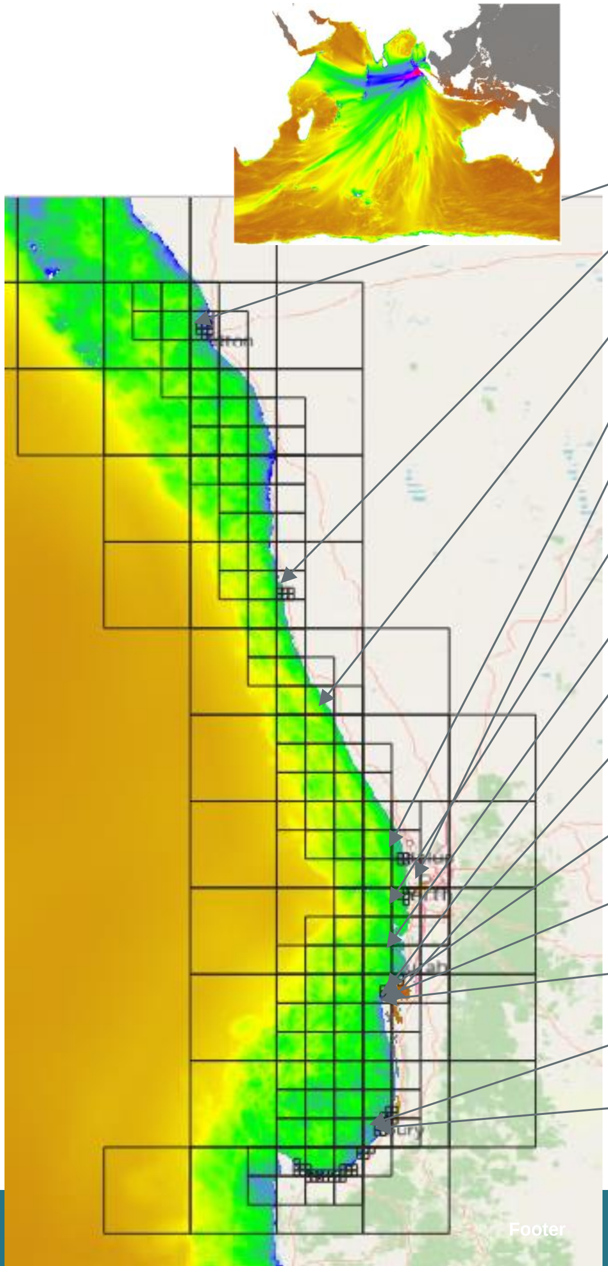
https://repository.oceanbestpractices.org/handle/11329/2062



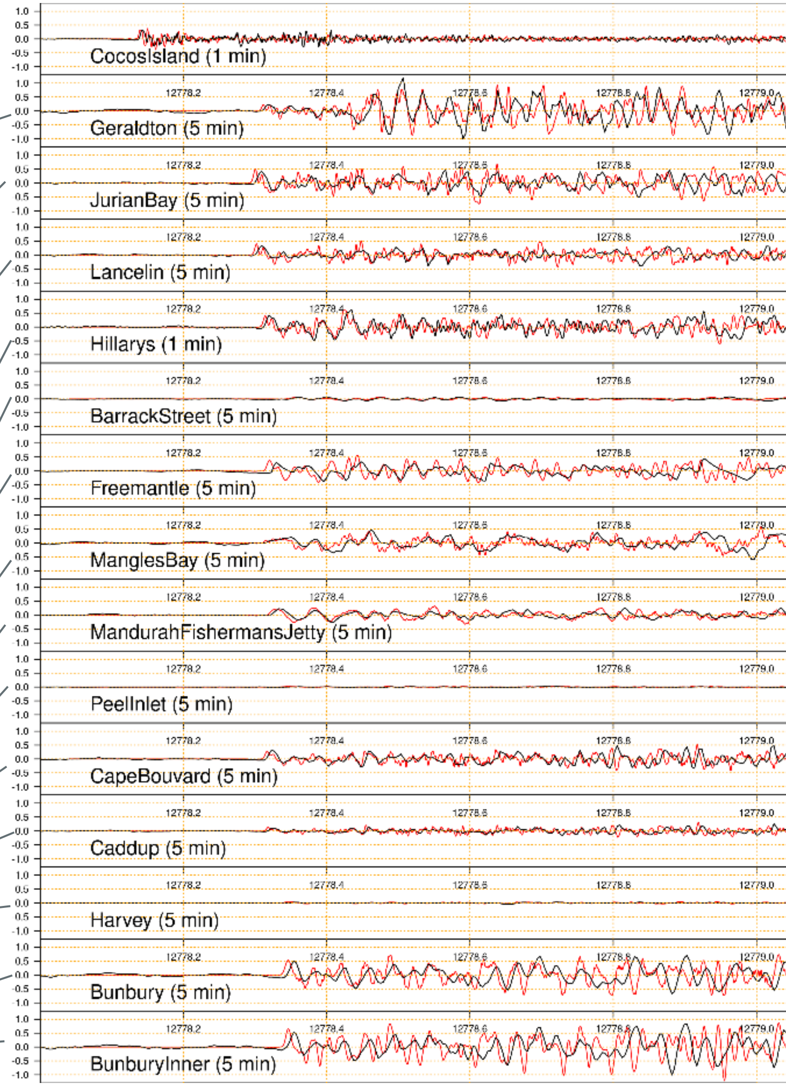
Example: Western Australia Tsunami Inundation Mapping

