The Use of Tsunameter Observations within the Australian Tsunami Warning System

www.cawcr.gov.au

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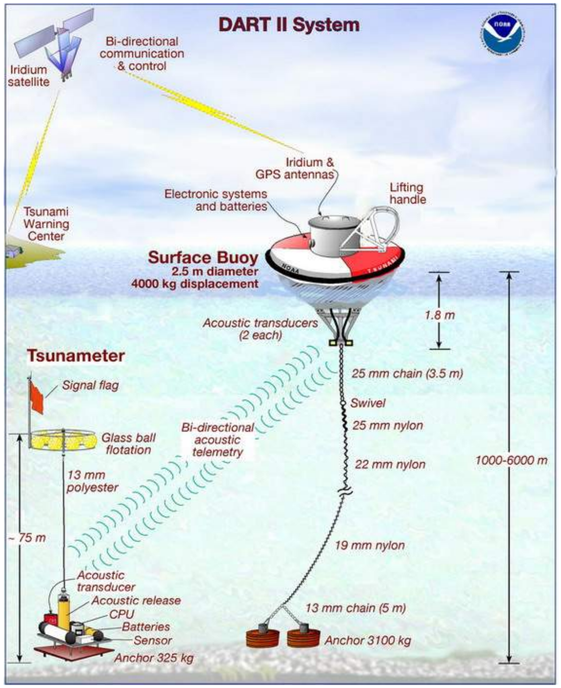
Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

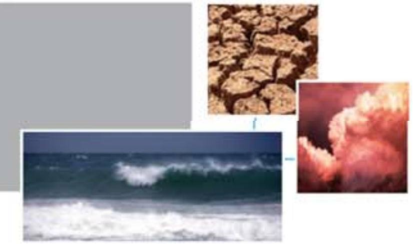
CSIRO

Outline

- Background
- Australian tsunameter network
    - Network design and assessment
- Model verification
- Future plans



Background

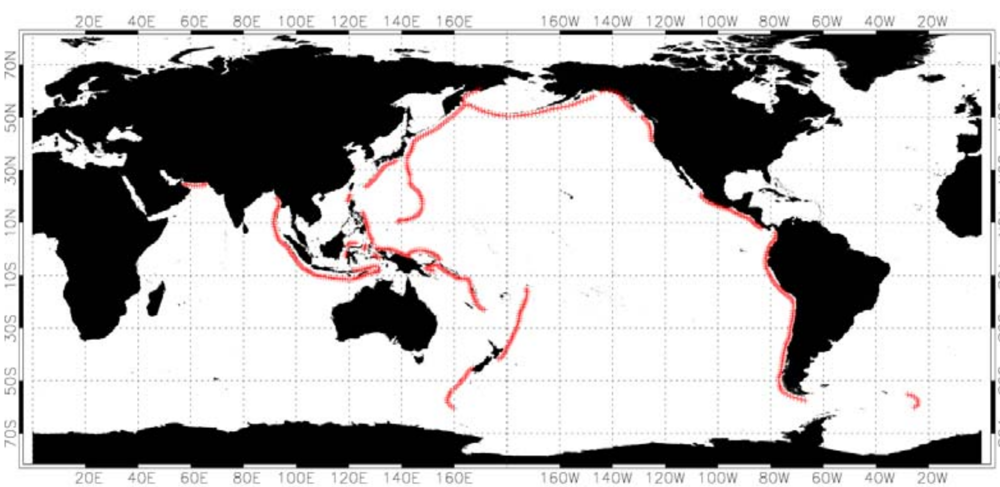


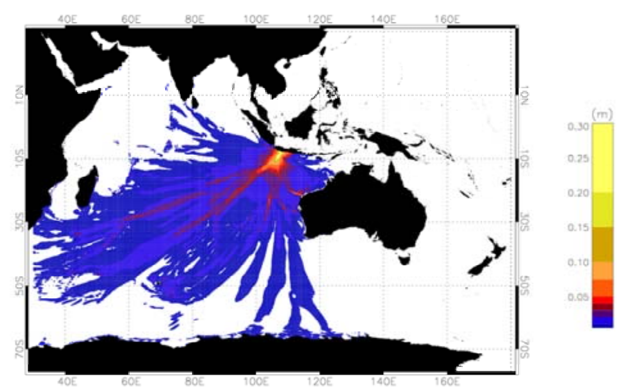
- The Australian Tsunami Warning System (ATWS) was a AU$68.9M 4-year project:
  - July 2005 – June 2009
- July 2009 – ATWS project transitioned to ongoing activity
- Major project achievements
  - Bureau of Meteorology and Geoscience Australia operate the Joint Australian Tsunami Warning Centre

    http://www.bom.gov.au/tsunami/
  - Expanded seismic network
  - Expanded sea-level observing network
  - Tsunami scenario database
  - Warnings based on numerical guidance

