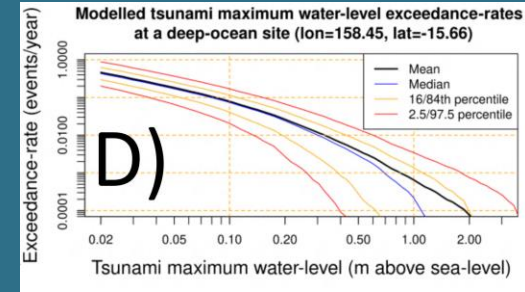


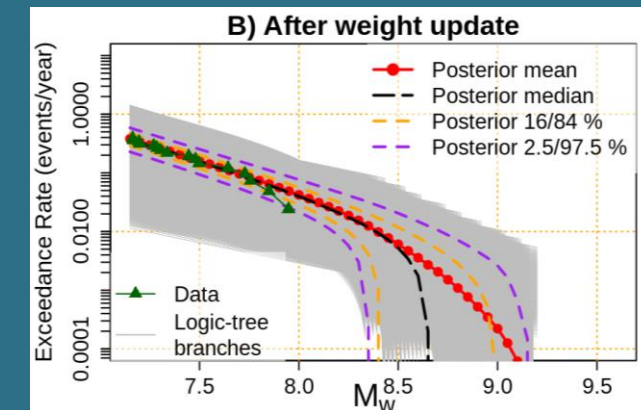
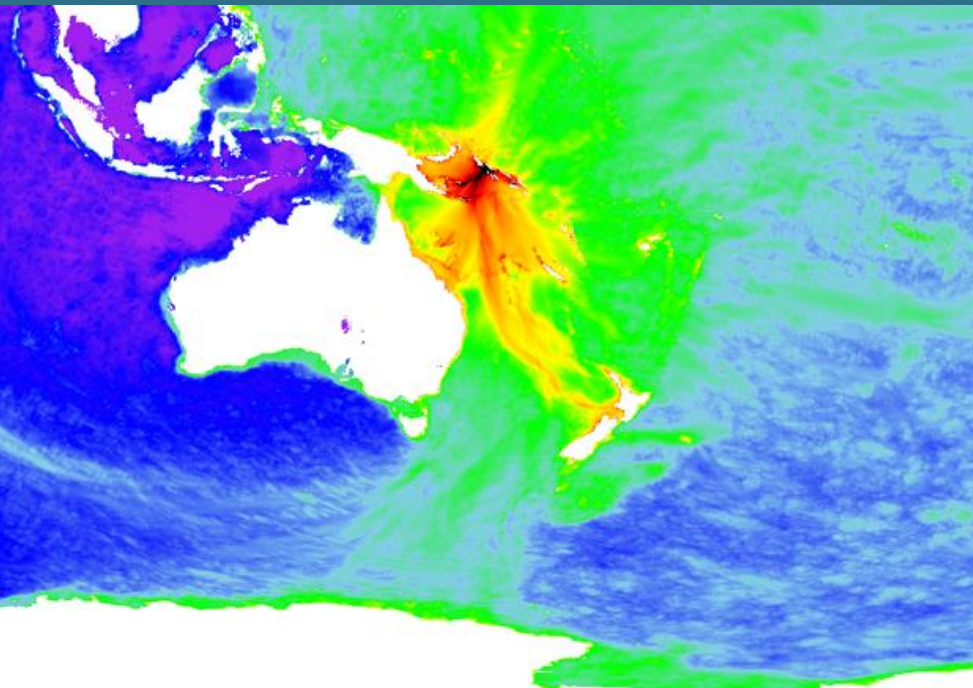
Australian Government
Geoscience Australia



Probabilistic seismic-tsunami hazard assessment options

ICG/PTWS Scientific meeting on the Vanuatu, San Cristobal and New Britain Subduction Zones

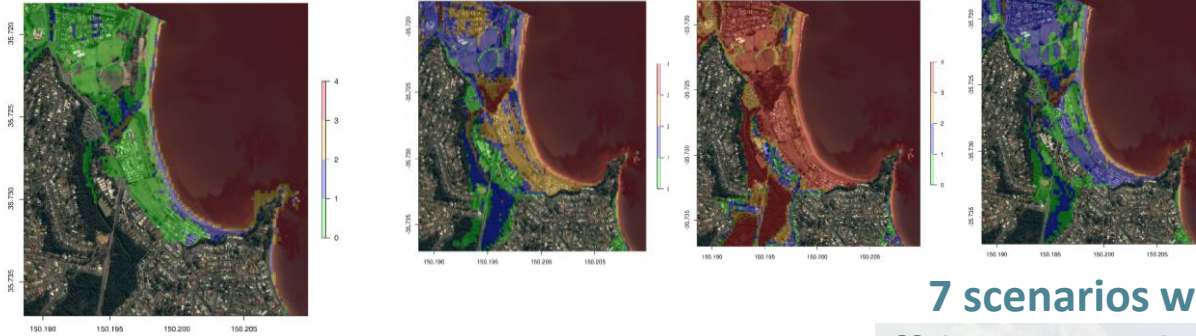
Gareth Davies



Approaches to tsunami inundation hazard assessment

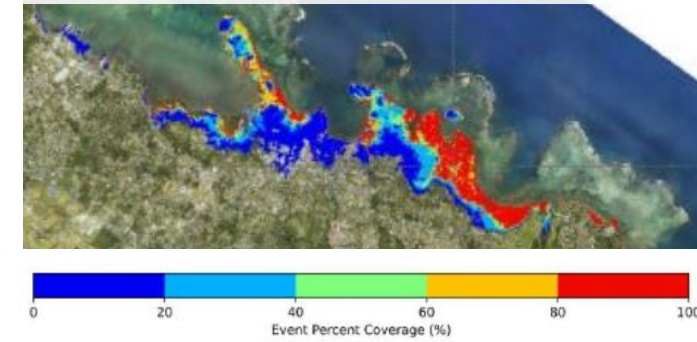
Deterministic

- **Single scenario**
- **Set of scenarios**



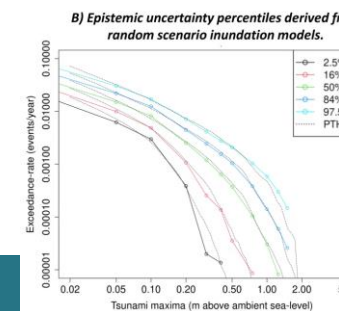
7 scenarios with 1/1000 year offshore wave height: Gibling et al. 2022

- **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.)

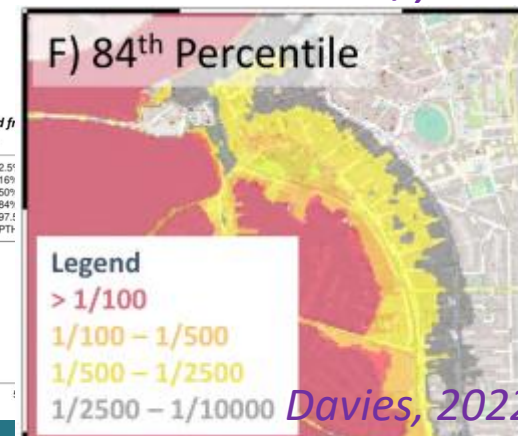


Probabilistic

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



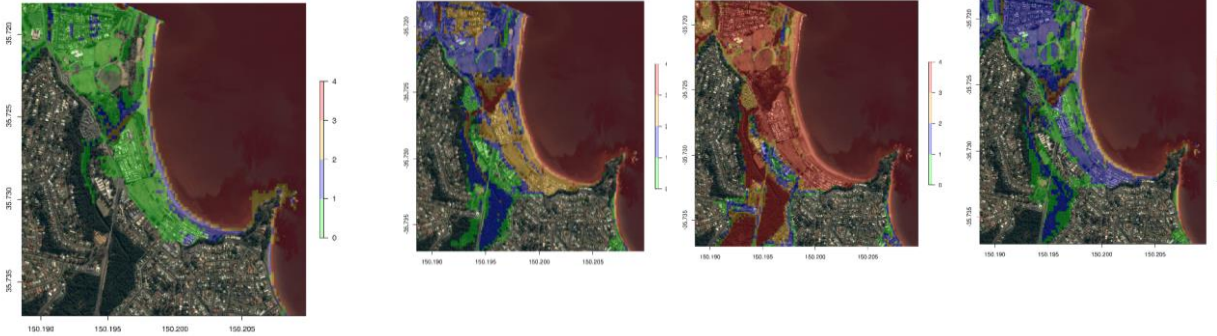
Inundation events/year



Approaches to tsunami inundation hazard assessment

Deterministic

- **Single scenario**
- **Set of scenarios**

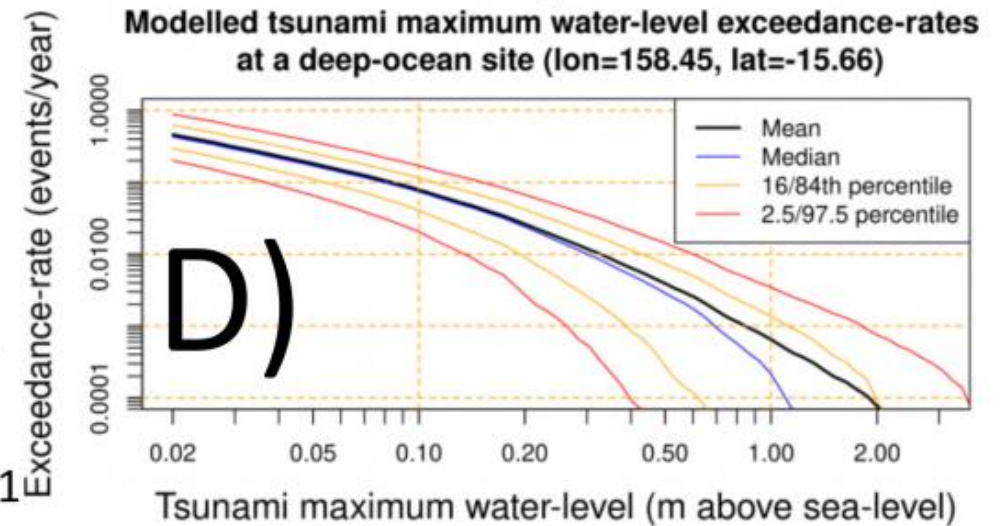
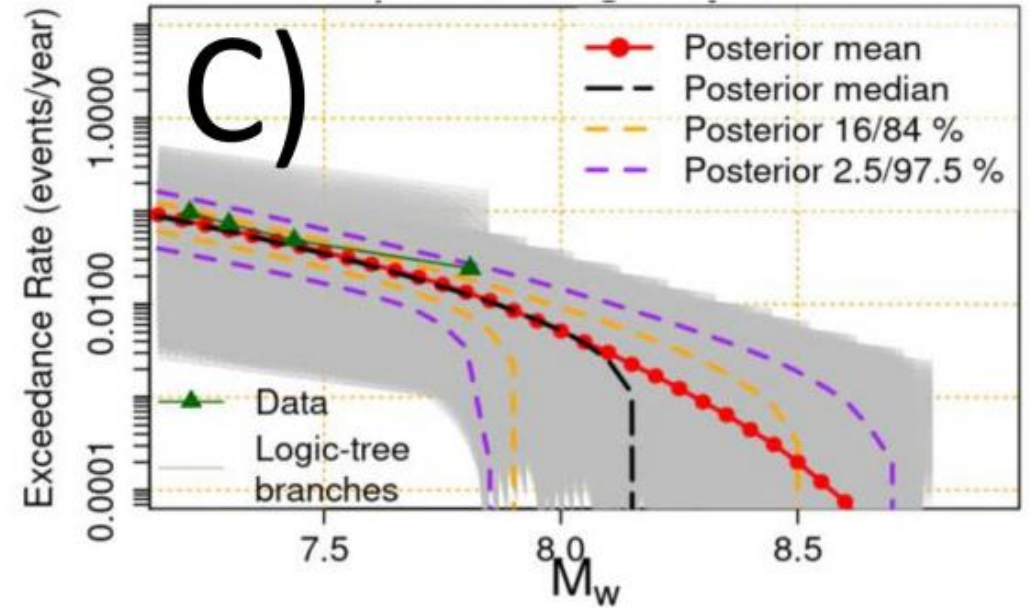
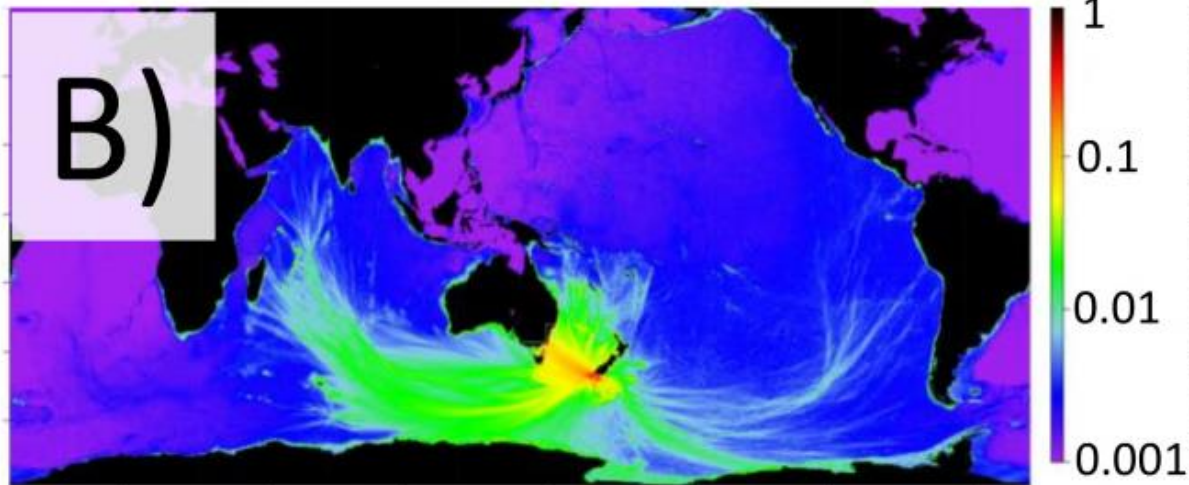
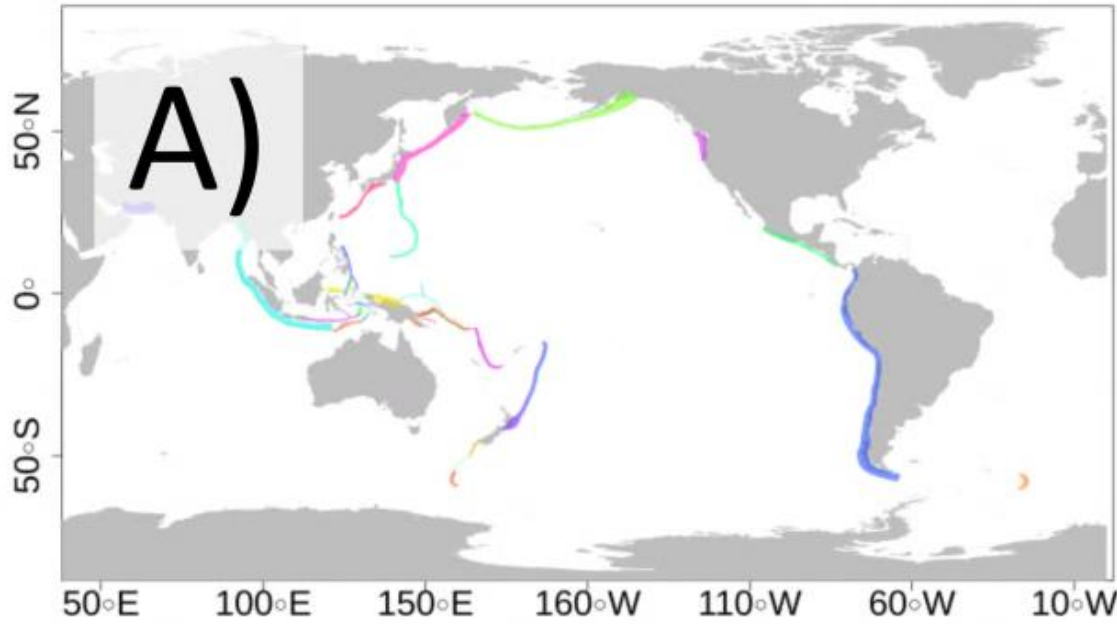


- **Set of scenarios informed by probabilistic analyses**
 - **Nominal average return period**, e.g.
 - 1/2500 wave height exceedance-rate at an offshore site
 - **Epistemic uncertainty**, e.g.
 - Likelihood that scenario is even possible (given M_w etc.)