1. ***Spatially extensive inundation models***
    - Mostly good quality elevation (LiDAR)
    - Tests with multiple historical events
    - Conservative assumptions
        - Tides (HAT)
        - Friction (Uniform Manning = 0.03)

2. ***Scenarios from 2018 Australian PTHA***
    - Inundation for 100s of scenarios
    - Hazards via Monte Carlo approach to compute
        - Rate of inundation (events/year)
        - Effect of uncertain earthquake frequencies



2004 IO tsunami: Model vs Obs.



Example: Western Australia Tsunami Inundation Mapping

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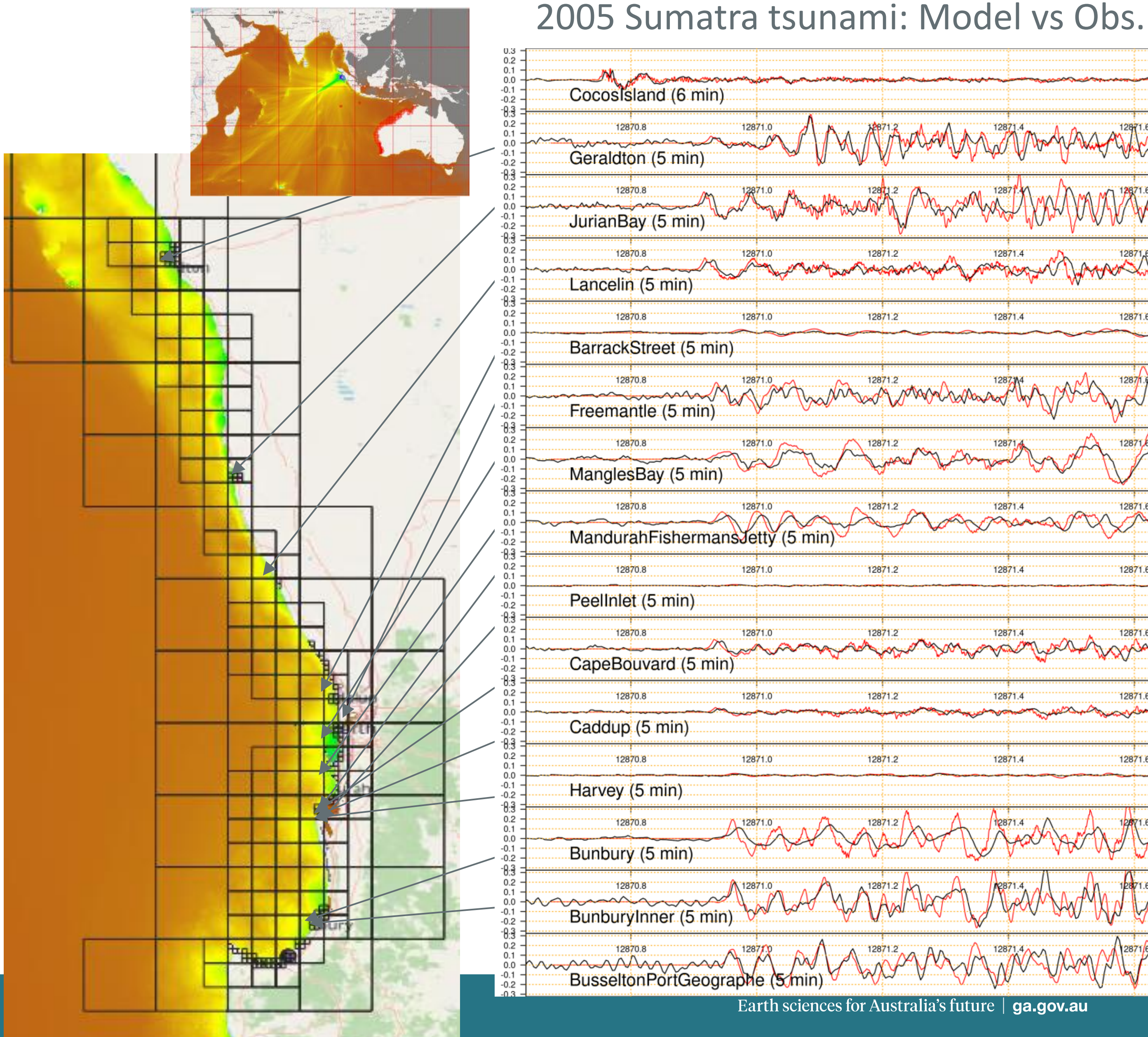
2005 Sumatra tsunami: Model vs Obs.