Tsunami Warning Systems

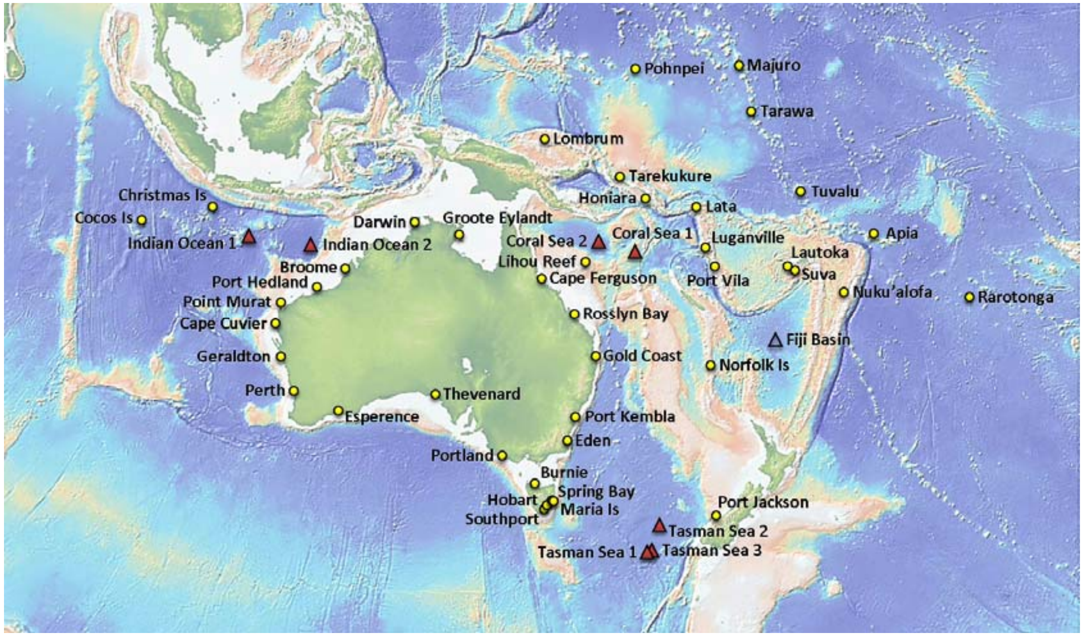
- Can't predict earthquakes, so don't know when tsunami will occur
- We know where tsunamis are likely to be generated
- In most cases, tsunami propagates too fast for event to be dynamically modelled
- Operational tsunami forecast systems based on pre-computed "tsunami scenarios"
- All possible tsunami events have been modelled and archived to produce a "scenario database" (T2)
- When an earthquake occurs, can extract closest scenario