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

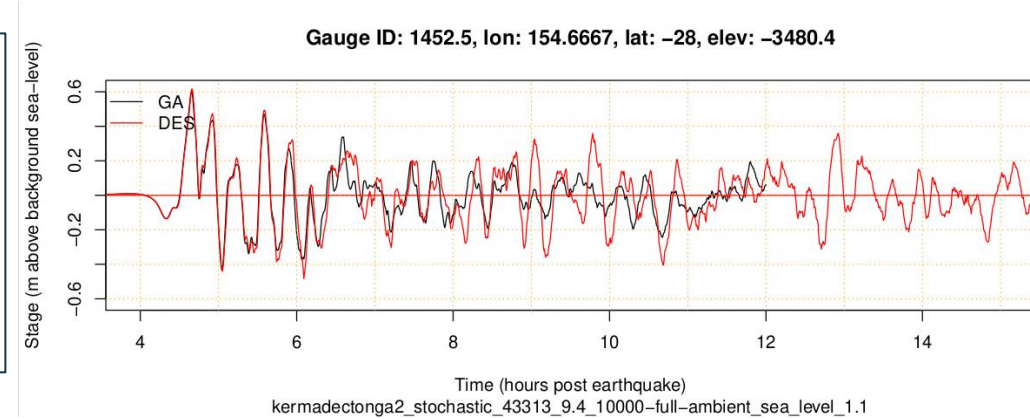
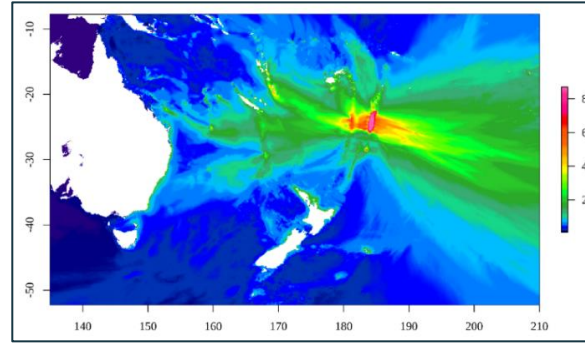
*Leverage an
Offshore
Probabilistic
Tsunami Hazard
Assessment?*

Offshore Probabilistic Tsunami Hazard Assessment: The basic idea

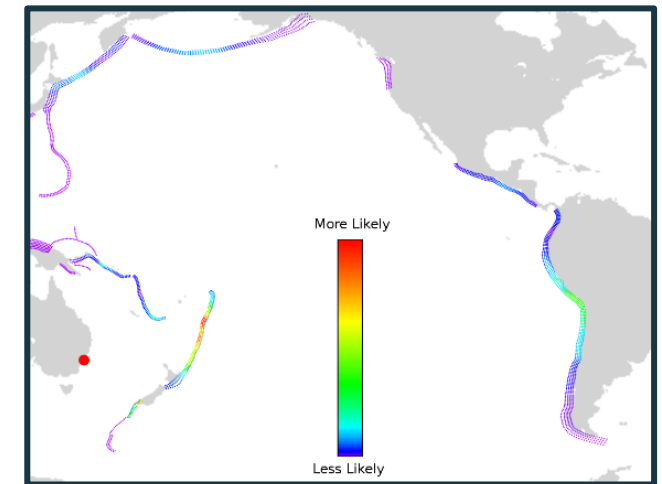
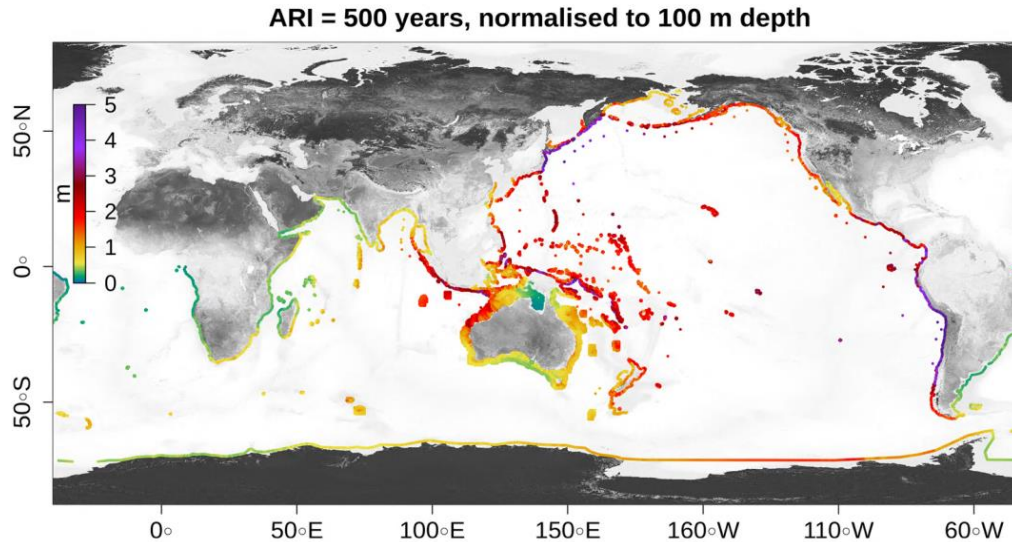


Offshore Probabilistic Tsunami Hazard Assessment: The basic idea

- *Earthquake scenario database*
 - *Tsunami initial conditions*
 - *Linear wave time series*



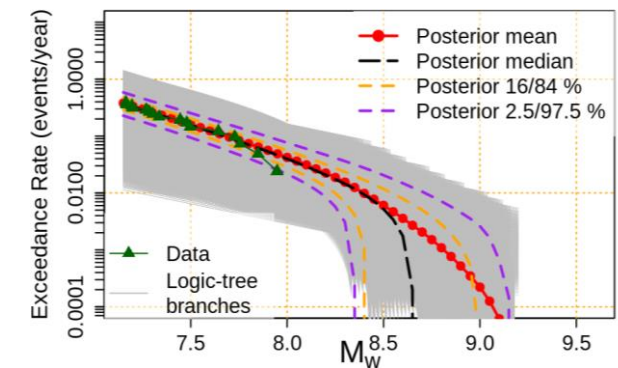
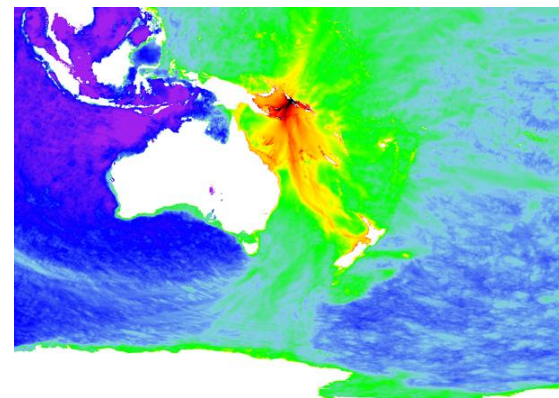
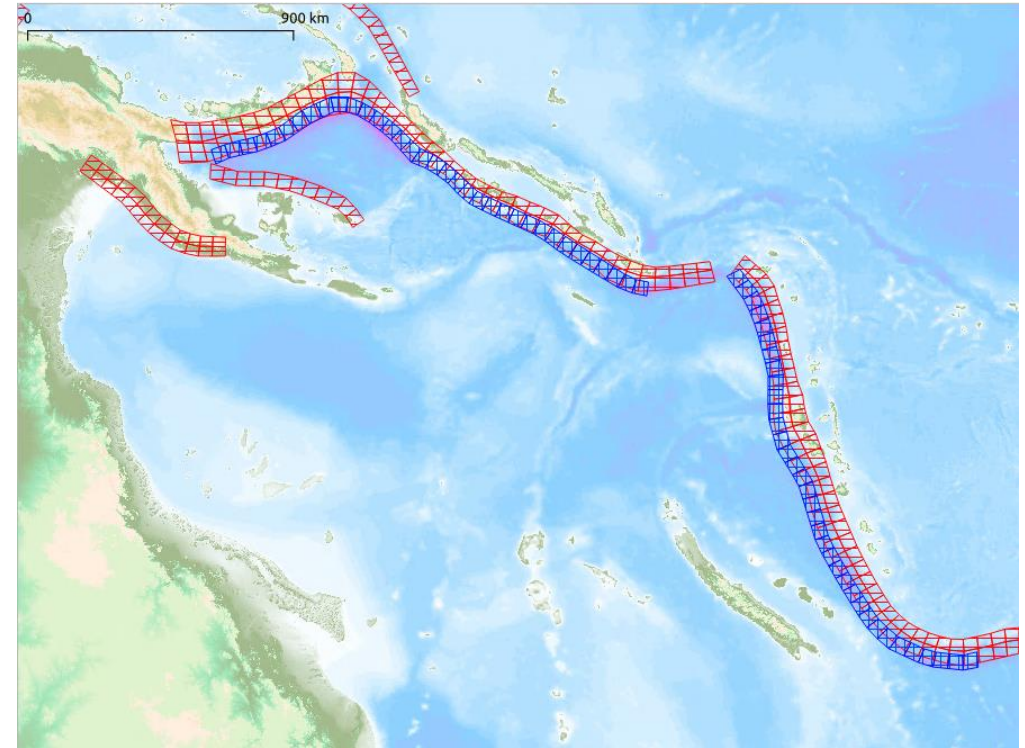
- *Exceedance-rates with epistemic uncertainty*
 - *M_w*
 - *Wave size*
- *Hazard deaggregation*



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

Probabilistic seismic tsunami inundation hazard assessment options

- Leverage an existing offshore PTHA?
 - 2018 Australian PTHA
 - New Zealand national PTHA
 - Many others in published literature & in development
 - Others I am missing?
- Develop your own?
- Things to consider
 - No option will be perfect
 - What will suit your end-users?
 - How well tested are the existing options?
 - Can you do better in the time you have?
 - Do existing PTHAs provide what you need?



SPC & GA guidelines on using offshore PTHA for inundation hazard

Deterministic

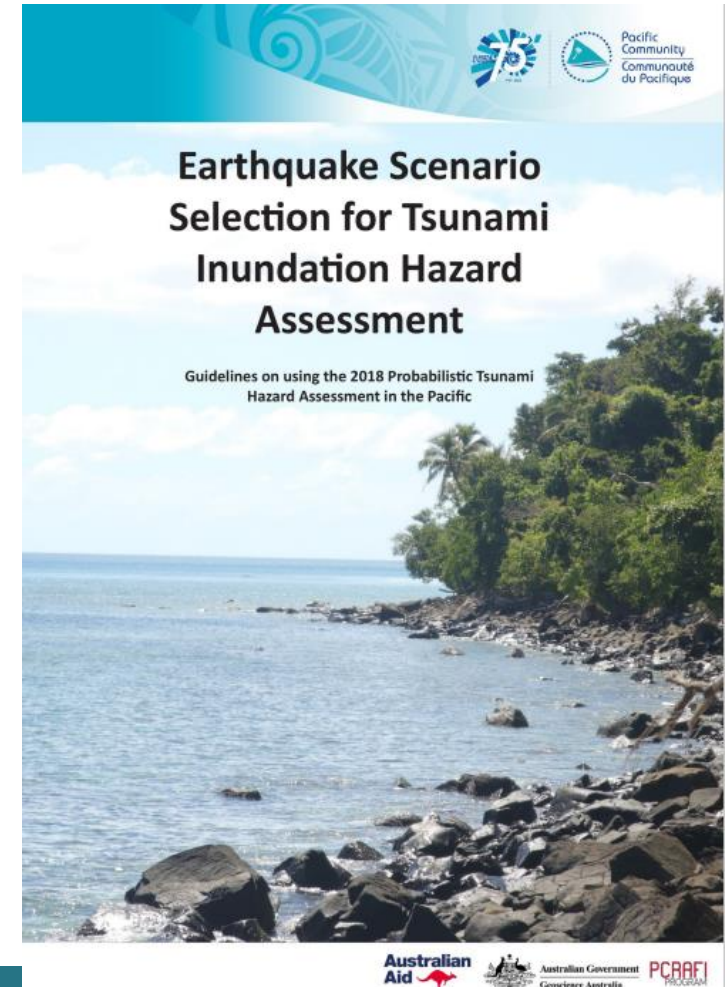
- **Single scenario**
- **Set of scenarios**

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

- **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

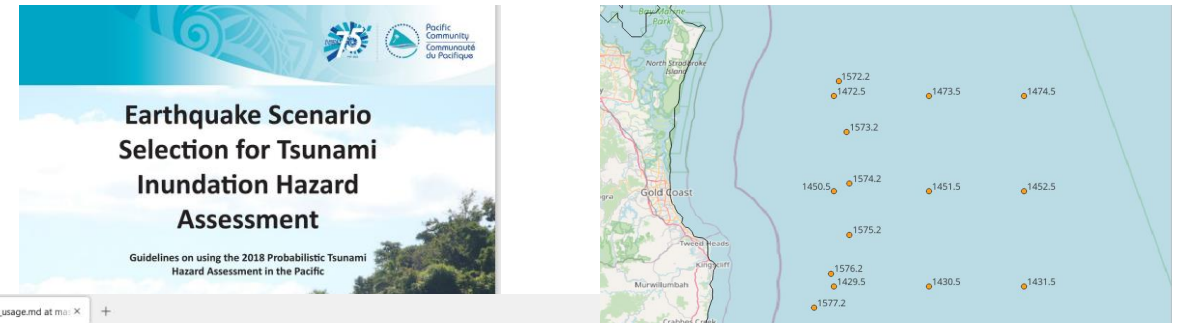
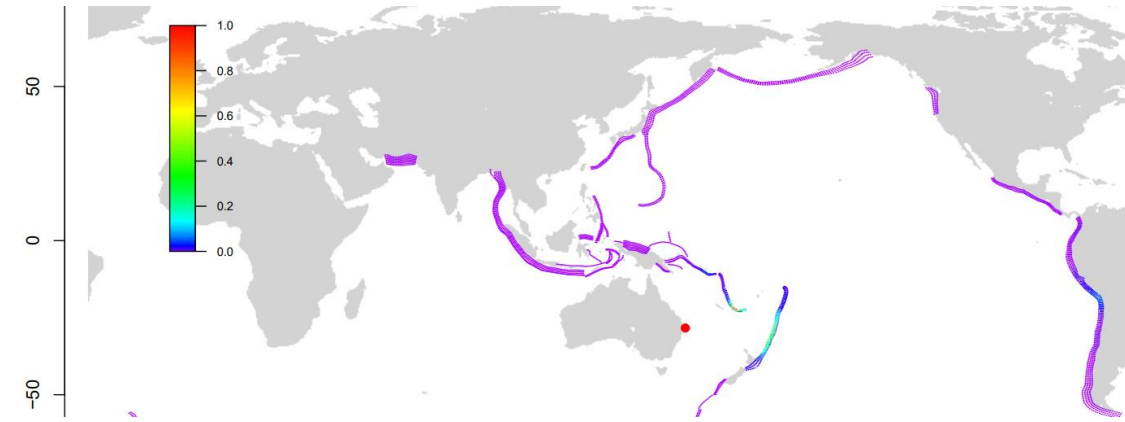
Probabilistic



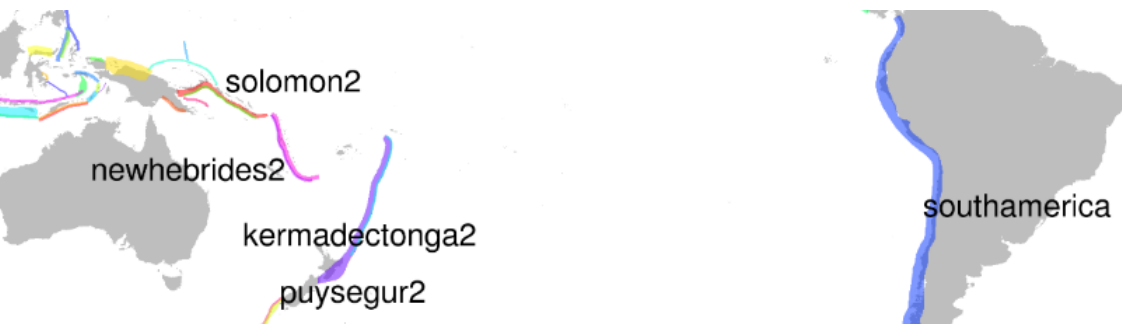
Examples of using offshore PTHA for inundation hazard assessment

Example: Set of scenarios informed by probabilistic analyses

- **Tsunami inundation scenarios for Gold Coast, Australia**
 - QLD Department of Environment & Science
- **44 scenarios from 2018 Australian PTHA**
 - Informed by wave height exceedance-rates
 - 1/100 to 1/10000 @ multiple offshore sites
 - Logic-tree-mean
 - Many other subjective judgements, e.g.
 - Prefer a range of source-zones
 - Prefer “more likely” scenarios
 - See the guidelines for ideas & code



A screenshot of a GitHub repository page for the file 'ptha/example_usage.md'. The page title is 'An approach for multi-gauge-based scenario selection'. The content includes a paragraph: "The code in select_scenarios.R can be used to identify a set of earthquake-tsunami scenarios from a given source-zone, which satisfy some max-stage exceedance-rate criteria at multiple gauges simultaneously. At gauges where the exceedance-rate criteria is not satisfied, the maximum-stage is always smaller than the target maximum-stage." and another paragraph: "Why do this? For hazard applications we might want to select a suite of scenarios (perhaps from multiple source-zones) that collectively meet some exceedance-rate criteria at multiple gauges of interest."



Example: Set of scenarios informed by probabilistic analyses

- Tsunami inundation scenarios for Gold Coast, Australia
 - QLD Department of Environment & Science
- Inundation hazard maps by merging scenarios for each nominal exceedance-rate
 - Onshore impacts vary for the same offshore wave height
 - Merging → likely conservative

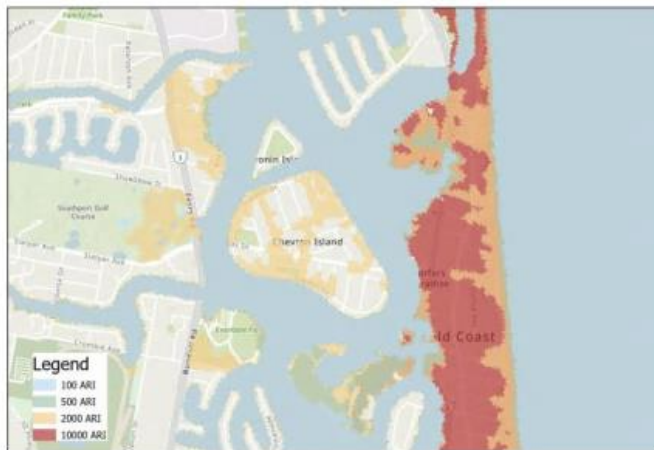


Figure 6 – Envelope of maximum inundation extents near Surfers Paradise for all ARIs at HAT.