JOURNAL ARTICLE

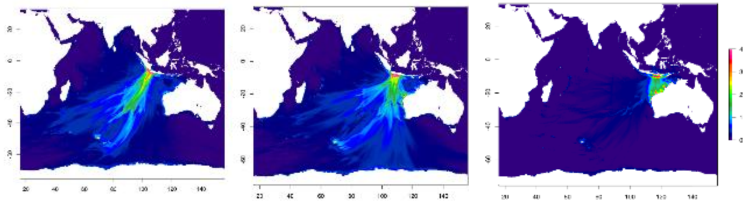
From offshore to onshore probabilistic tsunami hazard assessment via efficient Monte Carlo sampling
Gareth Davies, Rikki Weber, Kaya Wilson, Phil Cummins
Geophysical Journal International, Volume 230, Issue 3, September 2022, Pages 1630–1651, https://doi.org/10.1093/gji/ggac140

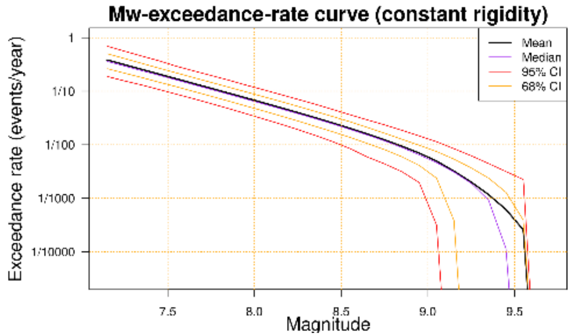
Published: 11 April 2022 **Article history** ▾

How we calculate onshore tsunami hazards

PTHA18

- Eq-tsunami scenarios
  - Sunda Arc: ~**130,000**
- Scenario frequencies
- Uncertainty in frequency (esp. at high magnitude)



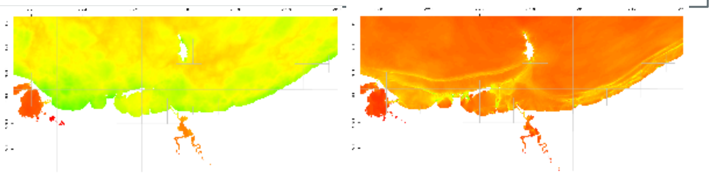


Monte-Carlo sampling (390 scenarios).
Optimised for region of interest (Greater Perth).

High-res model

(390 scenarios)