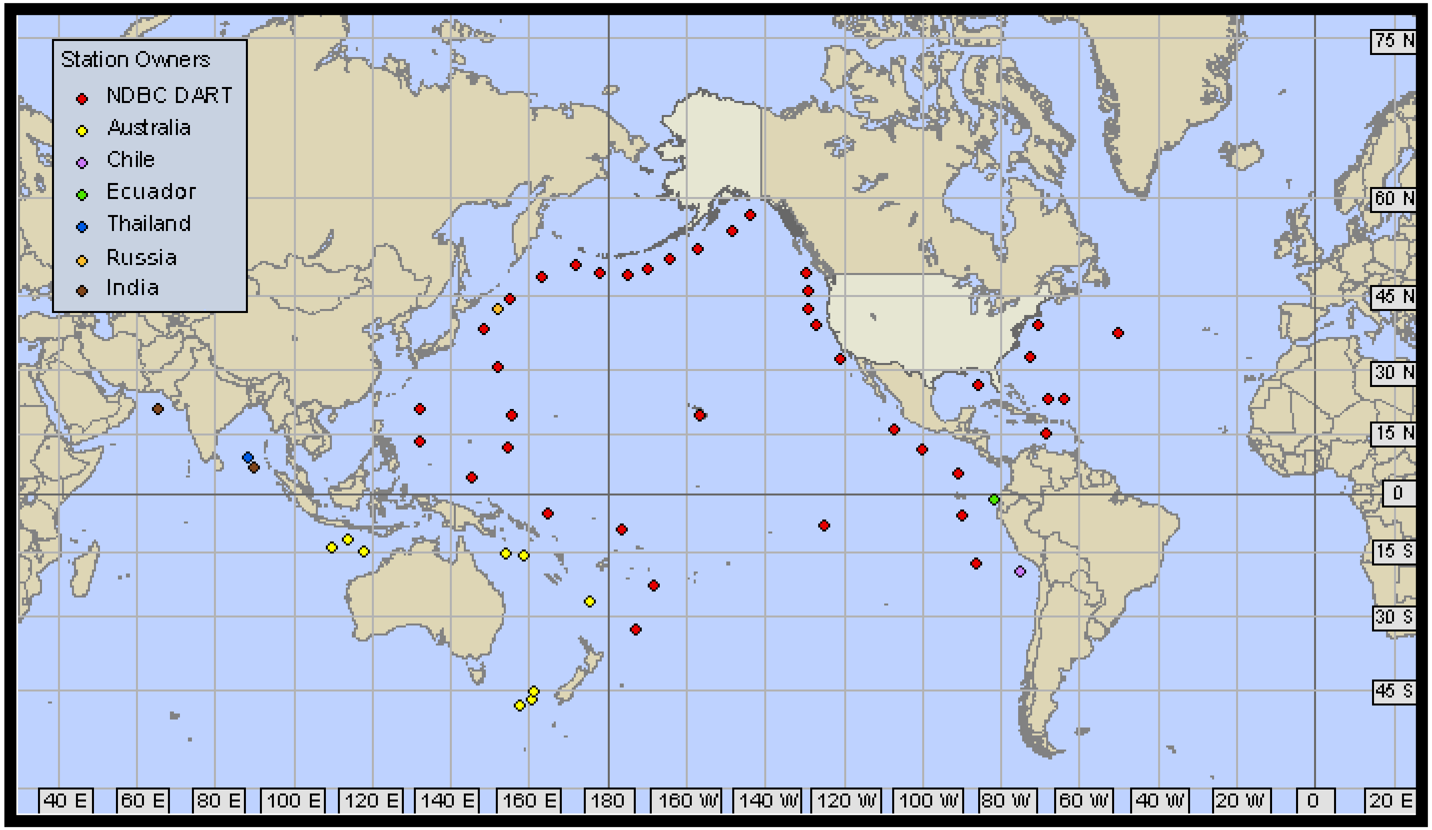


Australian tsunameter network

- Even if earthquake on subduction zone – don't know for sure whether tsunami has been generated or not
- Sea-level observations essential
- Two main "tsunami observing instruments" in Bureau network
  - Tide gauge
  - Tsunameter



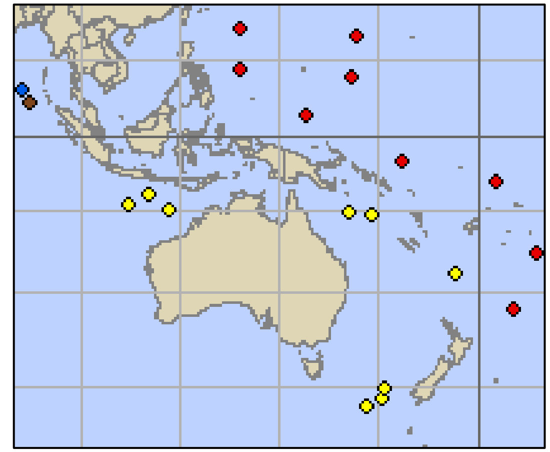
Australian tsunameter network



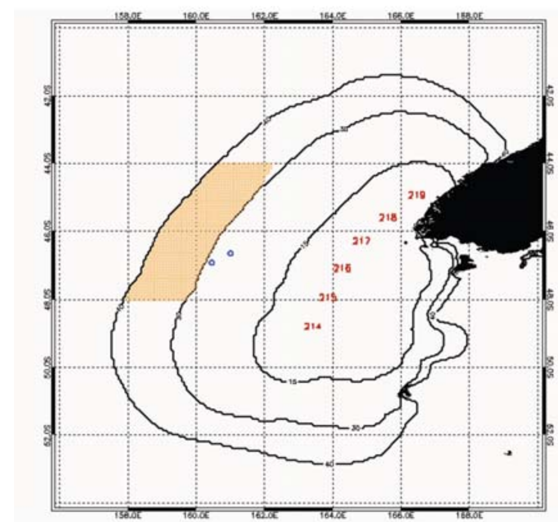
http://www.ndbc.noaa.gov/

Tsunameter network design

- How did we decide where to place tsunameters?
    - Broad brush assessment of tsunami risk based on location of subduction zones and travel times $c = \sqrt{gH}$
    - Decided on 3 main areas
        - Indian Ocean
        - Tasman Sea
        - Coral Sea
    - Two tsunameters in each area



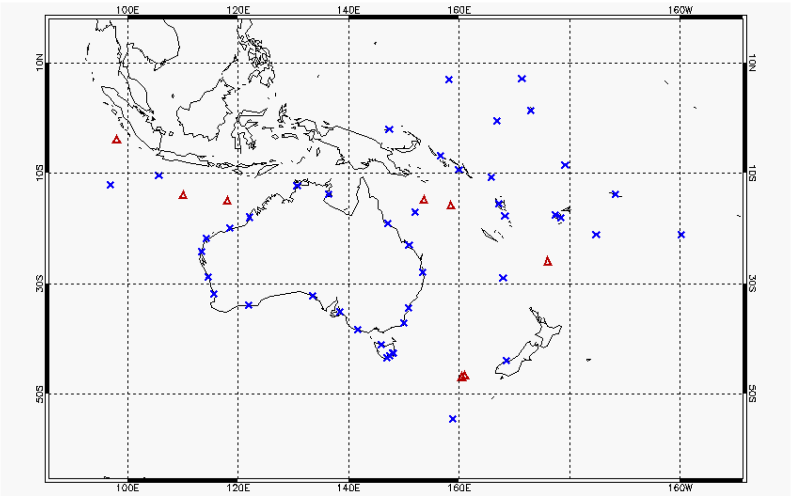
- Locations refined using modelled travel times from T2 scenario database



(Greenslade, D.J.M, 2012: The optimal placement of tsunameters in the Tasman Sea, *Aust. Met. Oc. Journal*, 62, pp 63 - 70.)