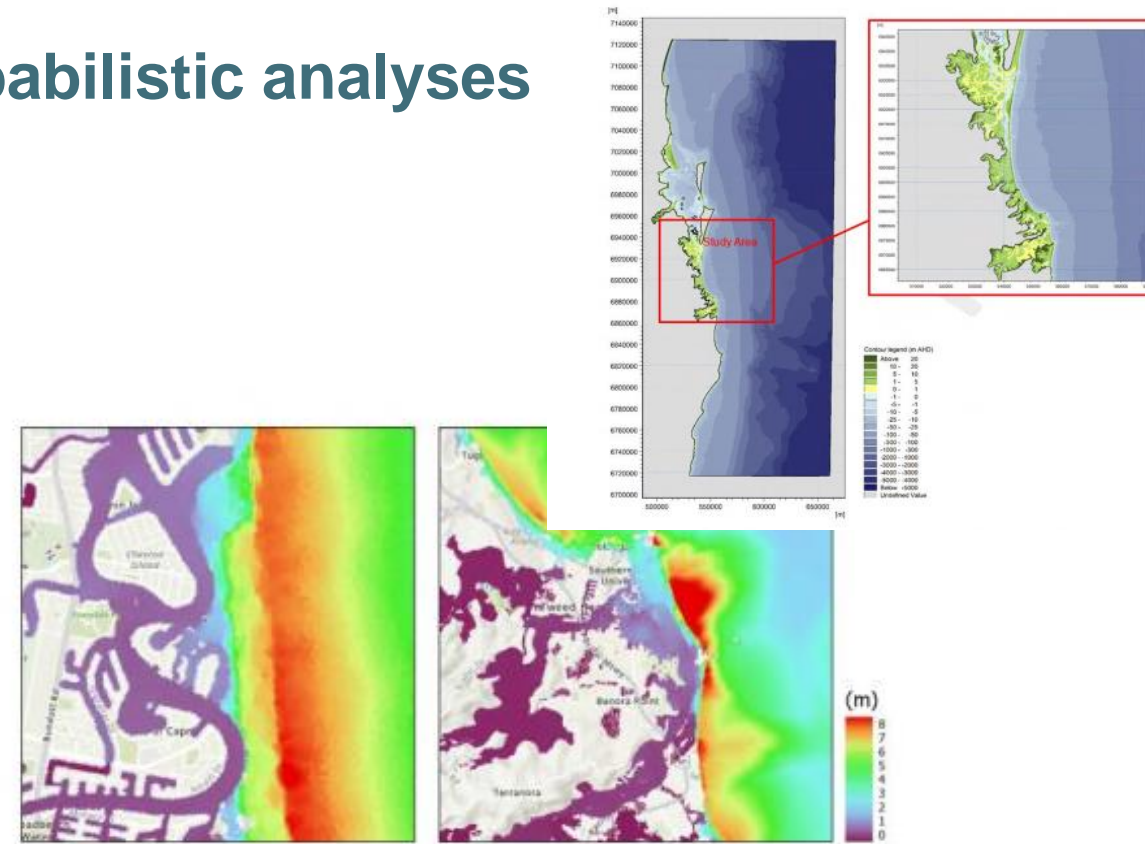


Figure 4 – Envelope of maximum water level for 10,000-yr ARI events at HAT. Left: Surfers Paradise; Right: Tweed Heads.

Australasian Coasts & Ports 2023 Conference – Sunshine Coast, QLD, 15 – 18 August 2023

Tsunami Inundation Modelling for City of Gold Coast, Australia

Neda Mardani, Paul K. Boswood, Youkai Li, Nick Naderi and Alex Atkinson

Tsunami Inundation Modelling for City of Gold Coast, Australia

Neda Mardani¹, Paul K. Boswood¹, Youkai Li¹, Nick Naderi¹ and Alex Atkinson¹

¹ Queensland Government Hydraulics Laboratory. Qld Department of Environment and Science, Brisbane, Queensland, Australia; Neda.Mardani@des.qld.gov.au

Example: Probabilistic tsunami inundation hazard assessment

- Inundation hazards for all NSW & Lord Howe Island, Australia

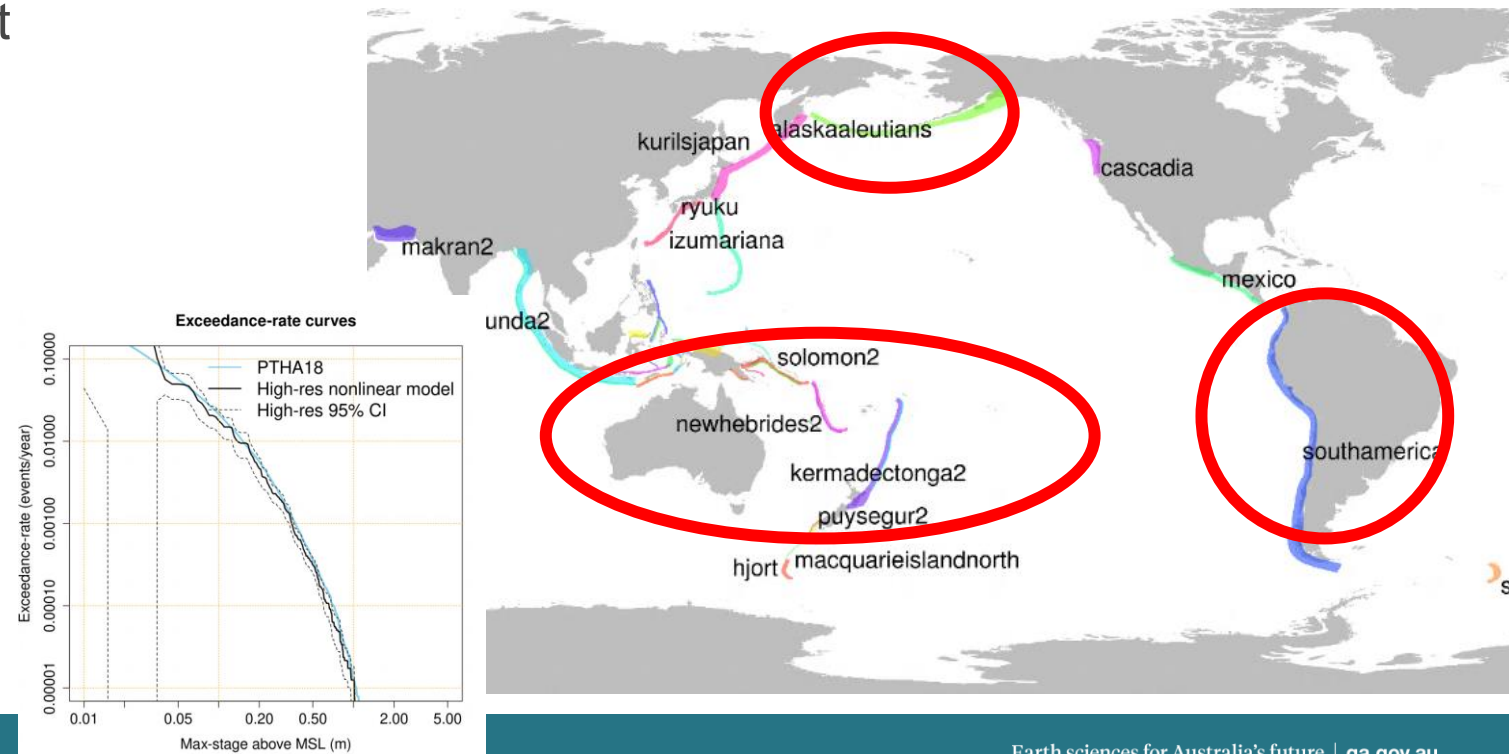
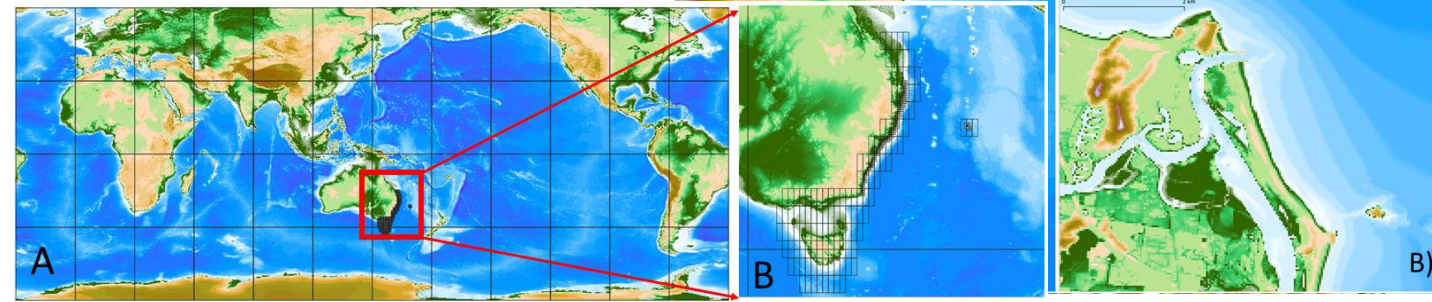
- ~1000 km coast @ ~33m res
- In-process

- Subset of PTHA18 source-zones

- Hazard deaggregation & judgement

- Monte Carlo approach

- Rigorously approximate the “all scenarios” solution
- Importance sampling
 - Focus on hazardous waves
 - ~1000 inundation scenarios total



Example: Probabilistic tsunami inundation hazard assessment

- PRELIMINARY!**

- More scenarios to run

Rate of inundation events/yr

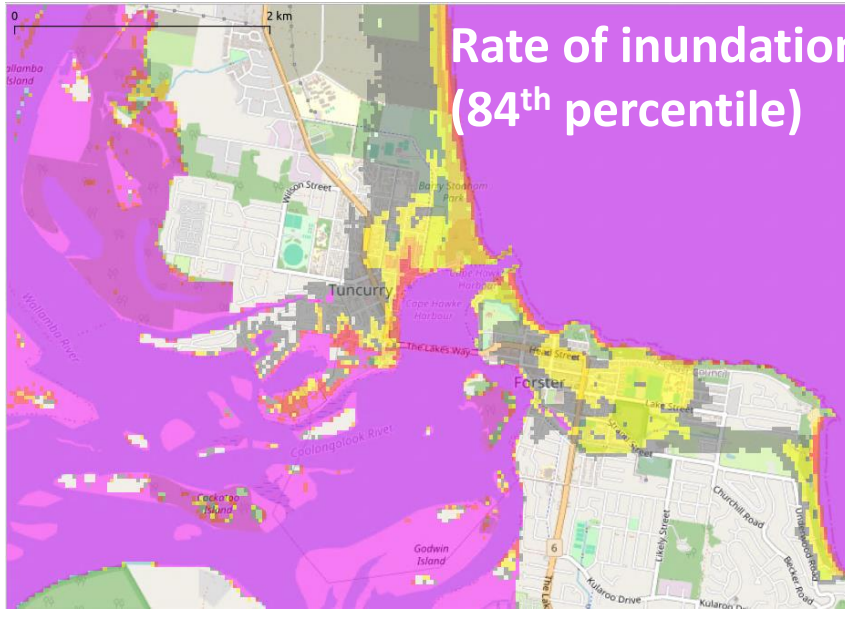
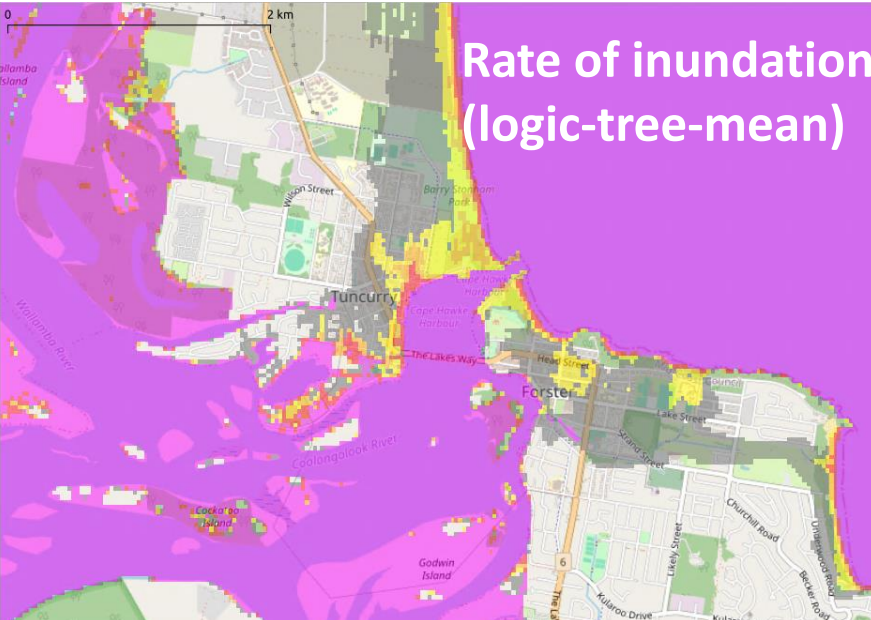
Purple: > 1

Red: 1 - 1/100

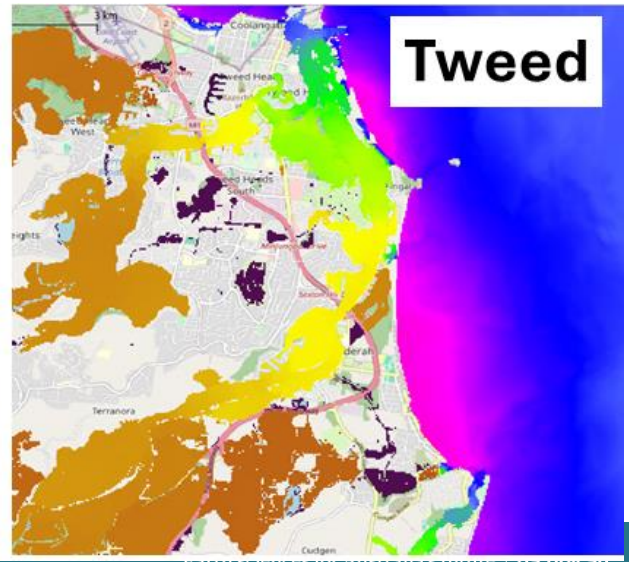
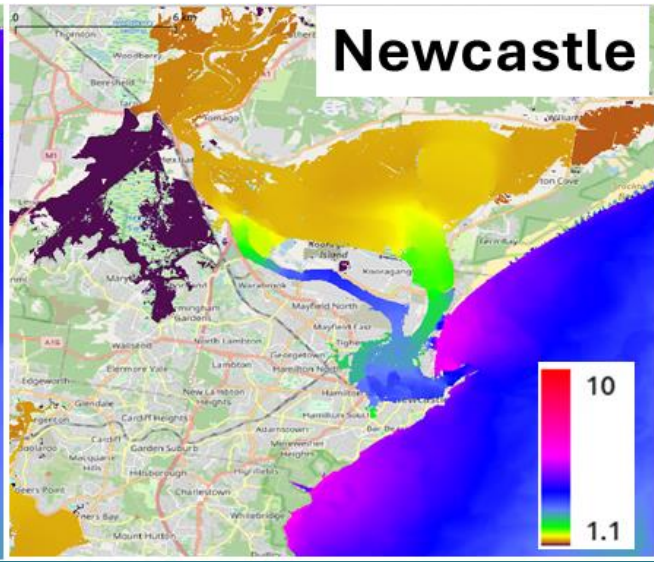
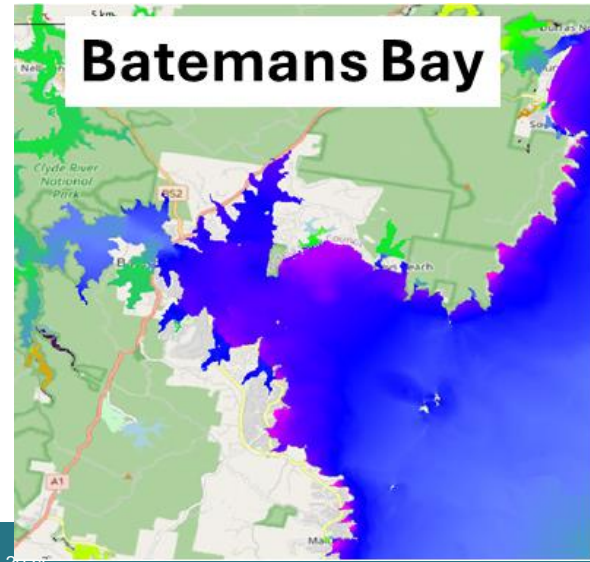
Orange: 1/100 – 1/500