- Depth
- Flow speed
- Arrival time
- Wave time-series

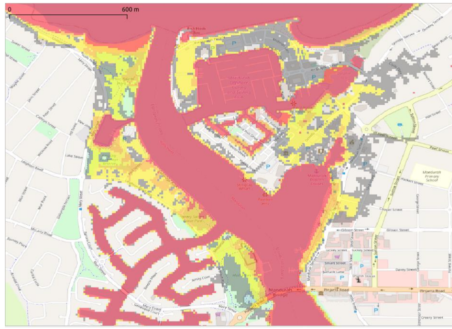


Monte-Carlo theory

Davies et al. (2022) https://doi.org/10.1093/gji/ggac140

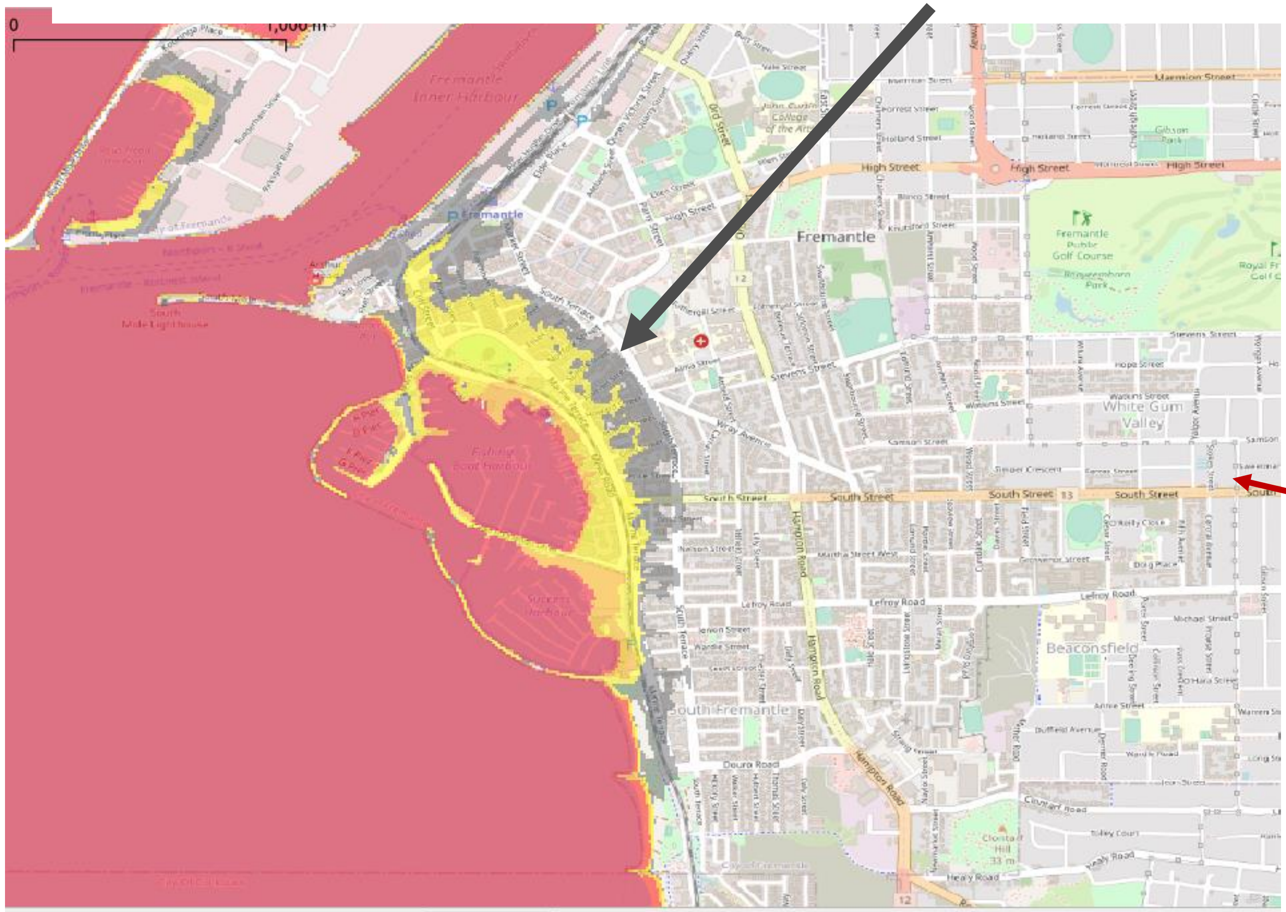
High-res frequency

- e.g. Rate of inundation.
  - Epistemic uncertainties



Inundation exceedance-rates: Examples