Assessment of network

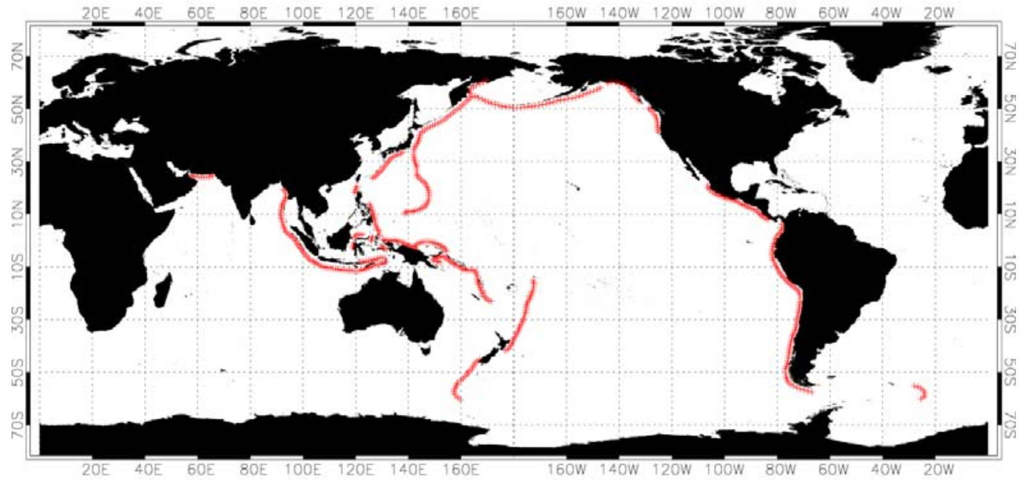
- Considerable effort has gone into installing (and maintaining) the sea-level observing network
- How do we know it is doing what it is supposed to?
- Determine the amount of warning time that an observation site can provide to the Australian coastline
  - Ensure that for all potentially tsunamigenic events, there will be observations from at least 2 sites, at least 105 minutes before the tsunami arrives at the coast



(Greenslade and Warne, 2012: An Assessment of the Effectiveness of a Sea-Level Observing Network for Tsunami Warning, *J. Waterw. Port, Coast. Ocean Eng.*, 138(3))

Assessment of network

- Results
  - Some network gaps, for example
    - – south western WA is vulnerable to South Sandwich subduction zone events
    - – Norfolk Island is vulnerable to events on the southern end of the Kermadec subduction zone
    - – Cocos Islands are vulnerable to events on the Makran trench



Assessment of network

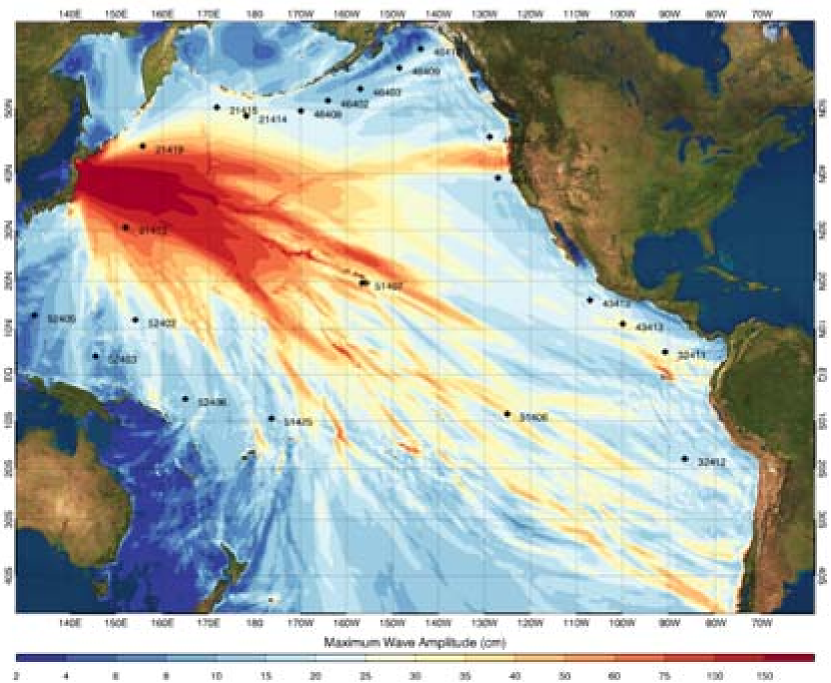
- Results
  - Can also determine overall value of site
    - – How many tsunamis does this site provide warning for
    - – How do the warning characteristics change if we remove this site
  - Tsunameters are well represented in these results. They make up 15% of the total number of observation sites analyzed, but they represent 30% - 50% of the critical sites