Yellow: 1/500 – 1/2500

Grey: 1/2500 – 1/10000



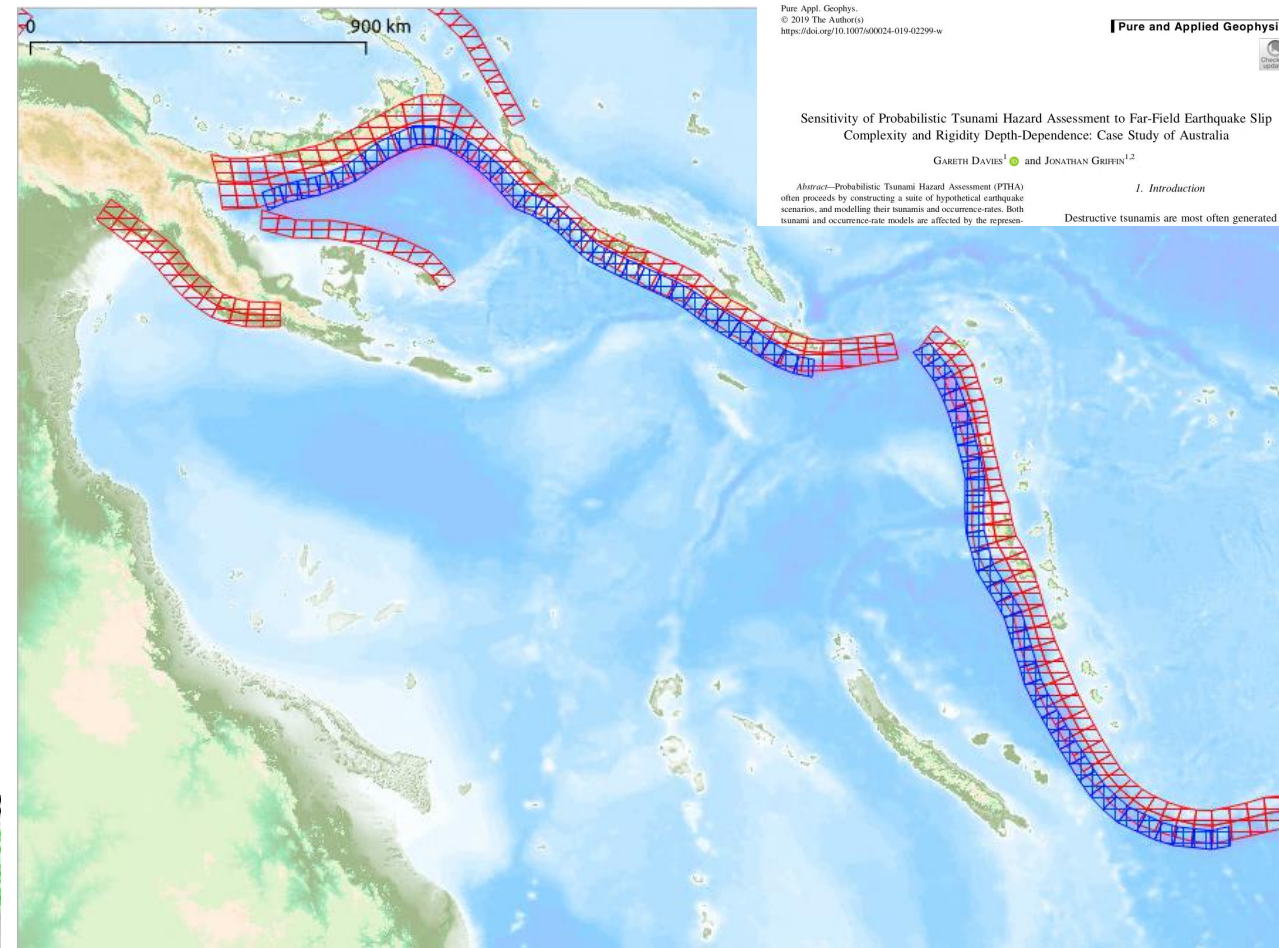
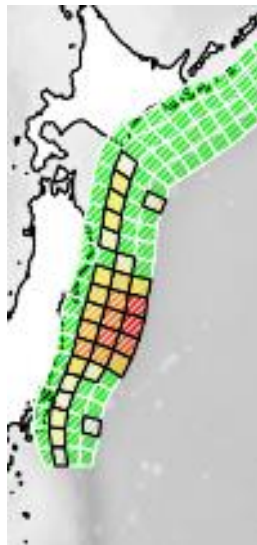
Tsunami maxima (m above MSL), exceedance-rate 1/2500, 84 percentile



2018 Australian PTHA in the region from New Hebrides to New Britain

The region according to PTHA18

- **Globally uniform methodology**
 - Not tuned to this region
 - Davies and Griffin (2020)
- **Two main subduction zones**
 - Solomon (inc. New Britain)
 - New Hebrides
 - 50% unsegmented, 50% segmented
- **Thrust and Outer-rise (normal)**
 - Separate (no mixed-mechanism scenarios)
 - Rigidity **30 GPA** and **60 GPA**
 - ~50x50 km² unit sources
 - Internal structure
 - Geometry from SLAB or other



Pure Appl. Geophys.
© 2019 The Author(s)
<https://doi.org/10.1007/s00024-019-02299-w>

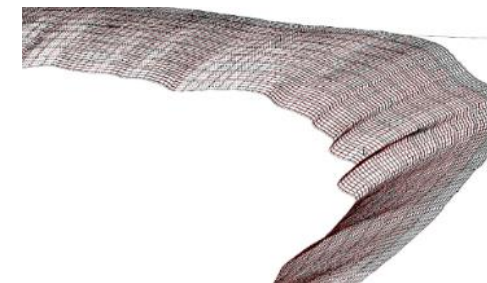
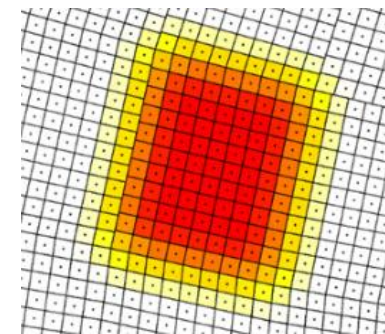
Pure and Applied Geophysics

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

GARETH DAVIES¹ and JONATHAN GRIFFIN^{1,2}

Abstract—Probabilistic Tsunami Hazard Assessment (PTHA) often proceeds by constructing a suite of hypothetical earthquake scenarios, and modelling their tsunamis and occurrence rates. Both tsunami and occurrence-rate models are affected by the representation of slip complexity and rigidity depth-dependence. Destructive tsunamis are most often generated by

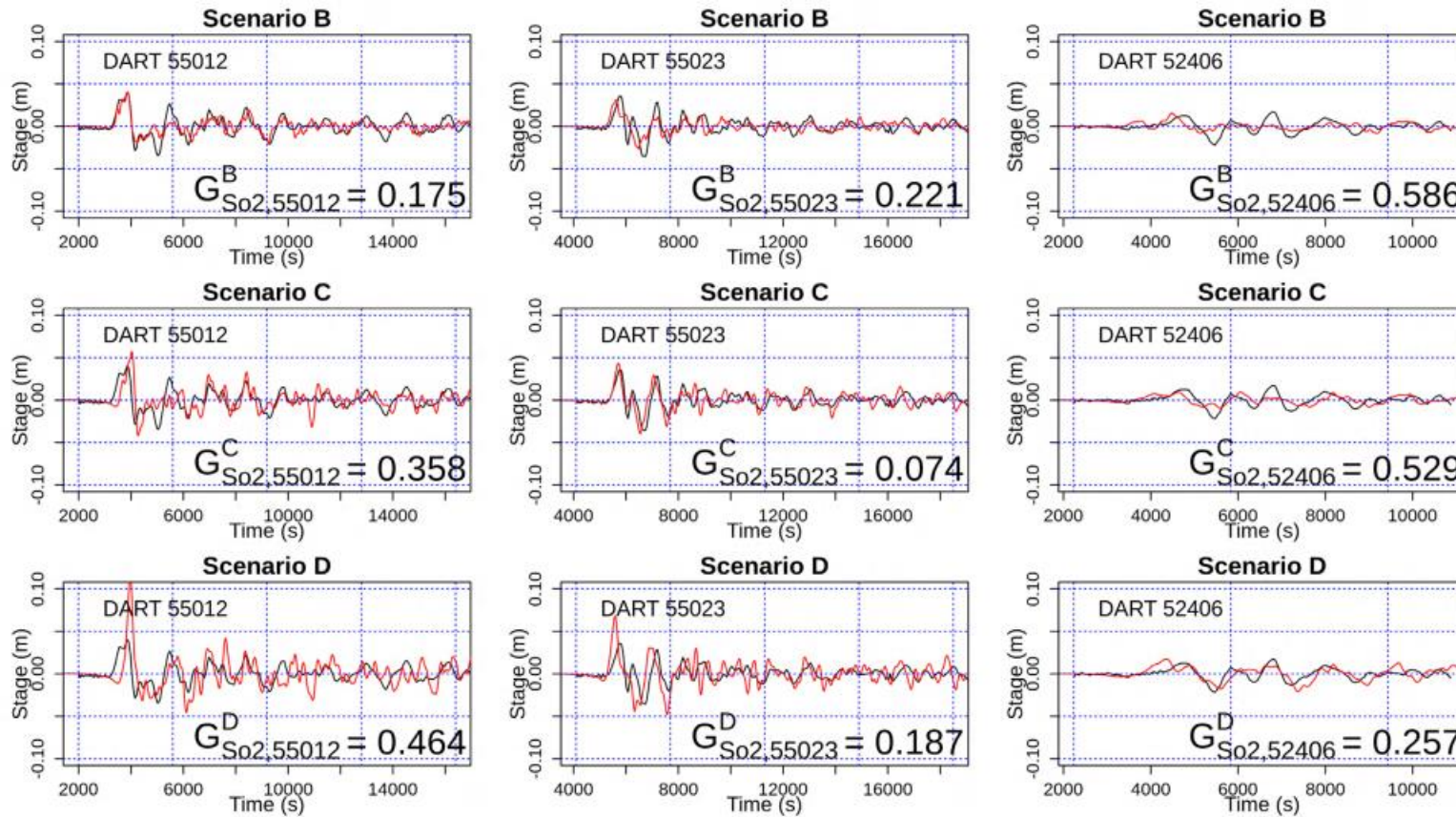
1. Introduction



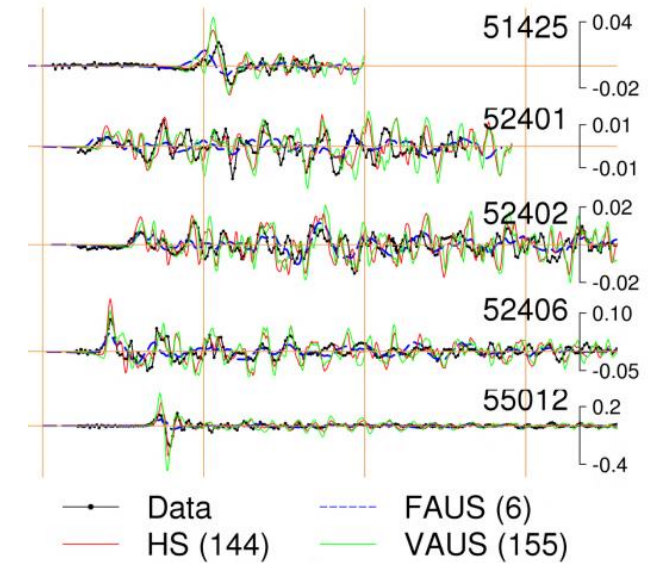
Historical tsunamis vs PTHA18 scenarios with “similar location & Mw”

- *Data vs “similar” random scenarios*

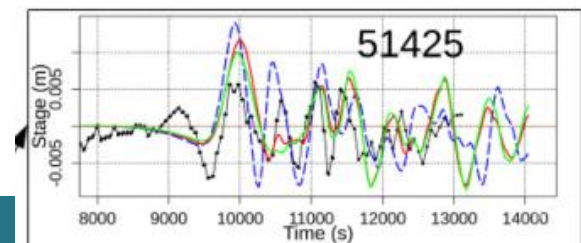
Solomon 2016/12/08 Mw 7.8



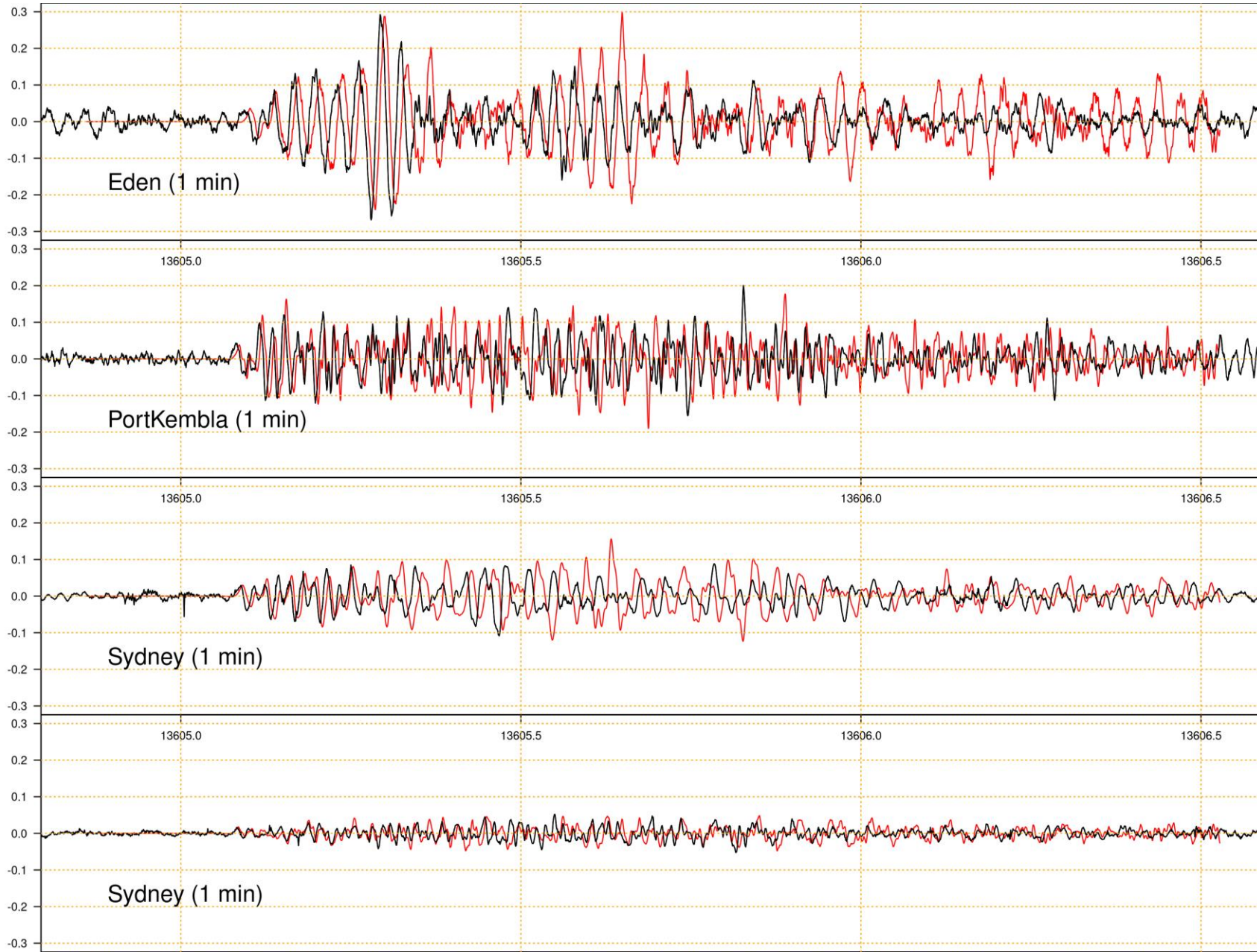
Santa Cruz 2013/02/06 Mw 7.9



2009/02/06 Mw 7.8



Nearshore tide-gauges in Australia

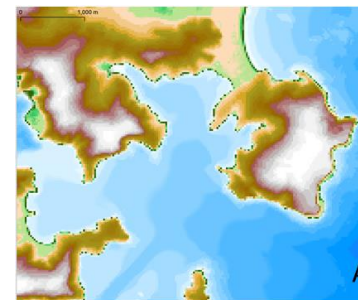
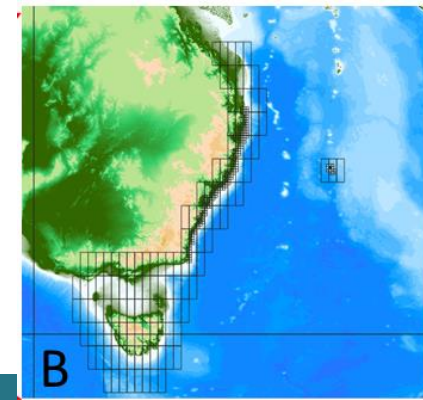
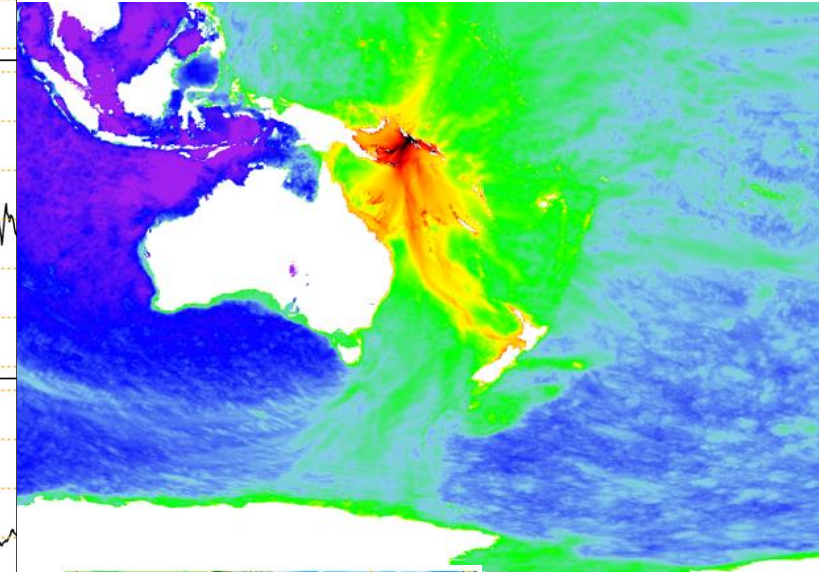