Area beyond grey zone may be inundated. But modelled as <1/10000

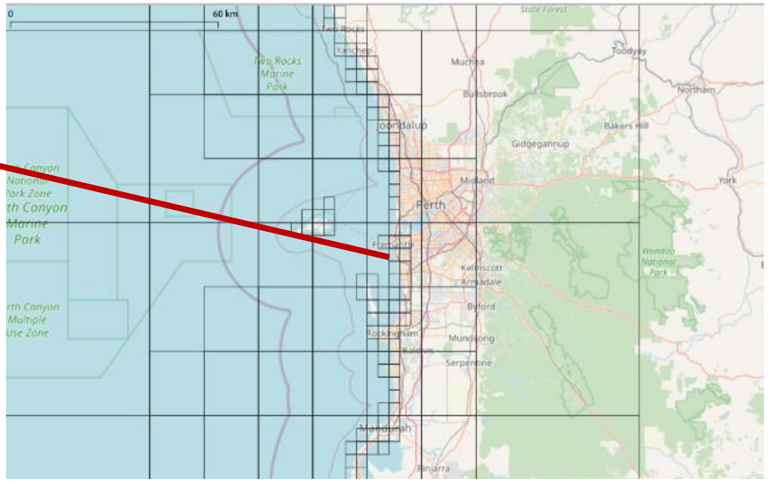


Red: > 1/100

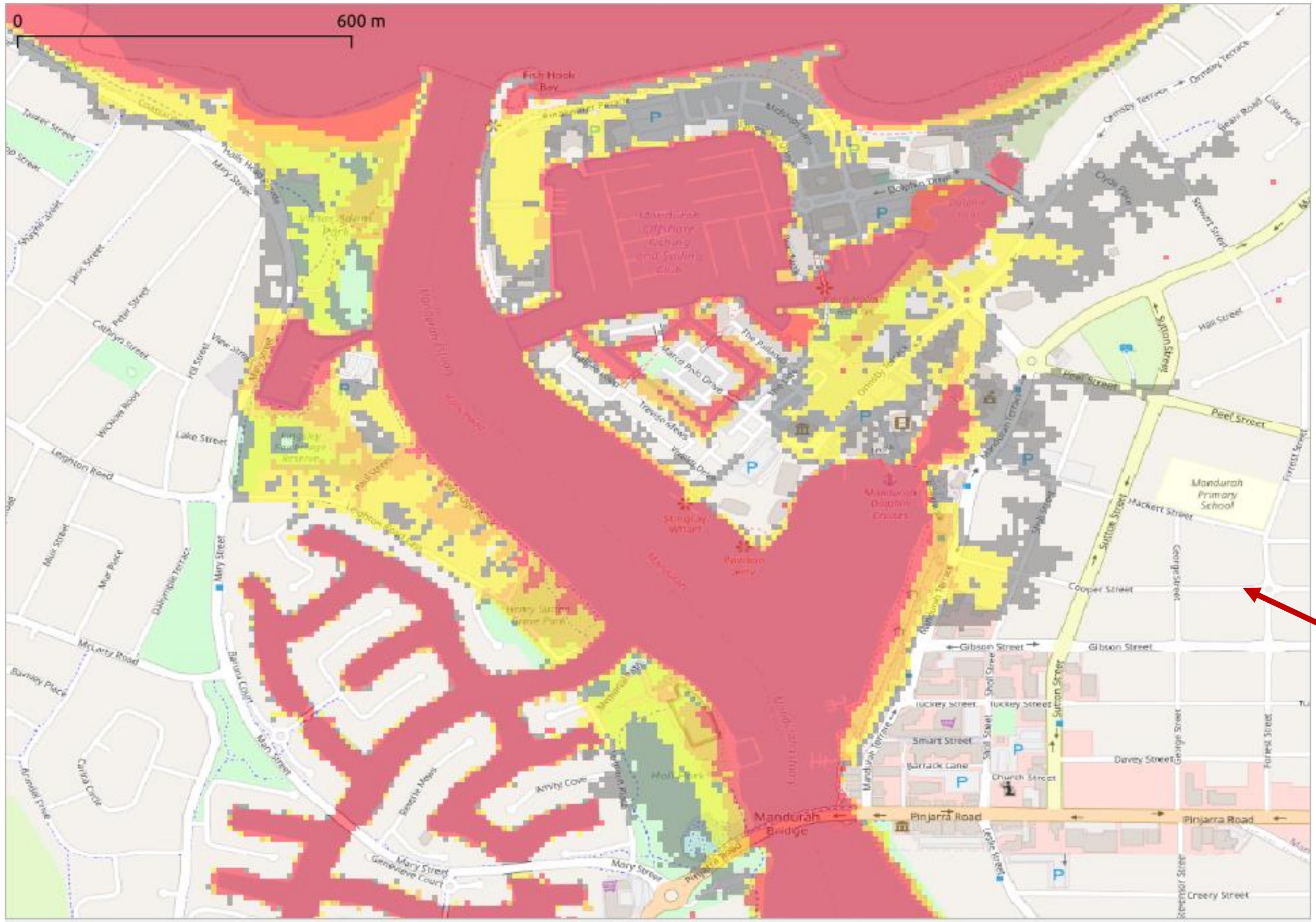
Orange: 1/100 – 1/500

Yellow: 1/500 – 1/2500

Grey: 1/2500 – 1/10000



Inundation exceedance-rates: Examples