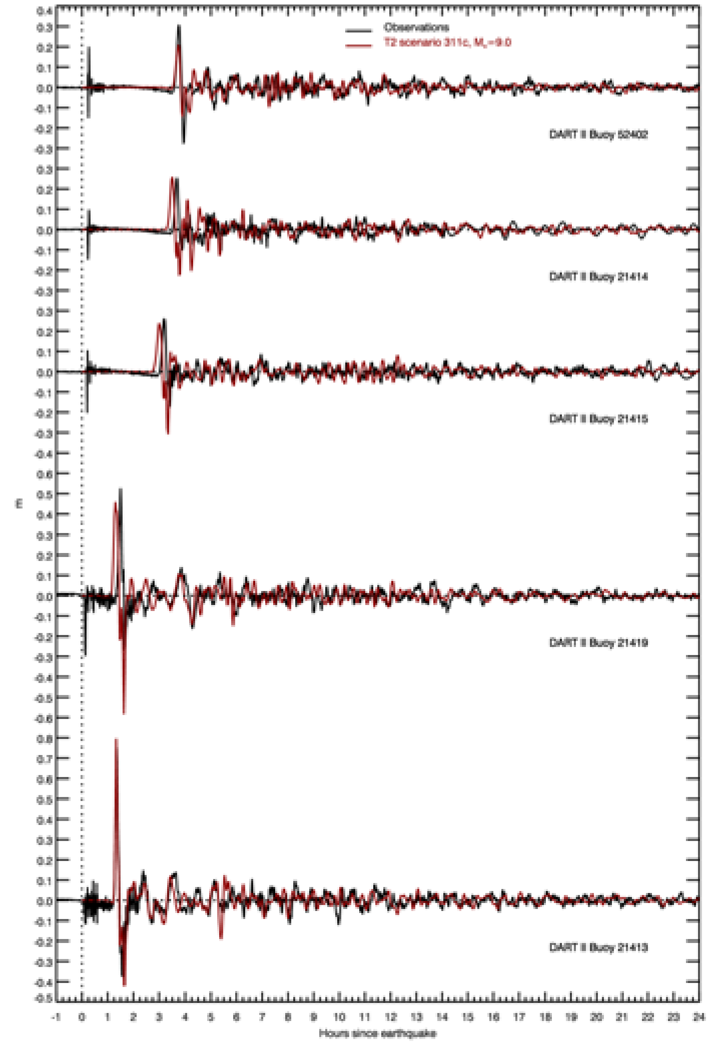
Table 5. Most Critical Sites for the JATWC Network Based on the Definition of Warning being at Least 105 Min Warning by at Least 2 Observations

Observation site name	Number of IEs with insufficient coverage (percentage increase)	Number of forecast sites with insufficient coverage (percentage increase)
Tsunameter 56003, Indian Ocean	367 (31.1)	40 (2.6)
Tsunameter 56001, Indian Ocean	364 (30.0)	40 (2.6)
Avatiu, Cook Islands	346 (23.6)	39 (0.0)
Macquarie Island, TAS	337 (20.4)	39 (0.0)
Nuku'alofa, Tonga	332 (18.6)	45 (15.4)
Tsunameter 55016, South Fiji Basin	322 (15.0)	45 (15.4)
Lombrum, PNG	294 (5.0)	41 (5.1)
Dekehtik, Federated States of Micronesia	292 (4.3)	41 (5.1)
Apia, Samoa	292 (4.3)	39 (0.0)
Christmas Island 1	284 (1.4)	39 (0.0)
Christmas Island 2	284 (1.4)	39 (0.0)
Port Vila, Vanuatu	282 (0.7)	39 (0.0)
Lata Wharf, Solomon Islands	282 (0.7)	39 (0.0)
Point Murat, WA	281 (0.4)	39 (0.0)
Ghinoa Wharf, Solomon Islands	281 (0.4)	40 (2.6)
Tsunameter 55015, Tasman Sea	281 (0.4)	39 (0.0)
Tsunameter 2, Coral Sea	281 (0.4)	40 (2.6)

Model verification

- Japan, Mar 11th 2011; $M_w = 9.0$





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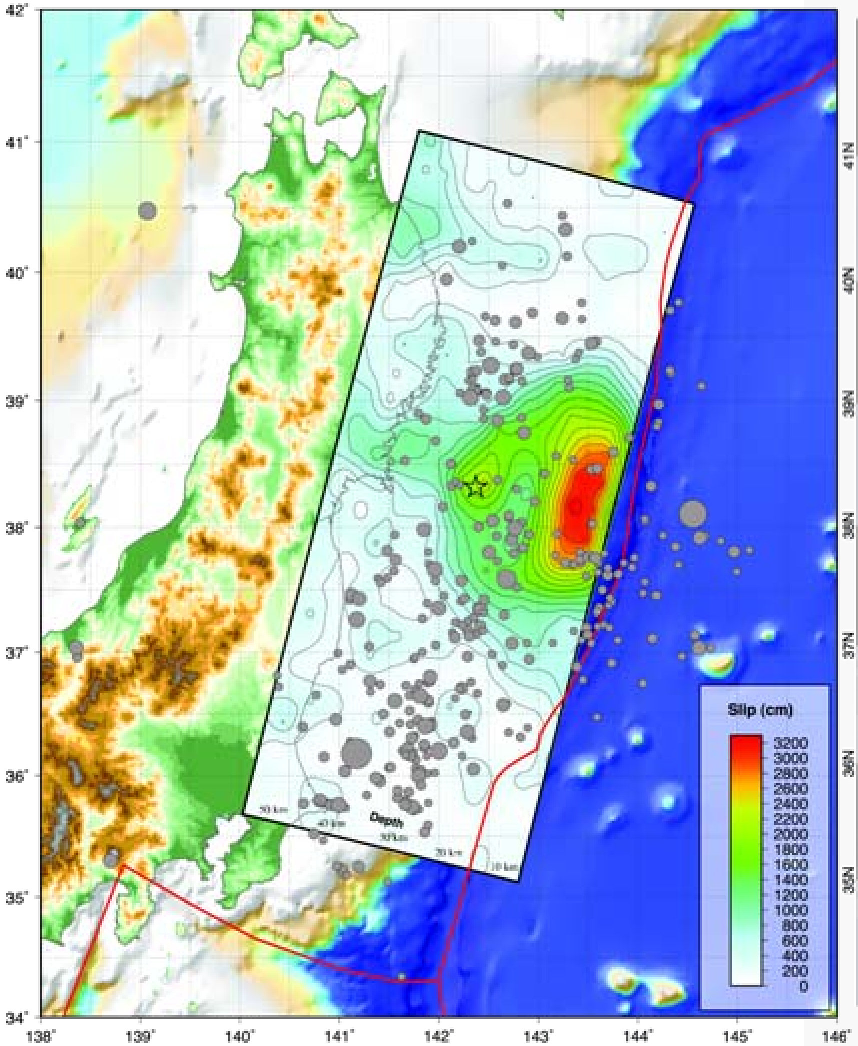