Solomon 2007/04/01

Mw 8.1

Observed

PTHA18 scenario

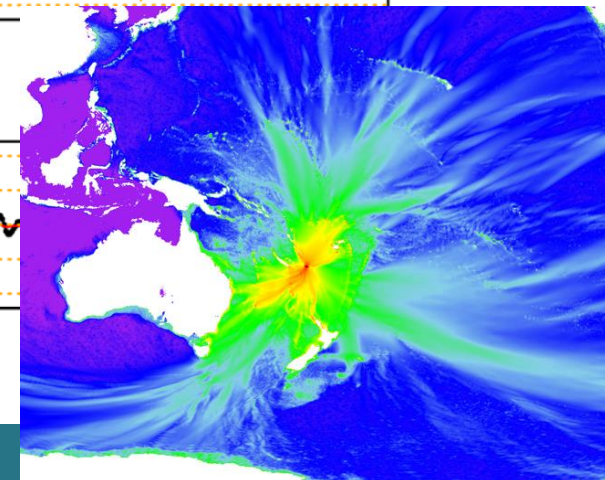
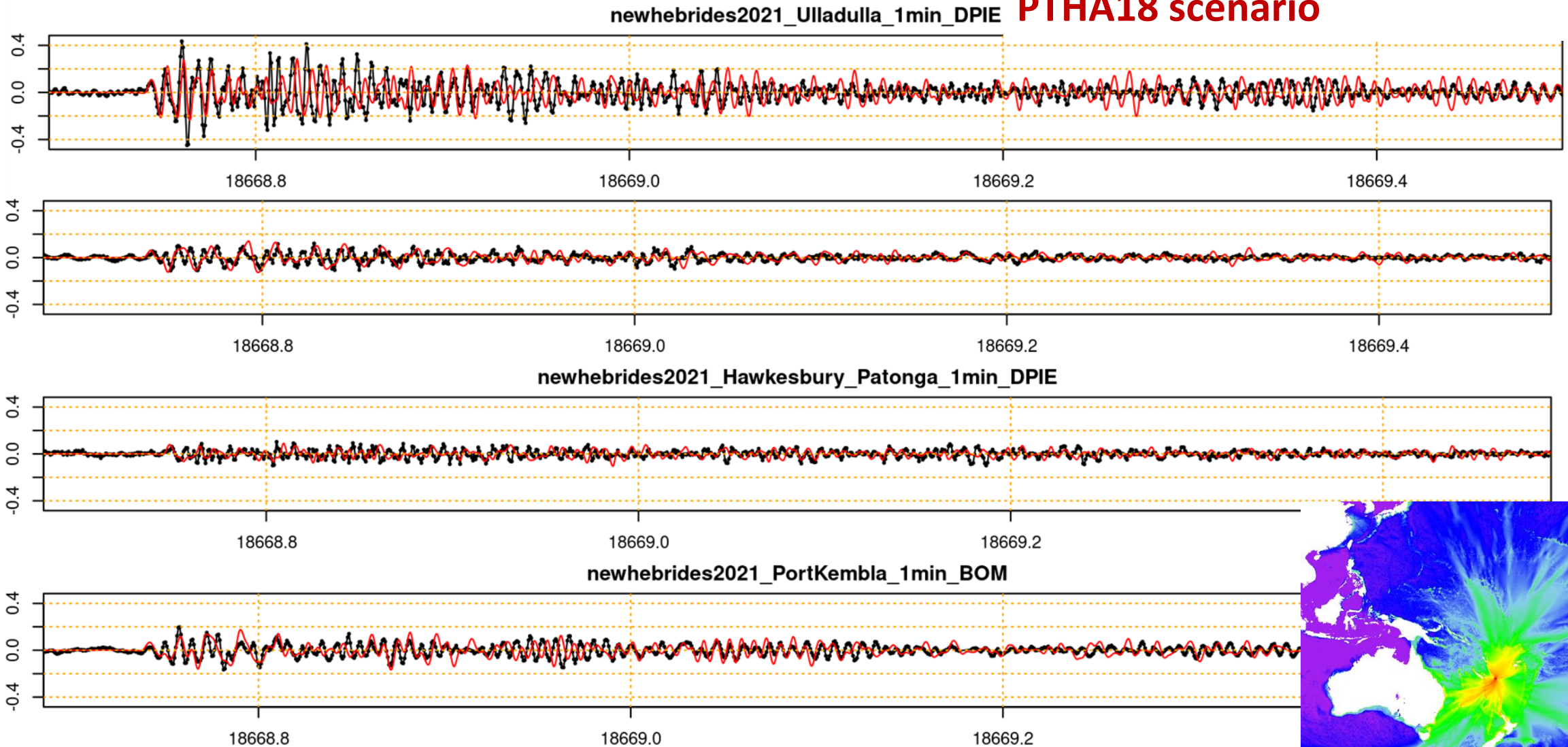


Nearshore tide-gauges in Australia

[New Hebrides 2021/02/04 Mw 7.7](#)

Observed

PTHA18 scenario



Mw-frequency models: 50:50 weight on unsegmented and union-of-segments

New Hebrides thrust: Unsegmented

Pure Appl. Geophys.
 © 2019 The Author(s)
<https://doi.org/10.1007/s00024-019-02299-w>

Pure and Applied Geophysics



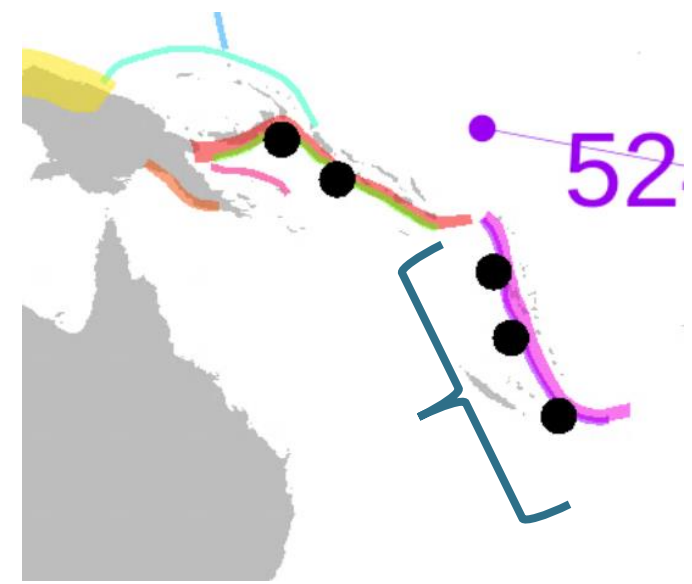
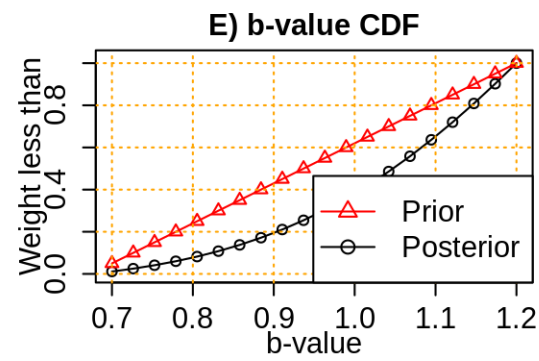
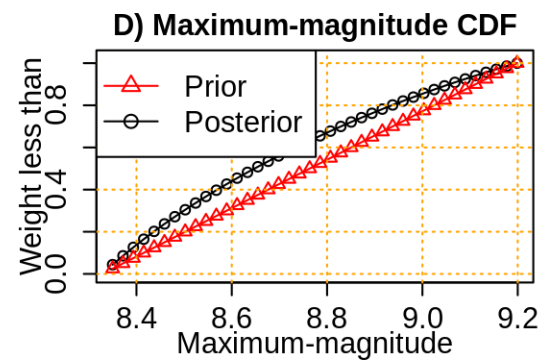
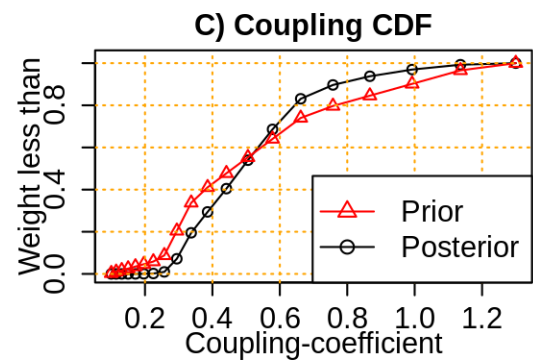
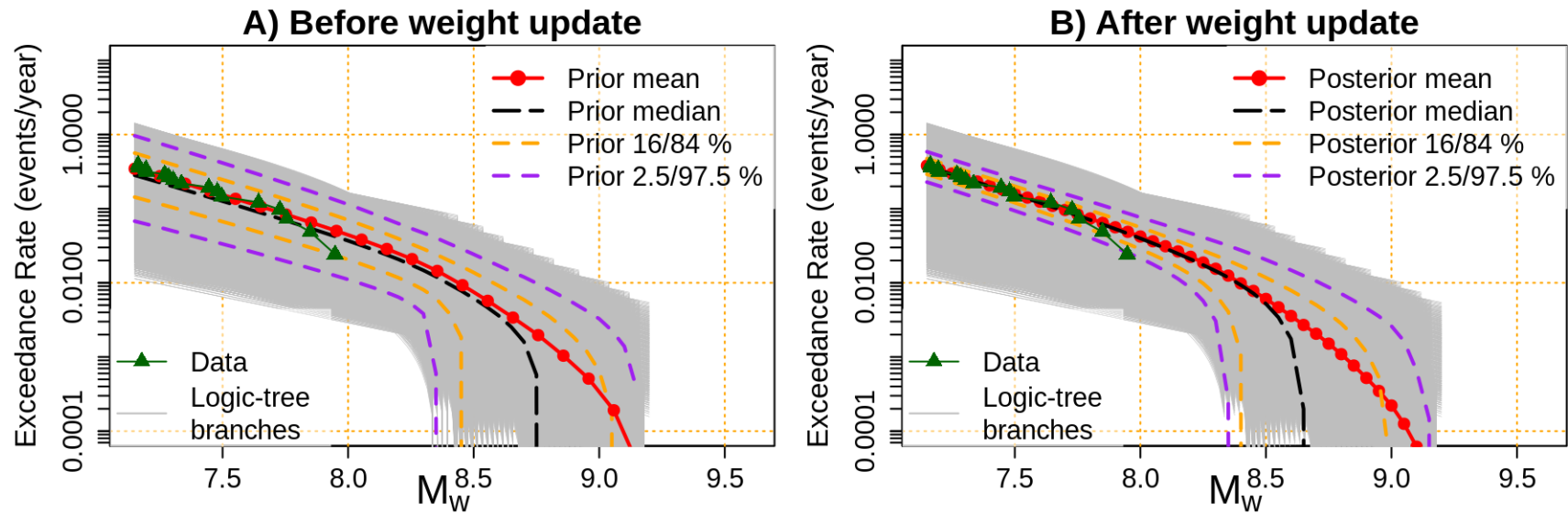
Sensitivity of Probabilistic Tsunami Hazard Assessment to Far-Field Earthquake Slip Complexity and Rigidity Depth-Dependence: Case Study of Australia

GARETH DAVIES¹ and JONATHAN GRIFFIN^{1,2}

Abstract—Probabilistic Tsunami Hazard Assessment (PTHA) often proceeds by constructing a suite of hypothetical earthquake scenarios, and modelling their tsunamis and occurrence-rates. Both tsunami and occurrence-rate models are affected by the repres-

1. Introduction

Destructive tsunamis are most often generated by



Mw-frequency models: 50:50 weight on unsegmented and union-of-segments

New Hebrides thrust: Matthew Hunter segment

Pure Appl. Geophys.
© 2019 The Author(s)
<https://doi.org/10.1007/s00024-019-02299-w>

Pure and Applied Geophysics



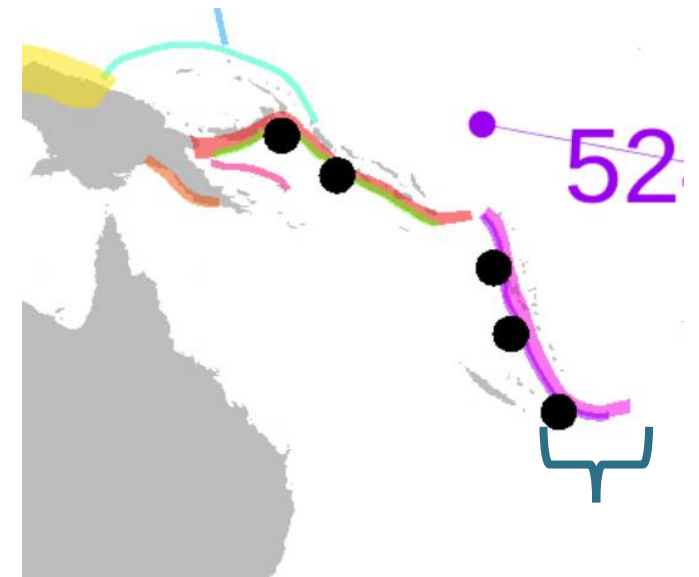
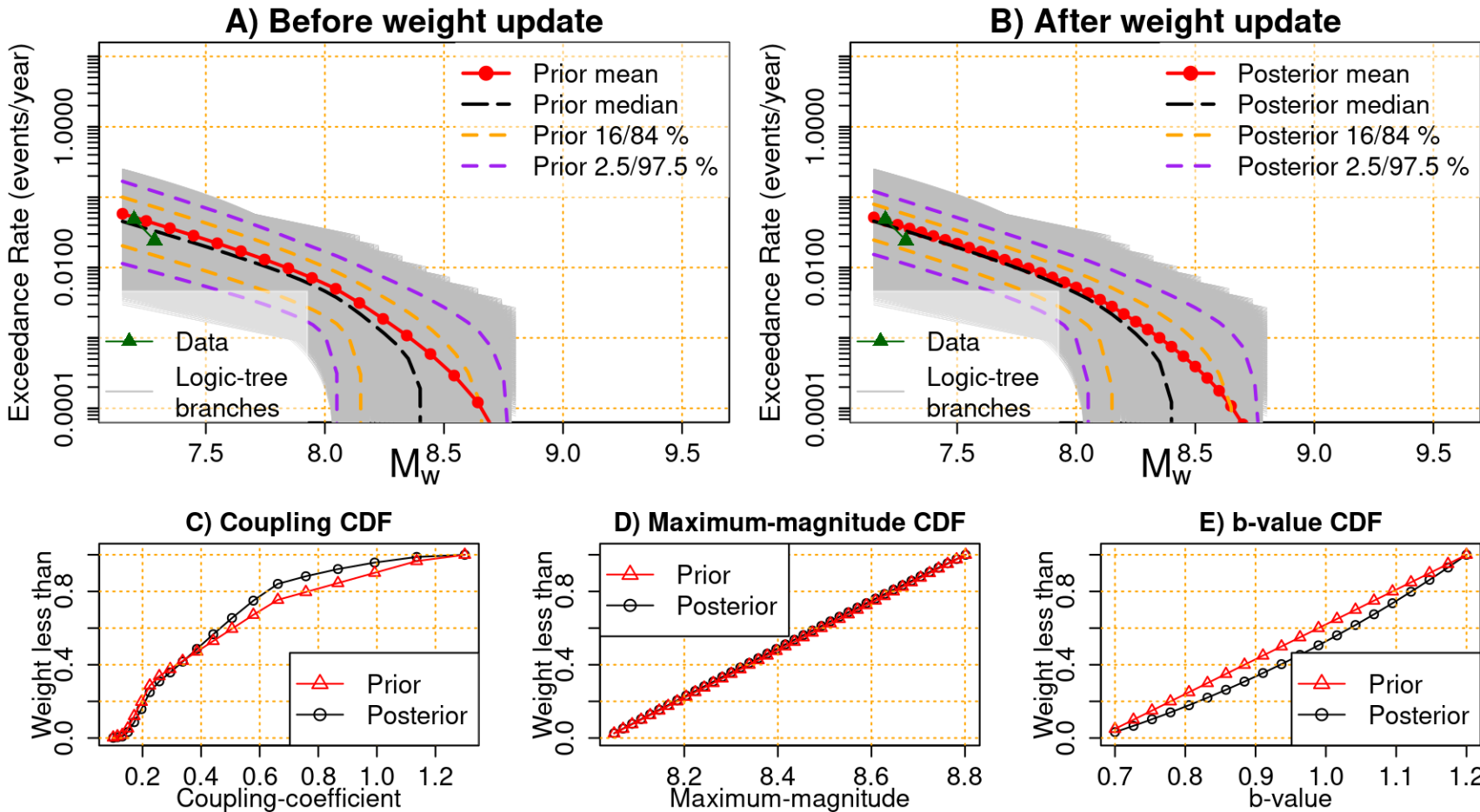
Sensitivity of Probabilistic Tsunami Hazard Assessment to Far-Field Earthquake Slip Complexity and Rigidity Depth-Dependence: Case Study of Australia

GARETH DAVIES¹ and JONATHAN GRIFFIN^{1,2}

Abstract—Probabilistic Tsunami Hazard Assessment (PTHA) often proceeds by constructing a suite of hypothetical earthquake scenarios, and modelling their tsunamis and occurrence-rates. Both tsunami and occurrence-rate models are affected by the repres-

1. Introduction

Destructive tsunamis are most often generated by



Mw-frequency models: 50:50 weight on unsegmented and union-of-segments

New Hebrides thrust: South segment

Pure Appl. Geophys.
© 2019 The Author(s)
<https://doi.org/10.1007/s00024-019-02299-w>