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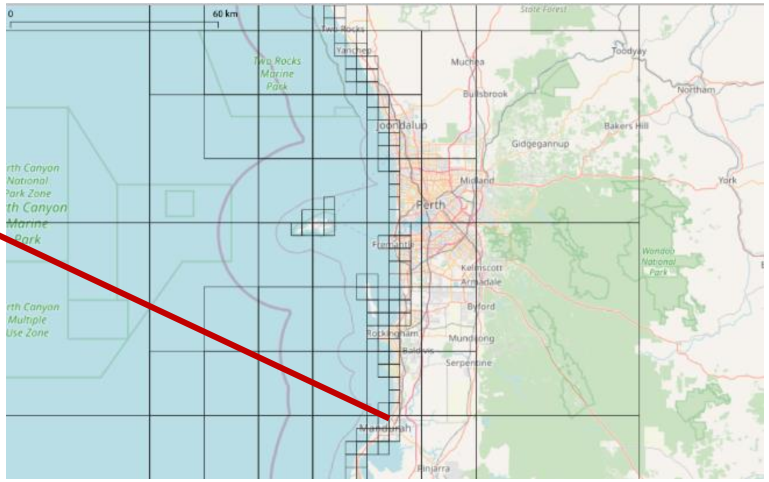
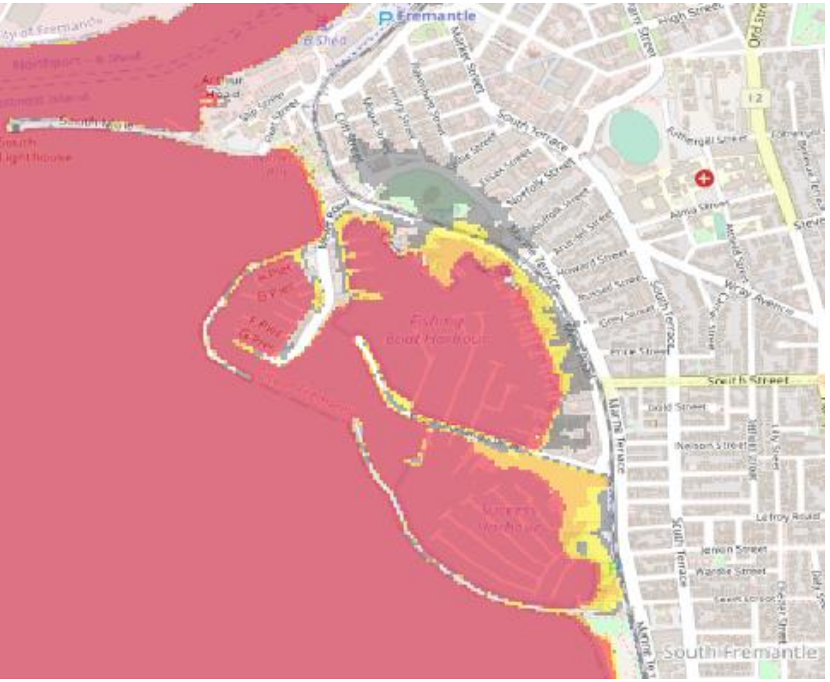


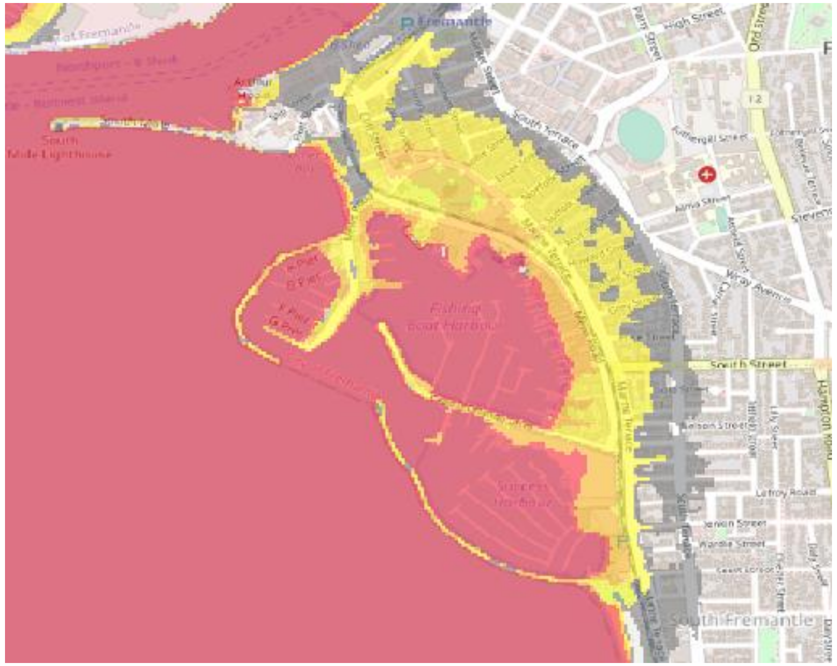
Sensitivity to uncertain frequency of large earthquakes

16th percentile



Mean (as previous)

84th percentile



Inundation frequencies are uncertain → but we can represent this with percentiles