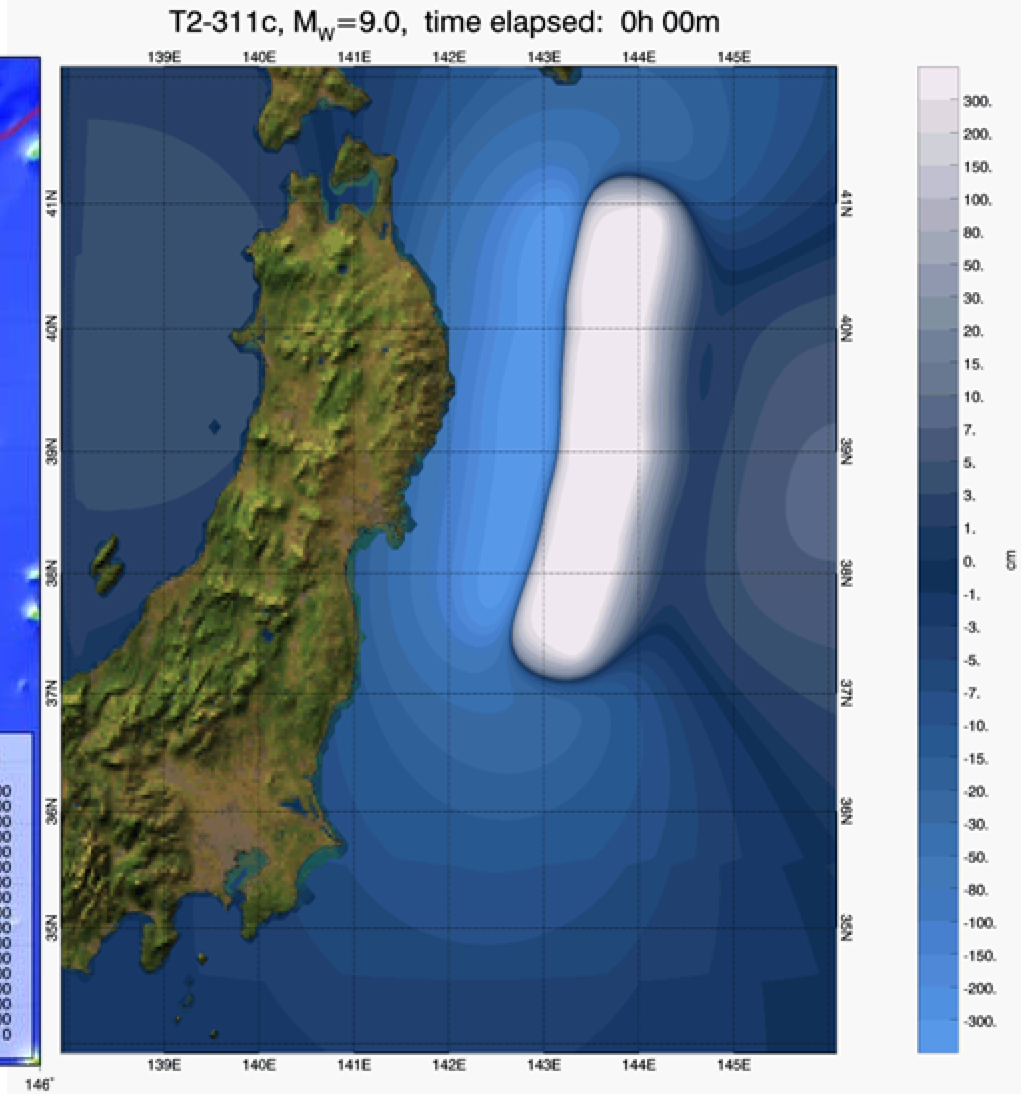

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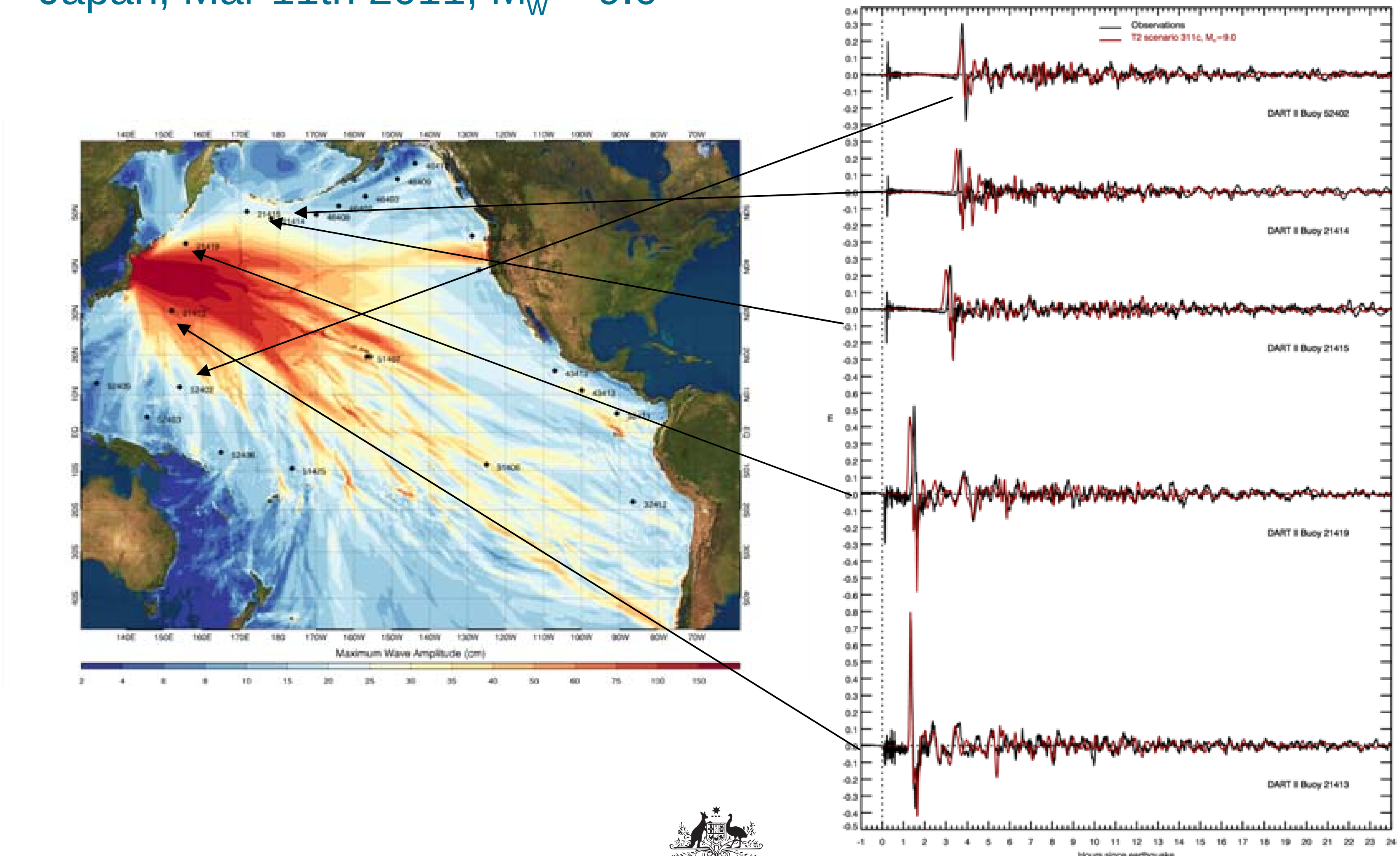
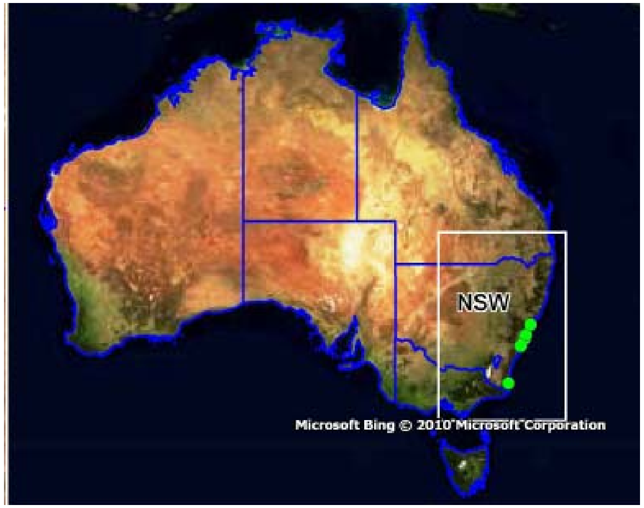


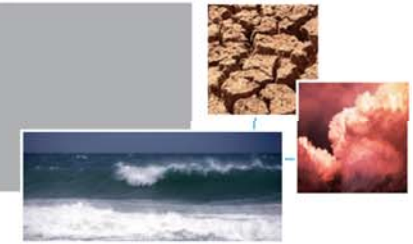
Model verification

- NSW tsunami hazard assessment study
- 5 events
  - Japan, M_w = 9.0, March 2011
  - Chile, M_w = 8.8, February 2010
  - Puysegur, M_w = 7.9, July 2009
  - Solomons, M_w = 8.1, April 2007
  - Chile, M_w = 9.5, May1960
- Used T2 scenarios, selected according to best fit with tsunameter observations (where available) and rupture details
- Ran Delft3D model nested within T2 and compared modelled sea-level to local tide gauge observations