Pure and Applied Geophysics



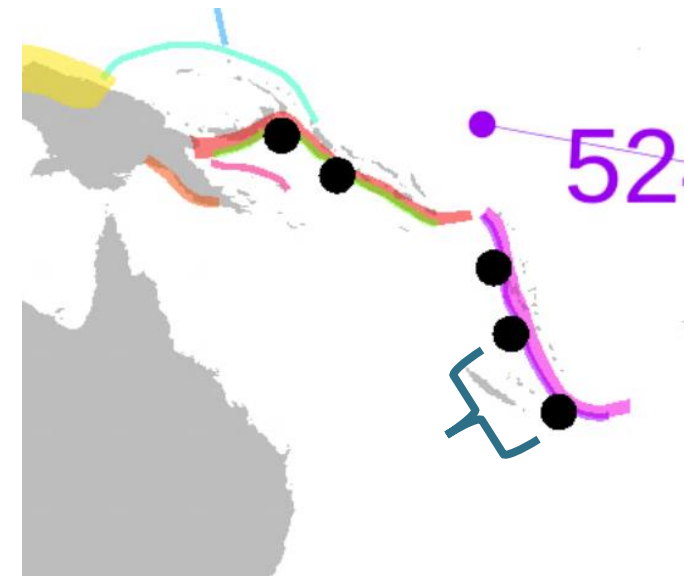
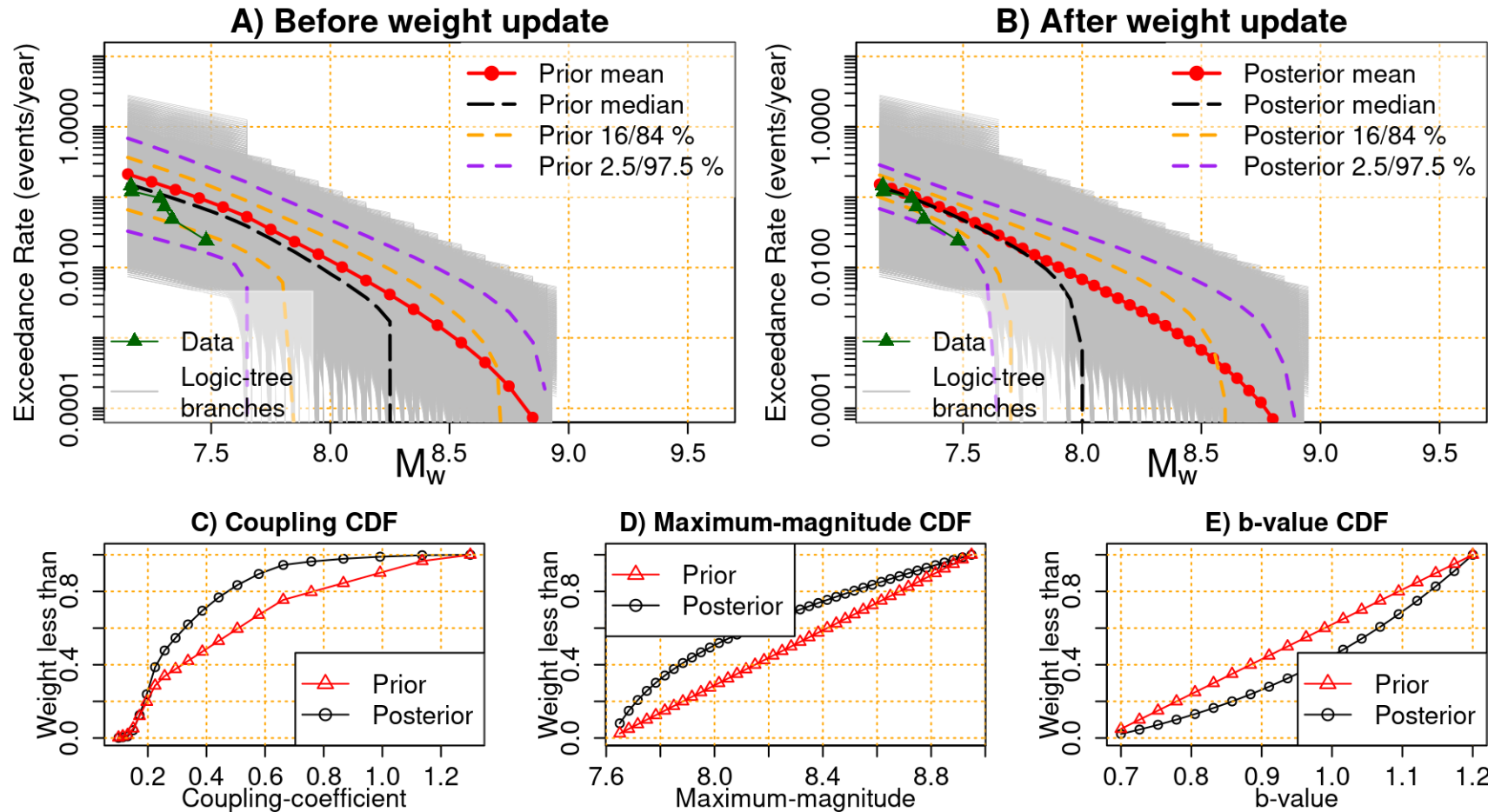
Sensitivity of Probabilistic Tsunami Hazard Assessment to Far-Field Earthquake Slip Complexity and Rigidity Depth-Dependence: Case Study of Australia

GARETH DAVIES¹ and JONATHAN GRIFFIN^{1,2}

Abstract—Probabilistic Tsunami Hazard Assessment (PTHA) often proceeds by constructing a suite of hypothetical earthquake scenarios, and modelling their tsunamis and occurrence-rates. Both tsunami and occurrence-rate models are affected by the repres-

1. Introduction

Destructive tsunamis are most often generated by



Mw-frequency models: 50:50 weight on unsegmented and union-of-segments

New Hebrides thrust: Central segment

Pure Appl. Geophys.
© 2019 The Author(s)
<https://doi.org/10.1007/s00024-019-02299-w>

Pure and Applied Geophysics



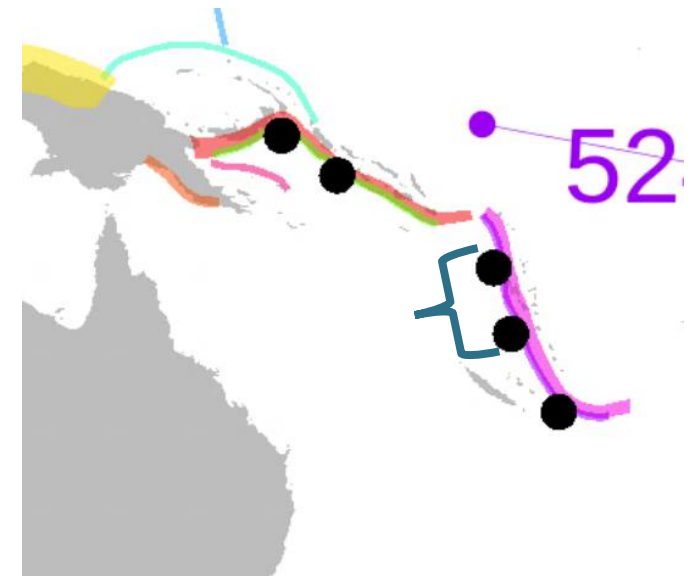
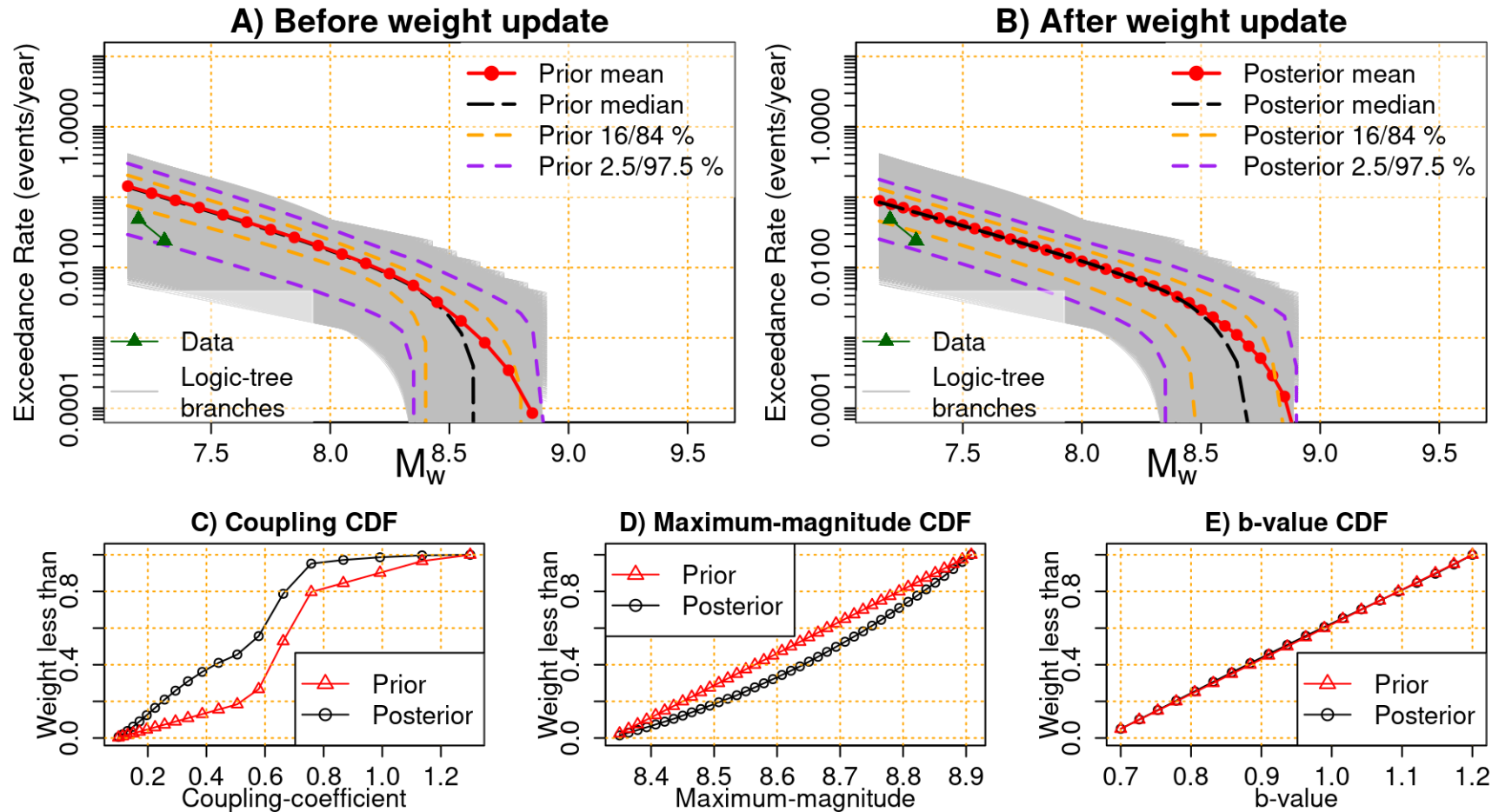
Sensitivity of Probabilistic Tsunami Hazard Assessment to Far-Field Earthquake Slip Complexity and Rigidity Depth-Dependence: Case Study of Australia

GARETH DAVIES¹ and JONATHAN GRIFFIN^{1,2}

Abstract—Probabilistic Tsunami Hazard Assessment (PTHA) often proceeds by constructing a suite of hypothetical earthquake scenarios, and modelling their tsunamis and occurrence-rates. Both tsunami and occurrence-rate models are affected by the represen-

1. Introduction

Destructive tsunamis are most often generated by



Mw-frequency models: 50:50 weight on unsegmented and union-of-segments

New Hebrides thrust: North segment

Pure Appl. Geophys.
© 2019 The Author(s)
<https://doi.org/10.1007/s00024-019-02299-w>

Pure and Applied Geophysics



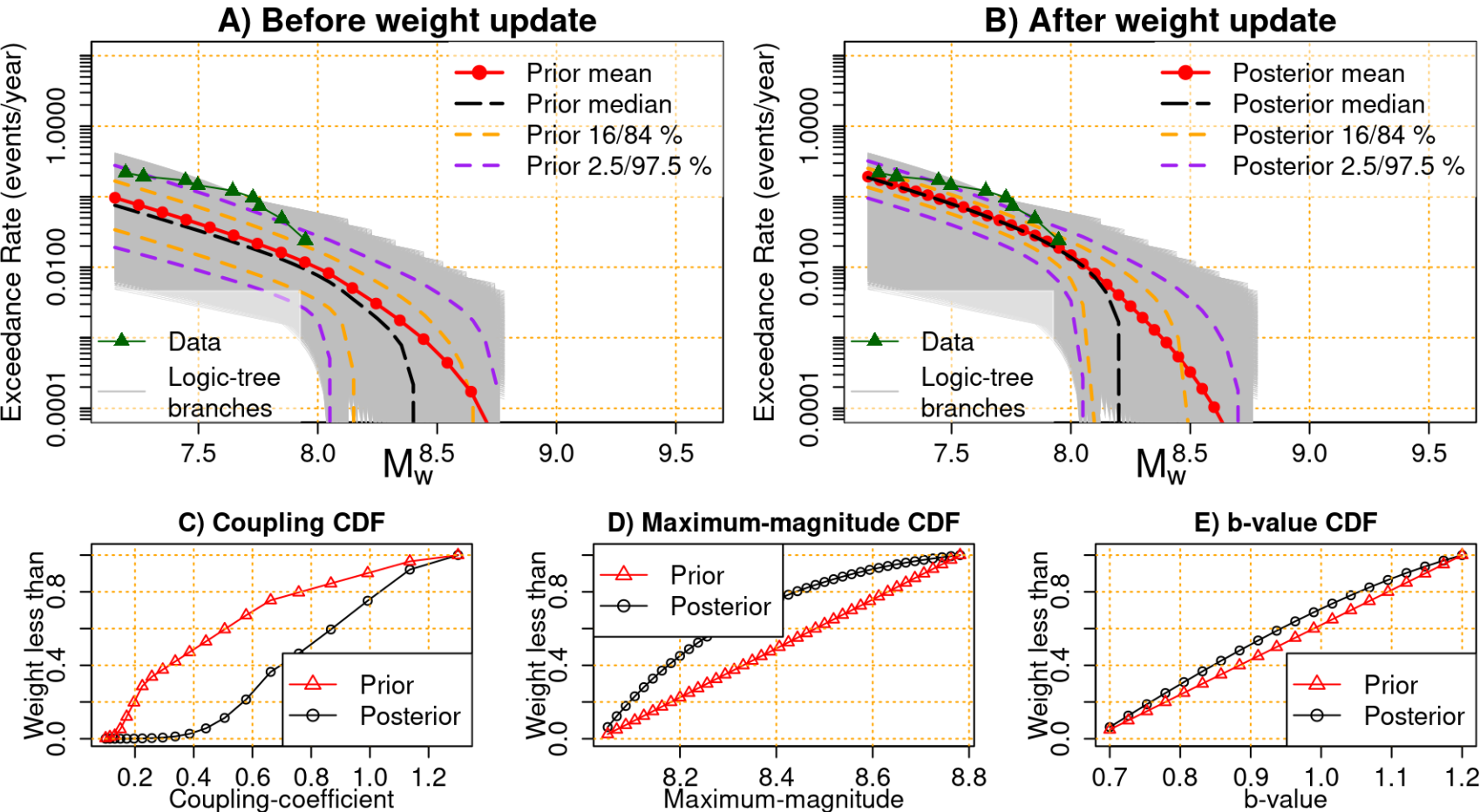
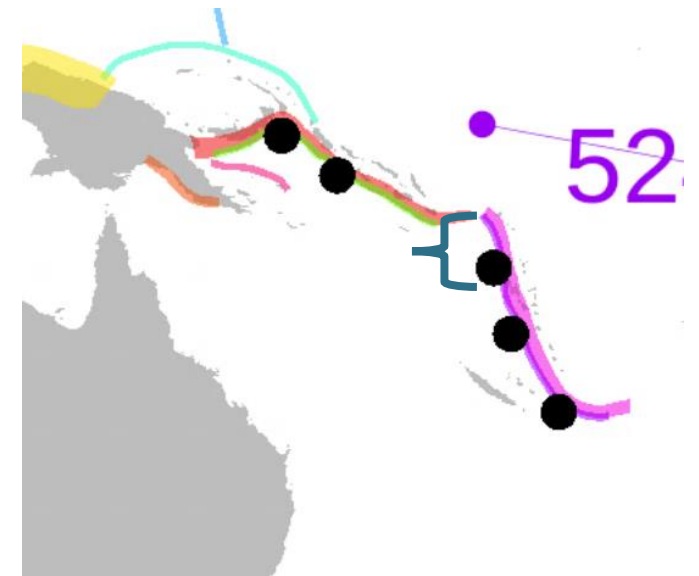
Sensitivity of Probabilistic Tsunami Hazard Assessment to Far-Field Earthquake Slip Complexity and Rigidity Depth-Dependence: Case Study of Australia

GARETH DAVIES¹ and JONATHAN GRIFFIN^{1,2}

Abstract—Probabilistic Tsunami Hazard Assessment (PTHA) often proceeds by constructing a suite of hypothetical earthquake scenarios, and modelling their tsunamis and occurrence-rates. Both tsunami and occurrence-rate models are affected by the repres-