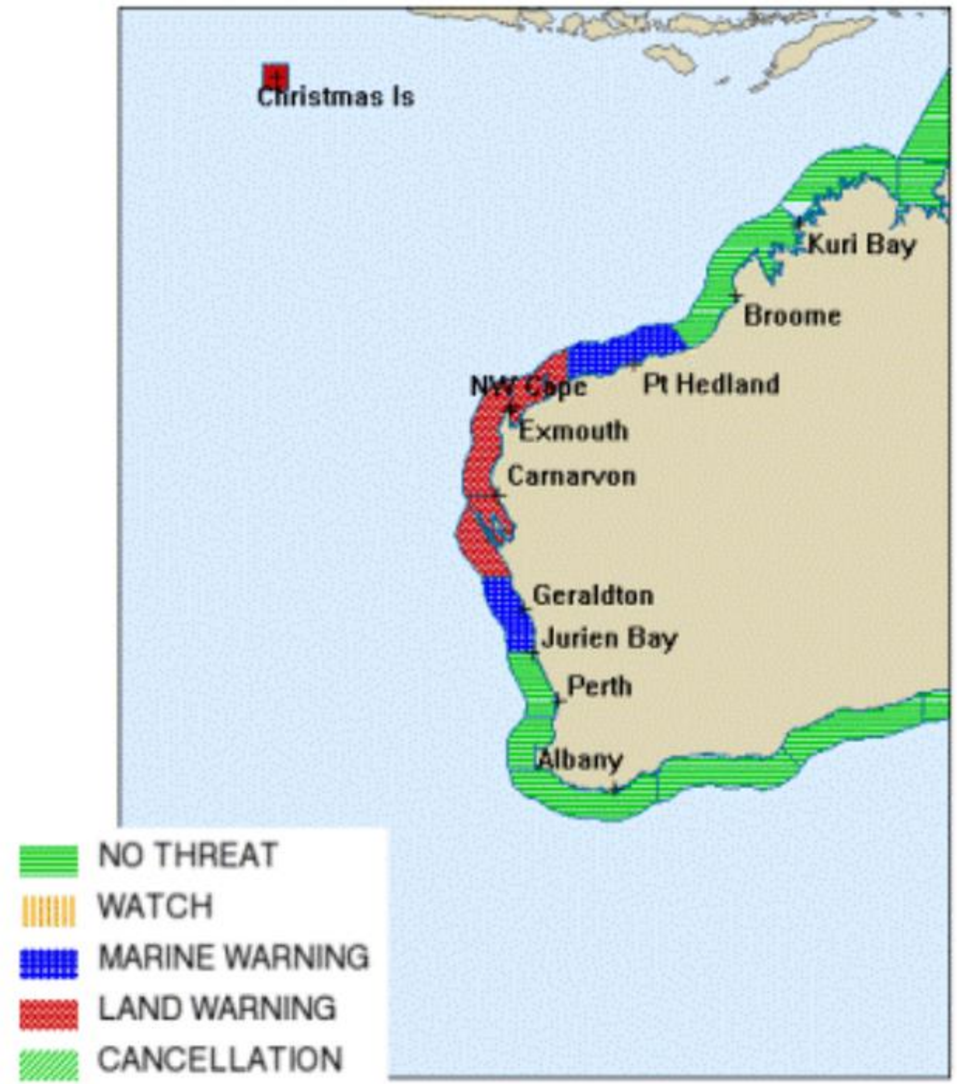
What about tsunami warning & evacuation?

- A bit different to probabilistic inundation

- **Real tsunami → JATWC will provide a warning**
  - 3 warning categories
    - **No threat**
    - **Marine and Immediate Foreshore threat**
    - **Land threat**
  - Applied separately to “coastal zone” polygons

- **Warnings do not include inundation maps**
  - Default advice for land warnings
    - 10m up, 1 km inland
    - Can be very conservative
    - Potentially hard to action