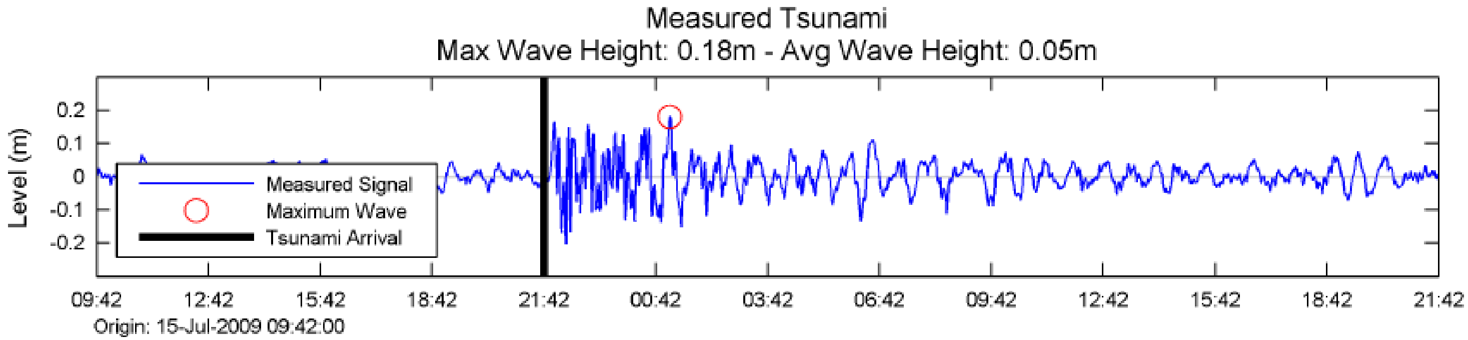


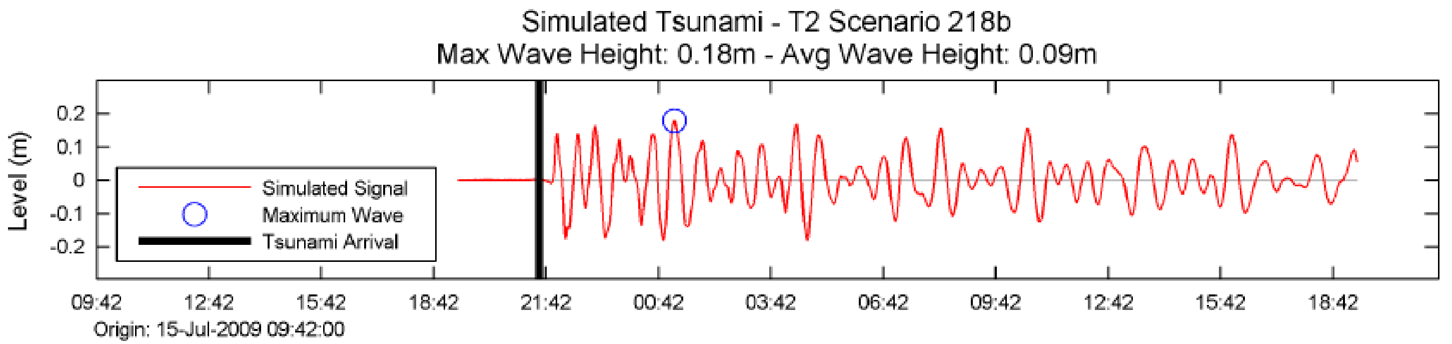
Garber and Beadle, NSW Tsunami Inundation Modelling and Risk Assessment LJ2874/Rep2703. Prepared for: NSW Office of Environment and Heritage and NSW State Emergency Service, May 2012

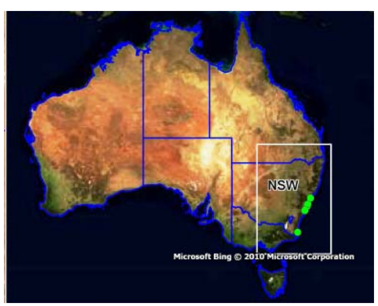
Model verification



- Results – Puysegur event at Eden







Model verification

- Results

	Mean error in maximum amplitude at up to 5 tide gauges
• Japan, M_w = 9.0, March 2011	0.06 m
• Chile, M_w = 8.8, February 2010	0.02 m
• Puysegur, M_w = 7.9, July 2009	0.03 m
• Solomons, M_w = 8.1, April 2007	0.08 m
• Chile, M_w = 9.5, May1960	0.26 m

- Best matches from 2011, 2010, 2009 events – those where tsunameter observations were available and could be used to select the best deep water scenarios.

Future Plans

- Real-time forecast system
  - Dynamic model, initialised with real-time seismic data
  - ‘Ensemble’ system with data assimilation scheme to assimilate sea-level and seismic observations
    - Earthquake occurs
    - Initialise N models (Initial conditions determined by uncertainty in earthquake parameters)
    - Produce N tsunami forecasts
    - As earthquake information improves or sea-level observations come in, eliminate forecasts that don’t match
  - Real-time inundation modelling

Summary

- Bureau owns and operates 9 tsunameters in Australian region, of which 6 form a core network
- Located in 3 groups of 2
- Network assessment shows that they are critical components of the overall network for tsunami warning purposes.
- Play an essential role in model verification and scenario selection
  - Improve forecasting of coastal impacts

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Thank you

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