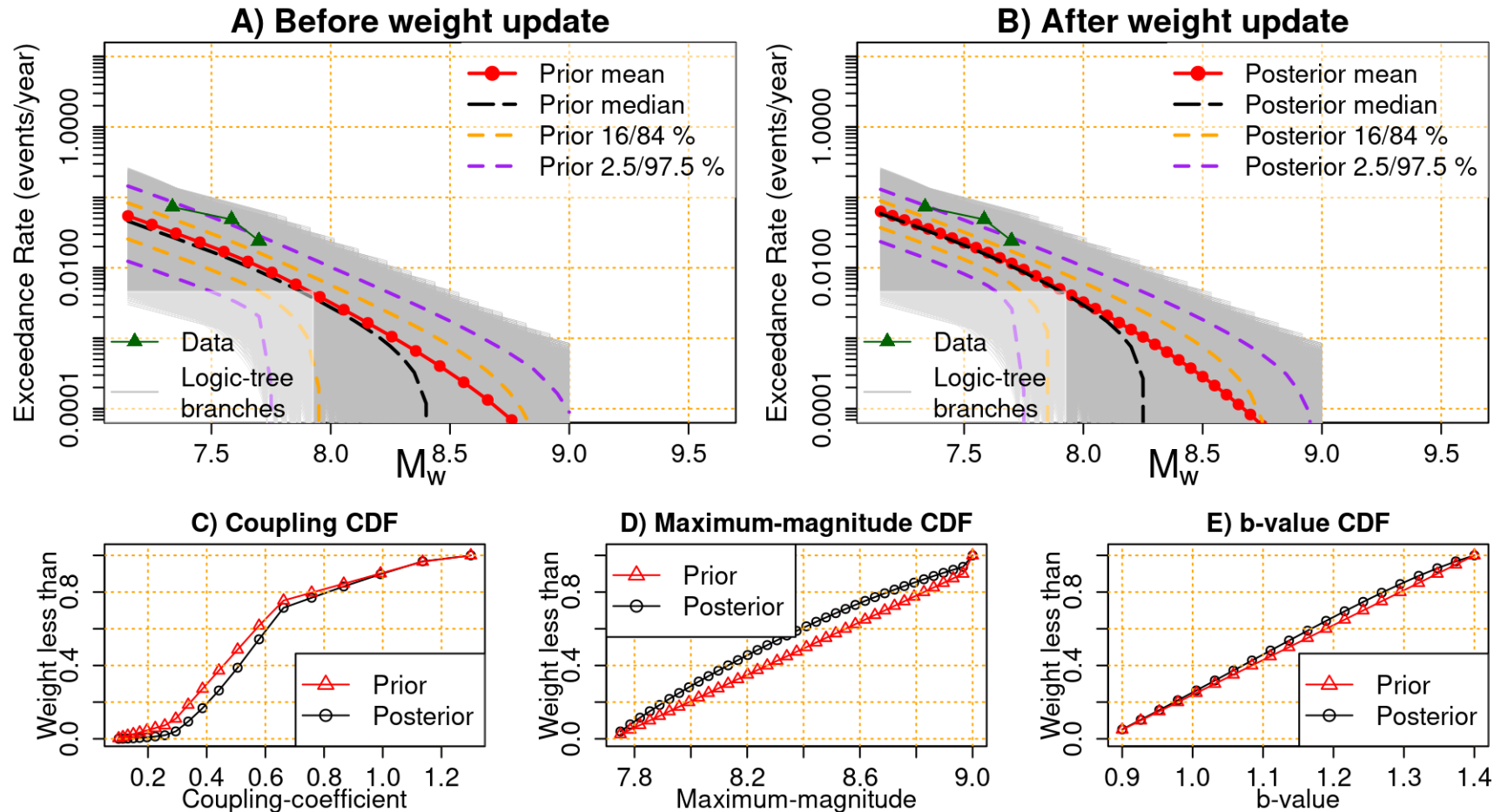
1. Introduction

Destructive tsunamis are most often generated by



Mw-frequency models: outer rise

New Hebrides outer rise



Pure Appl. Geophys.
© 2019 The Author(s)
<https://doi.org/10.1007/s00024-019-02299-w>

Pure and Applied Geophysics



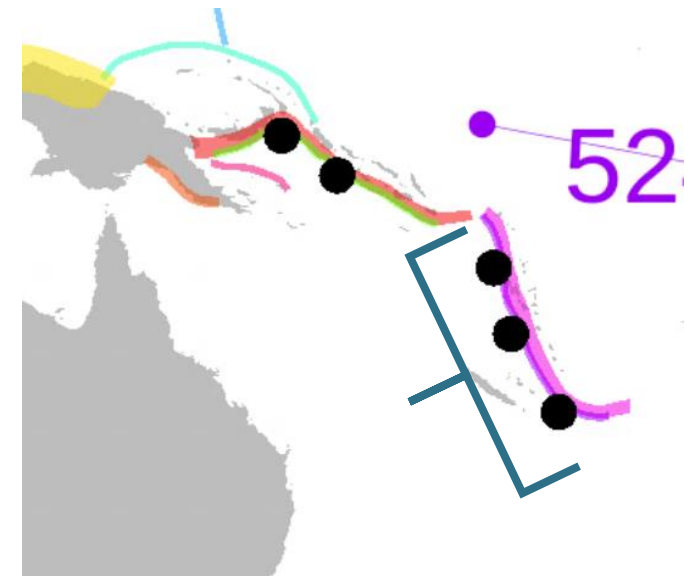
Sensitivity of Probabilistic Tsunami Hazard Assessment to Far-Field Earthquake Slip Complexity and Rigidity Depth-Dependence: Case Study of Australia

GARETH DAVIES¹ and JONATHAN GRIFFIN^{1,2}

Abstract—Probabilistic Tsunami Hazard Assessment (PTHA) often proceeds by constructing a suite of hypothetical earthquake scenarios, and modelling their tsunamis and occurrence-rates. Both tsunami and occurrence-rate models are affected by the repres-

1. Introduction

Destructive tsunamis are most often generated by



Mw-frequency models: 50:50 weight on unsegmented and union-of-segments

Solomon: Unsegmented

Pure Appl. Geophys.
© 2019 The Author(s)
<https://doi.org/10.1007/s00024-019-02299-w>

Pure and Applied Geophysics



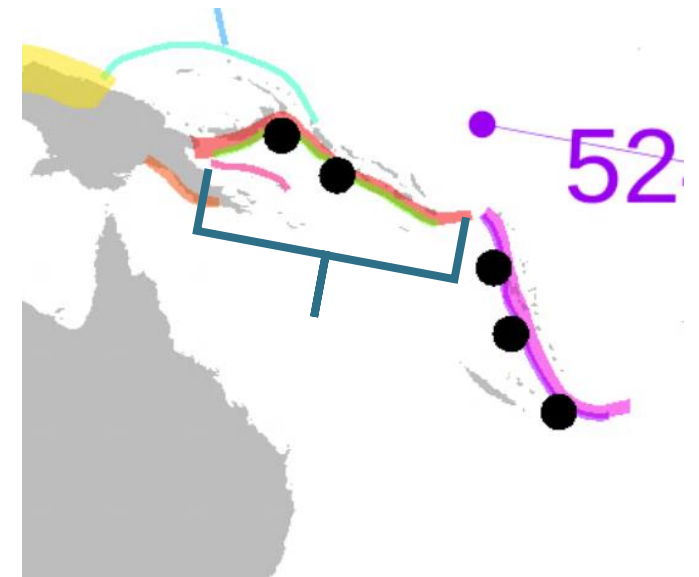
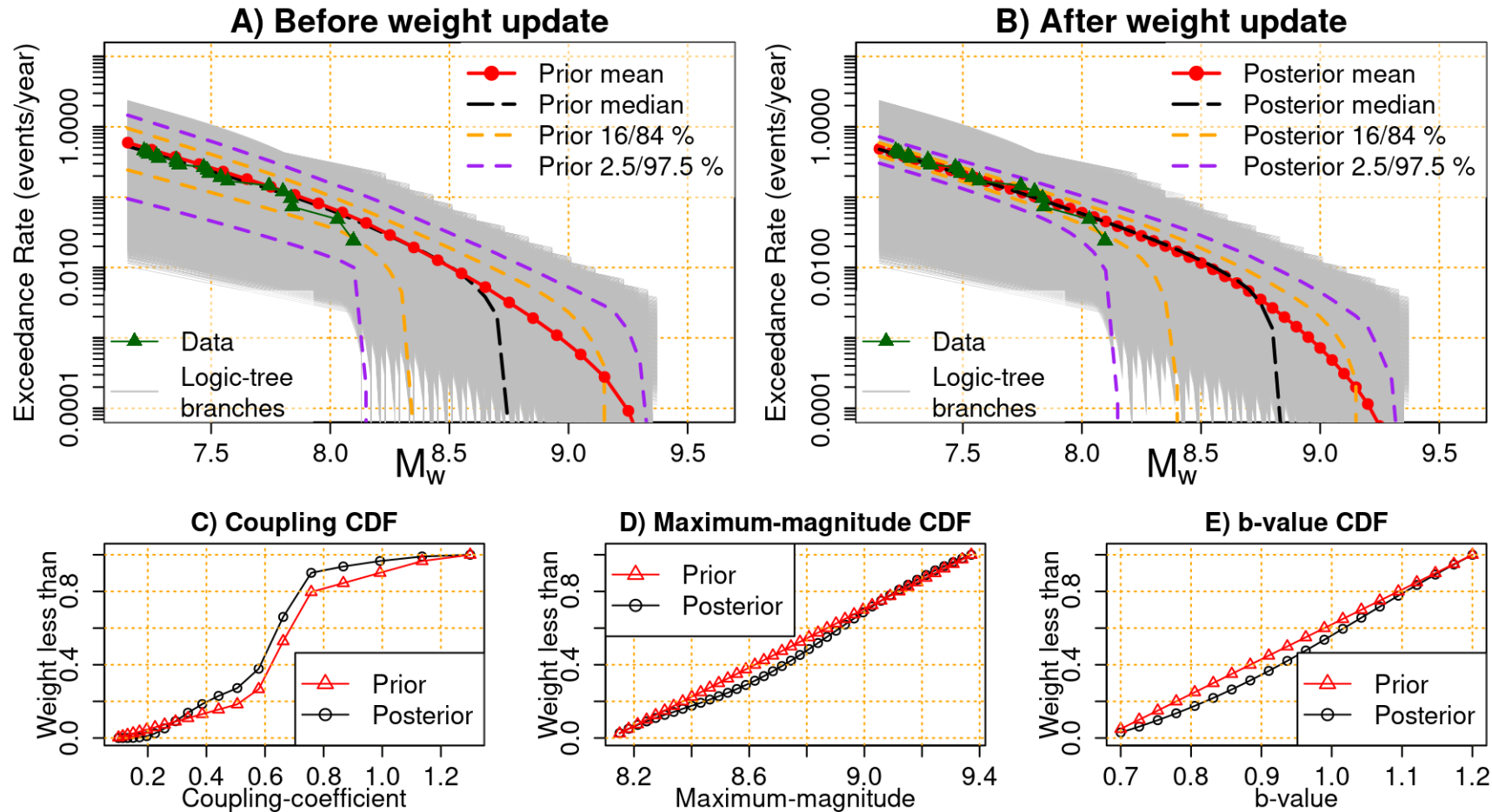
Sensitivity of Probabilistic Tsunami Hazard Assessment to Far-Field Earthquake Slip Complexity and Rigidity Depth-Dependence: Case Study of Australia

GARETH DAVIES¹ and JONATHAN GRIFFIN^{1,2}

Abstract—Probabilistic Tsunami Hazard Assessment (PTHA) often proceeds by constructing a suite of hypothetical earthquake scenarios, and modelling their tsunamis and occurrence-rates. Both tsunami and occurrence-rate models are affected by the repres-

1. Introduction

Destructive tsunamis are most often generated by



Mw-frequency models: 50:50 weight on unsegmented and union-of-segments

Solomon: Southeast segment

Pure Appl. Geophys.
© 2019 The Author(s)
<https://doi.org/10.1007/s00024-019-02299-w>

Pure and Applied Geophysics



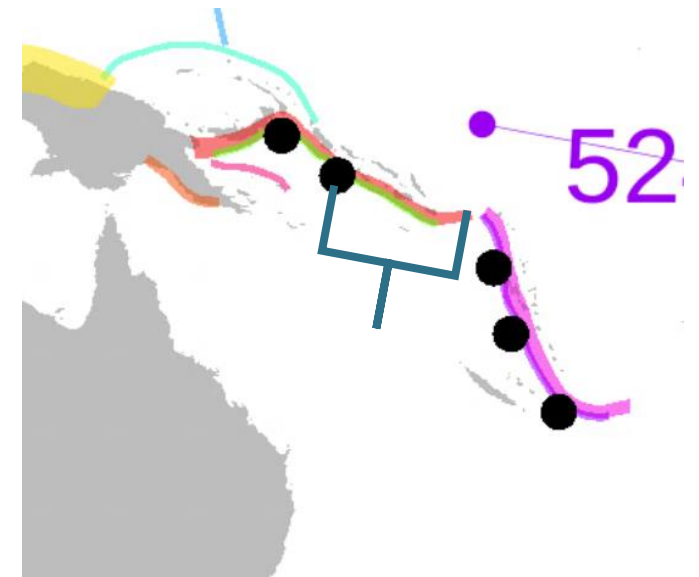
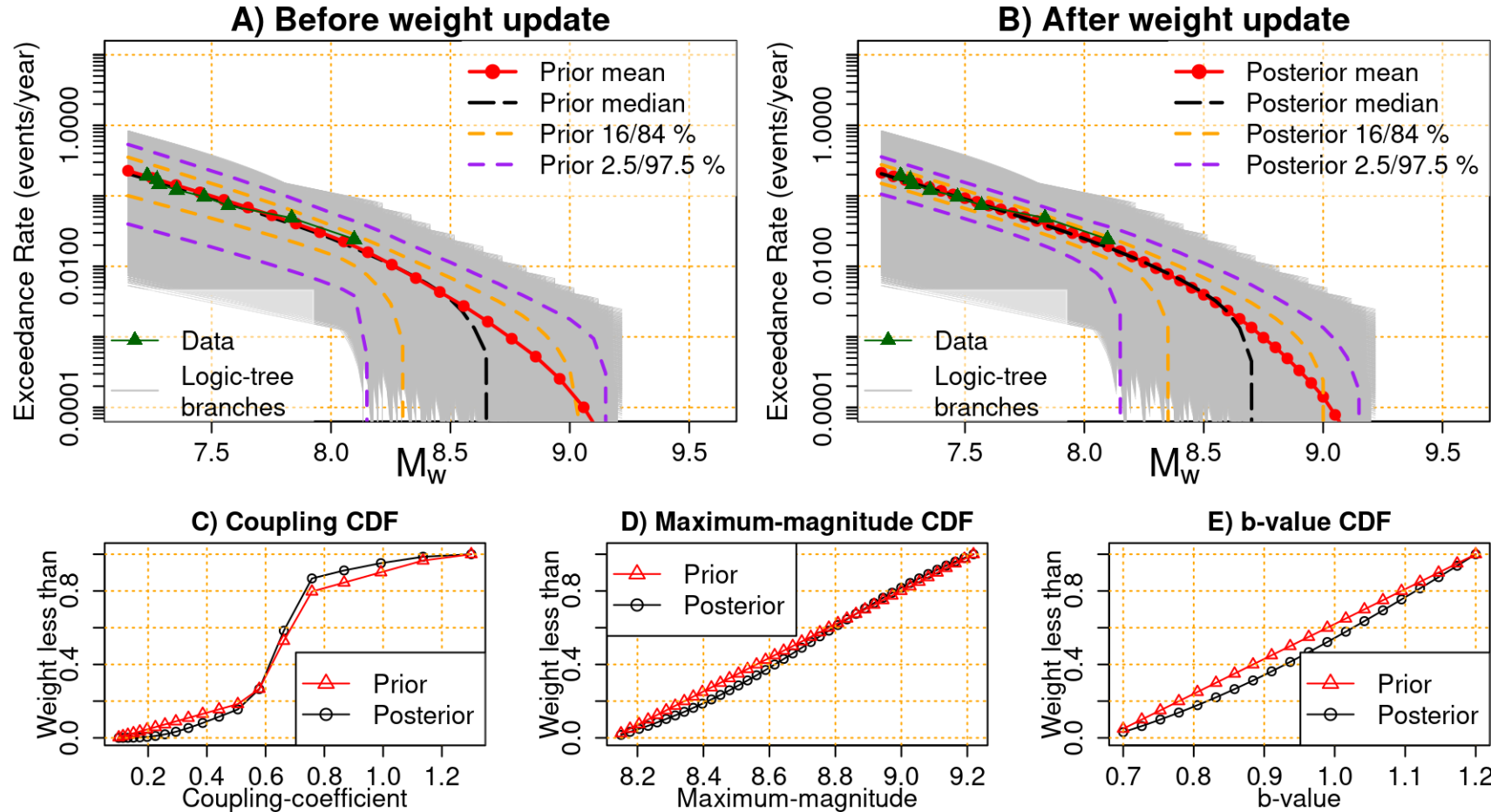
Sensitivity of Probabilistic Tsunami Hazard Assessment to Far-Field Earthquake Slip Complexity and Rigidity Depth-Dependence: Case Study of Australia

GARETH DAVIES¹ and JONATHAN GRIFFIN^{1,2}

Abstract—Probabilistic Tsunami Hazard Assessment (PTHA) often proceeds by constructing a suite of hypothetical earthquake scenarios, and modelling their tsunamis and occurrence-rates. Both tsunami and occurrence-rate models are affected by the repres-

1. Introduction

Destructive tsunamis are most often generated by



Mw-frequency models: 50:50 weight on unsegmented and union-of-segments

Solomon: Northwest segment

Pure Appl. Geophys.
 © 2019 The Author(s)
<https://doi.org/10.1007/s00024-019-02299-w>