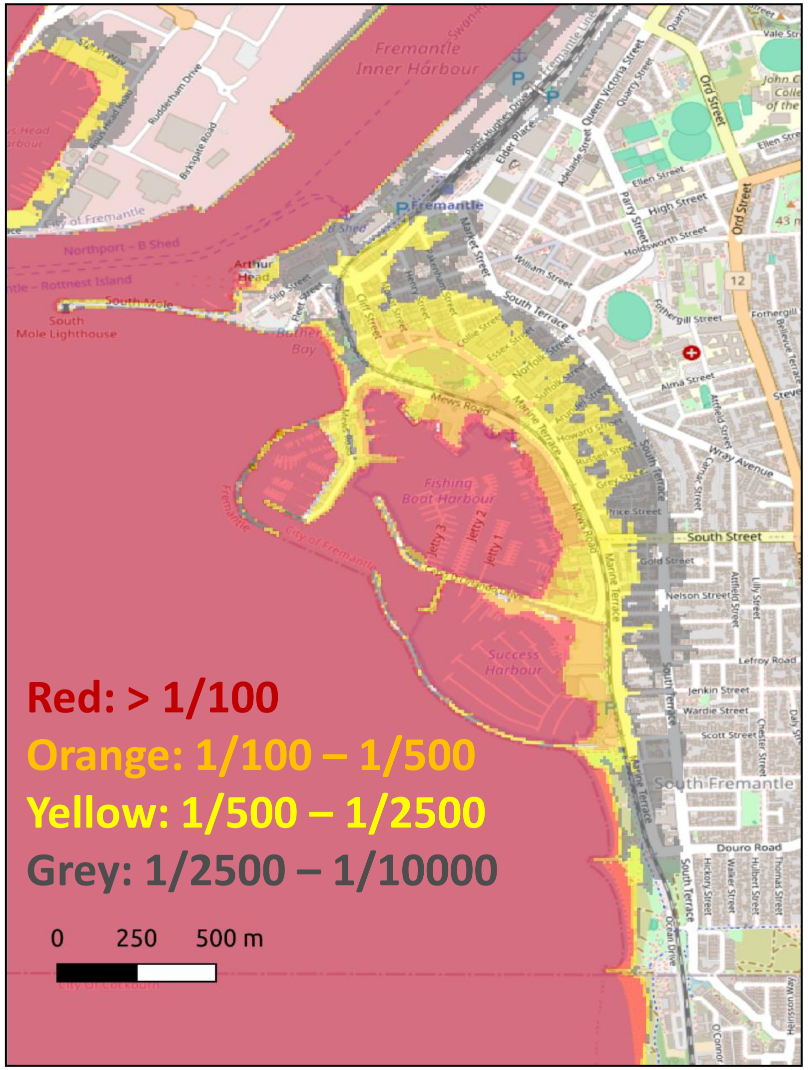
- *DFES combine models with advice from emergency management to make evacuation maps*



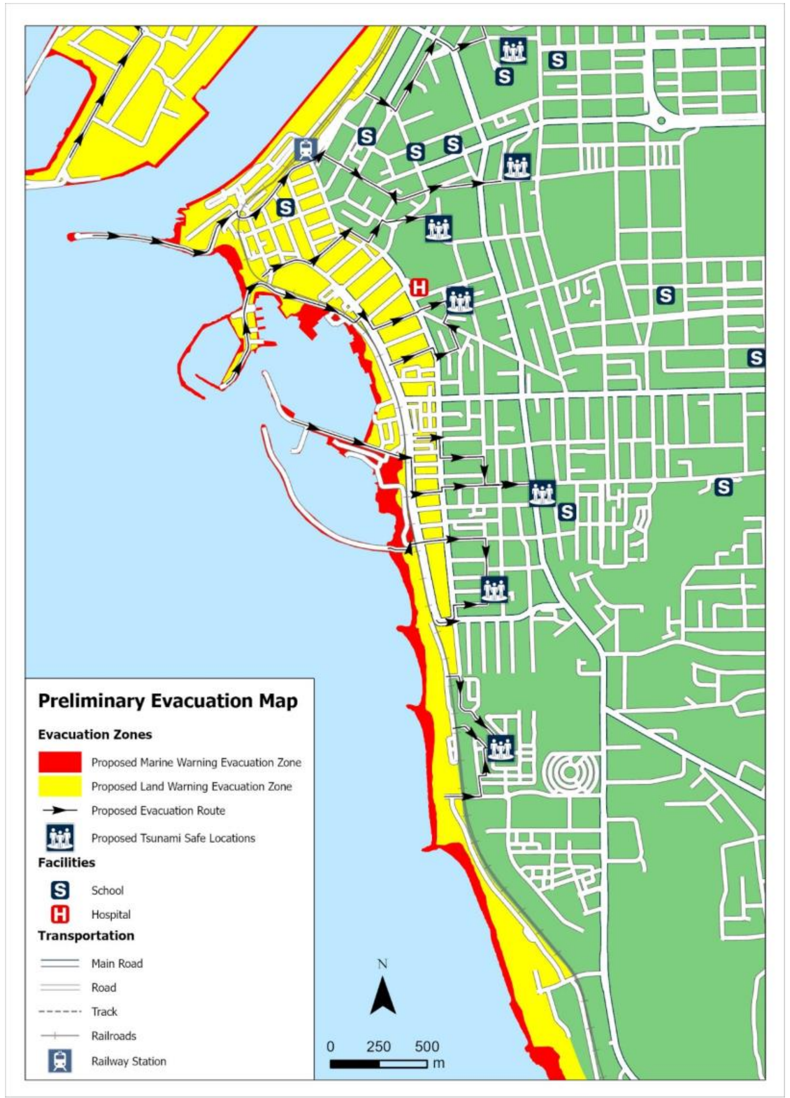
Tsunami watches and warnings indicating the level of threat are issued for coasta zones around Australia and its offshore territories.

Models & emergency-services judgement are combined to make zoned maps

MODELLED EVENTS PER YEAR



DFES EVAC ZONE



COMPARISON WITH 10m / 1km