Pure and Applied Geophysics



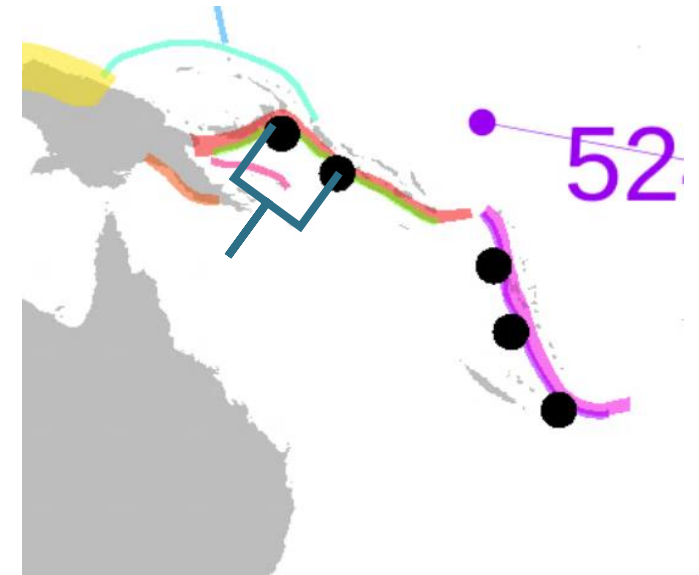
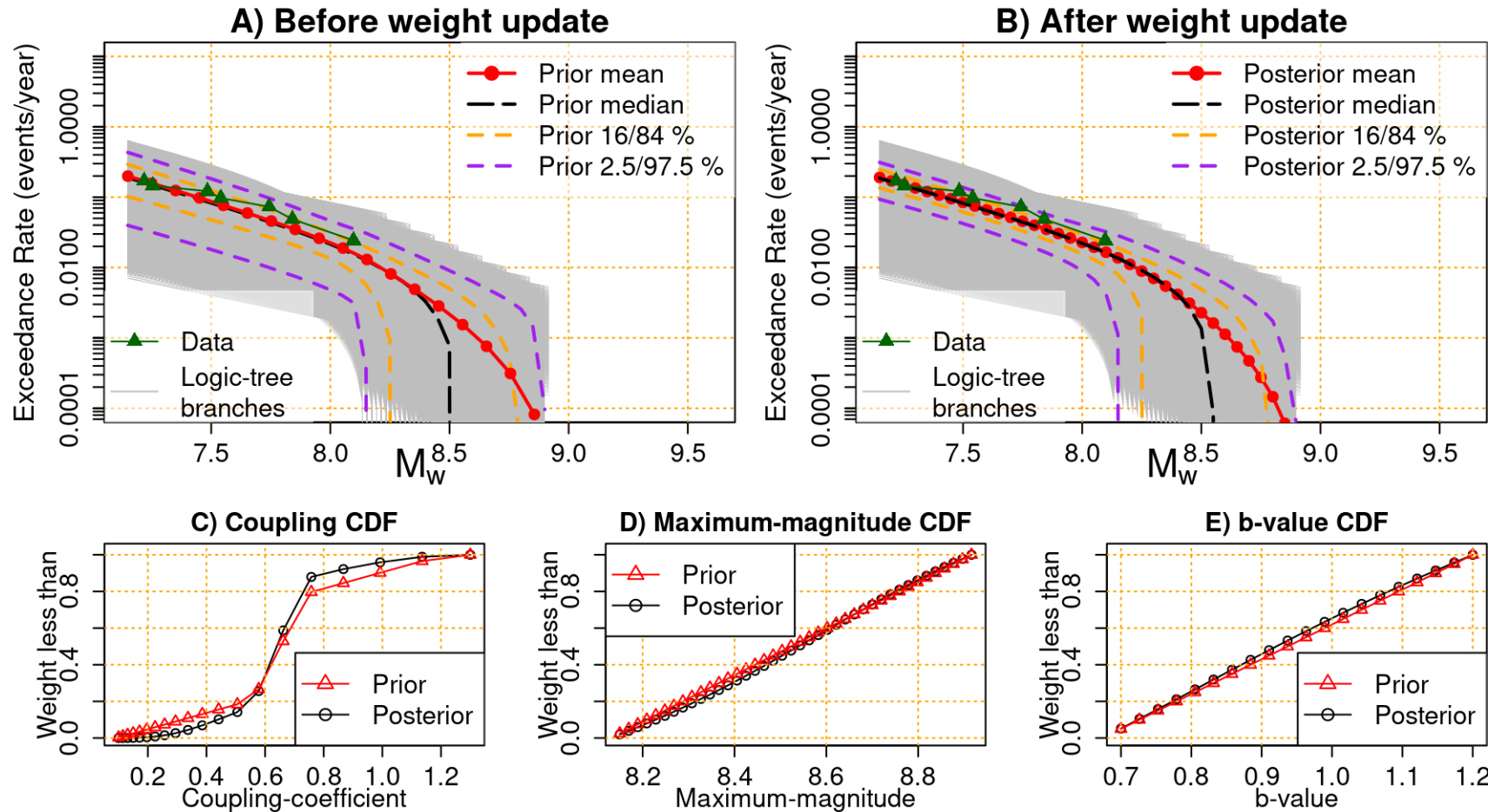
Sensitivity of Probabilistic Tsunami Hazard Assessment to Far-Field Earthquake Slip Complexity and Rigidity Depth-Dependence: Case Study of Australia

GARETH DAVIES¹ and JONATHAN GRIFFIN^{1,2}

Abstract—Probabilistic Tsunami Hazard Assessment (PTHA) often proceeds by constructing a suite of hypothetical earthquake scenarios, and modelling their tsunamis and occurrence-rates. Both tsunami and occurrence-rate models are affected by the represen-

1. Introduction

Destructive tsunamis are most often generated by



Mw-frequency models: 50:50 weight on unsegmented and union-of-segments

Solomon: New Britain segment

Pure Appl. Geophys.
© 2019 The Author(s)
<https://doi.org/10.1007/s00024-019-02299-w>

Pure and Applied Geophysics



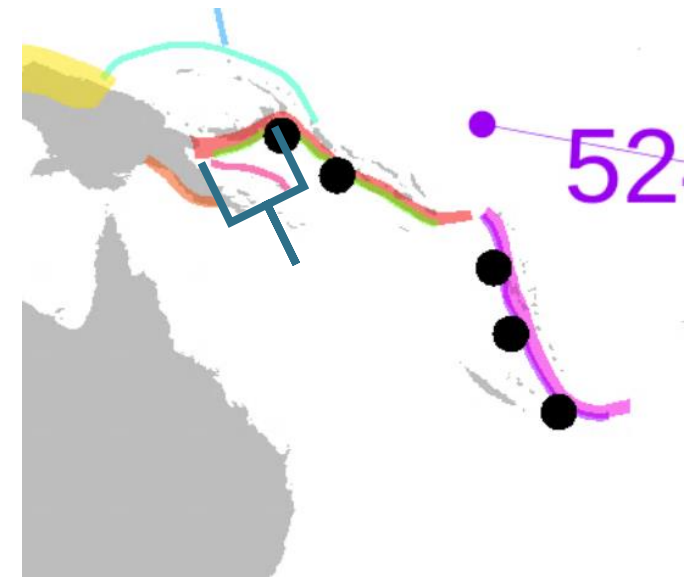
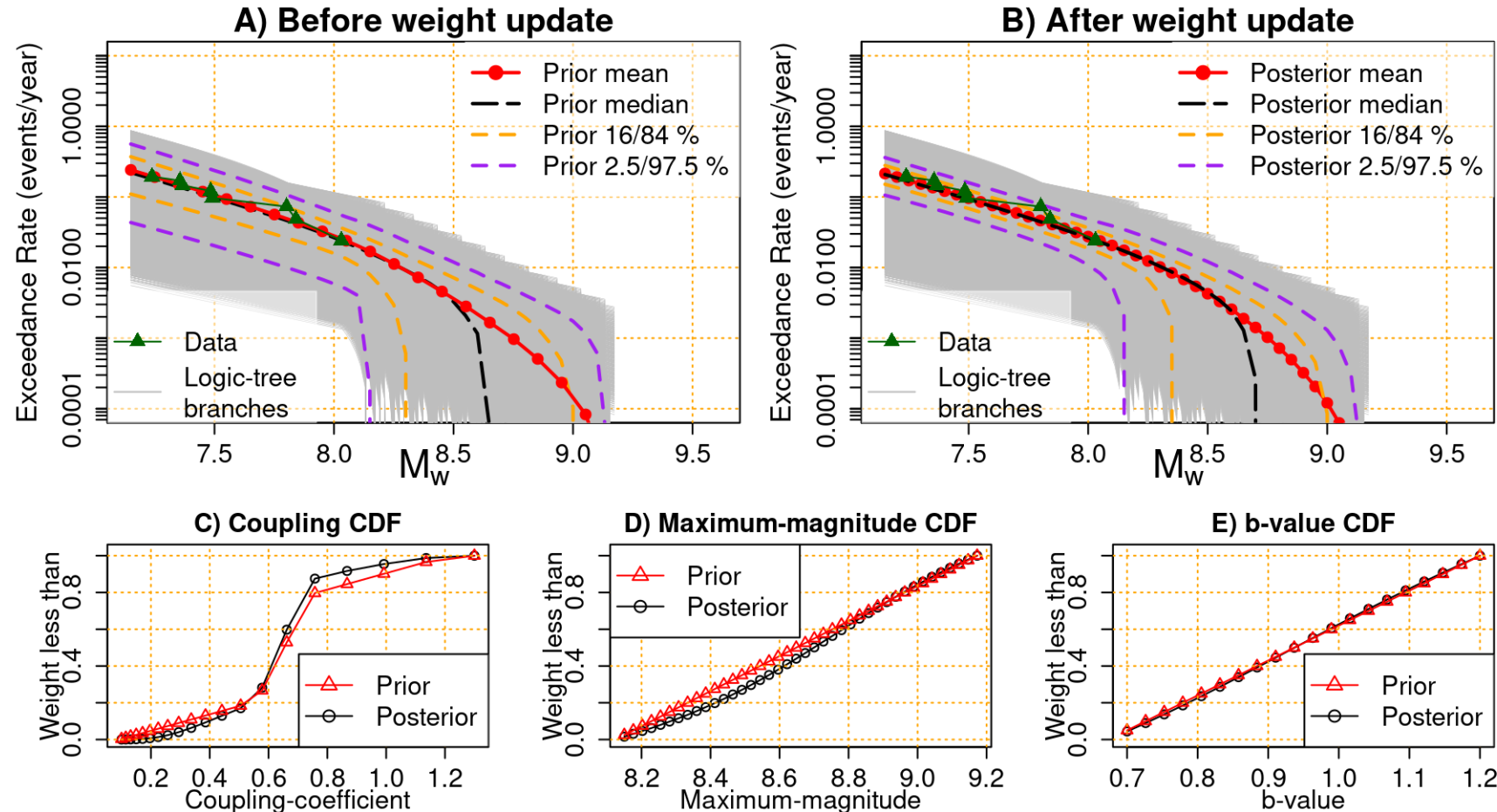
Sensitivity of Probabilistic Tsunami Hazard Assessment to Far-Field Earthquake Slip Complexity and Rigidity Depth-Dependence: Case Study of Australia

GARETH DAVIES¹ and JONATHAN GRIFFIN^{1,2}

Abstract—Probabilistic Tsunami Hazard Assessment (PTHA) often proceeds by constructing a suite of hypothetical earthquake scenarios, and modelling their tsunamis and occurrence-rates. Both tsunami and occurrence-rate models are affected by the repres-

1. Introduction

Destructive tsunamis are most often generated by



Mw-frequency models: outer rise

Solomon: outer rise

Pure Appl. Geophys.
 © 2019 The Author(s)
<https://doi.org/10.1007/s00024-019-02299-w>

Pure and Applied Geophysics



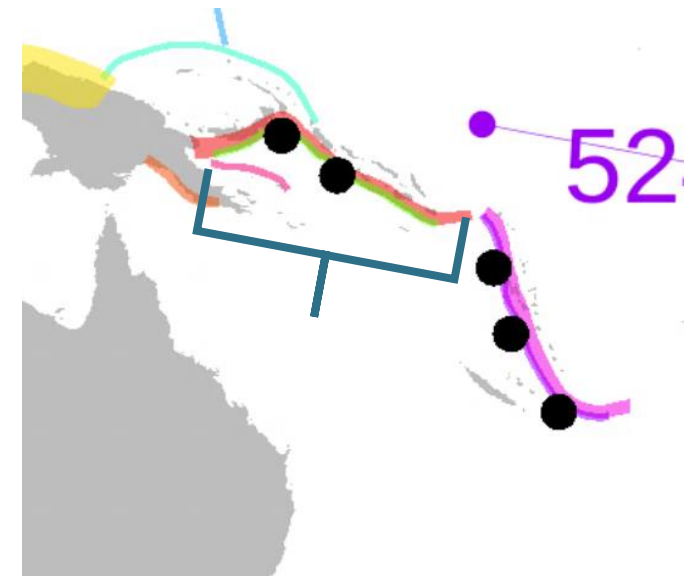
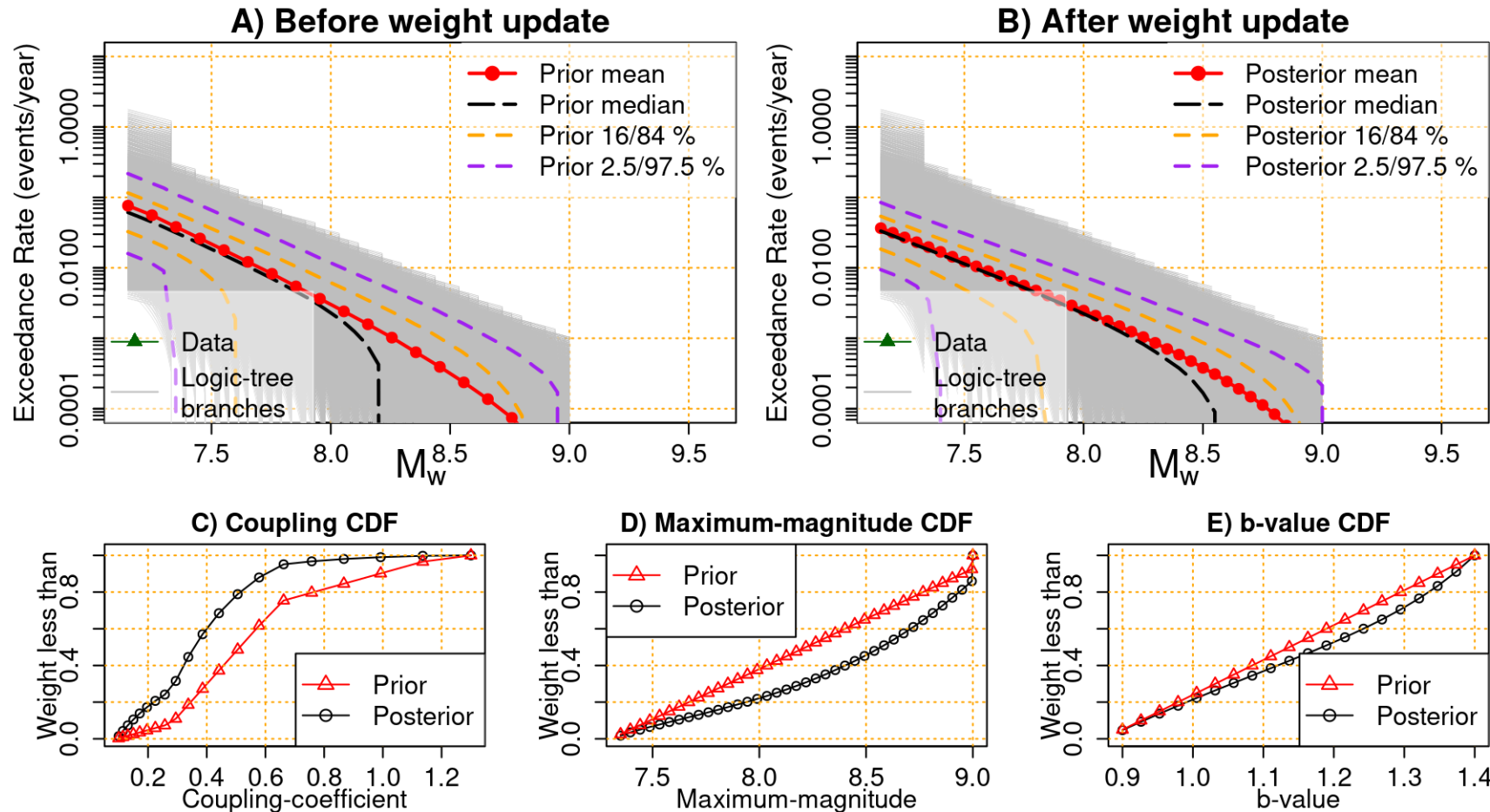
Sensitivity of Probabilistic Tsunami Hazard Assessment to Far-Field Earthquake Slip Complexity and Rigidity Depth-Dependence: Case Study of Australia

GARETH DAVIES¹ and JONATHAN GRIFFIN^{1,2}

Abstract—Probabilistic Tsunami Hazard Assessment (PTHA) often proceeds by constructing a suite of hypothetical earthquake scenarios, and modelling their tsunamis and occurrence-rates. Both tsunami and occurrence-rate models are affected by the repres-

1. Introduction

Destructive tsunamis are most often generated by



Thanks!

<https://github.com/GeoscienceAustralia/ptha/tree/master/ptha> access

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.

Pacific Community
Communauté du Pacifique

Earthquake Scenario Selection for Tsunami Inundation Hazard Assessment

Guidelines on using the 2018 Probabilistic Tsunami Hazard Assessment in the Pacific

Australian Aid
Australian Government
Geoscience Australia
PCRAFI
PROGRAM

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 J
2601, Australia. E-mail: gareth.davies@ga.gov.au

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 ▼

Pure Appl. Geophys.
© 2019 The Author(s)
<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 DAVIES¹ and JONATHAN GRIFFIN^{1,2}

Abstract—Probabilistic Tsunami Hazard Assessment (PTHA)

1. Introduction

often proceeds by
scenarios, and me
tsunami and occu

FROM OFFSHORE TO ONSHORE PROBABILISTIC TSUNAMI HAZARD ASSESSMENT WITH QUANTIFIED UNCERTAINTY: EFFICIENT MONTE CARLO TECHNIQUES

Gareth Davies¹

Offshore probabilistic tsunami hazard assessments (PTHAs) are increasingly available for earthquake generated tsunamis. They provide standardized representations of tsunami scenarios, their uncertain occurrence-rates, and models of the deep ocean waveforms. To quantify onshore hazards it is natural to combine this information with a site-specific