TTTWS TTDMP
March 5-8, 2026

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7: Optimal Monitoring Networks

Presentation given by Bill Fry, ICG-PTWS WG2 Chair

SAPIENZA UNIVERSITÀ DI ROMA
INCOIS
Te Whakaahuatanga Tere o ngā Rū Whenua me ngā Parawhenua
R-CET Rapid Characterisation of Earthquakes and Tsunamis
A GNS Science Led Research Programme
ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA
University of Otago ŌTĀKOU WHAKAIHU WAKA
SMART CABLES
NPL
Measurement Standards Laboratory of New Zealand
Australian Government Geoscience Australia
PMEL Pacific Marine Environmental Laboratory
NASA

Agenda

- Review of tsunami threat lifecycle
- Kamchatka learnings
- Overview of integrated sensing
- Status of ODTP forecasting goals
- Novel Data
  - SMART (Agenda 8)
  - Acoustic-gravity waves (Agenda 9)
  - GNSS TEC
  - Quantum sensing on fibre-optic cables
- Proposed ISN 3-stage forecasting framework

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Ideal Tsunami Threat Lifecycle:
A User Perspective on Tsunami Alerts

	EM Response
1. **Initial indicators**—typically the traditional seismic proxy	1. High Alert (Near Field); Standby (Far Field)
2. **Confirmation**—we have observed a tsunami	2. Execute Response (conservative)
3. **Forecasting**—predict coastal amplitude and arrival time	3. Target response to projected impacts
4. **Verification**—high confidence in forecast	4. Amend or fine-tune response
5. **Cancellation**—forecast is good enough to predict time for “all clear”	5. Stand down

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Forecast model accuracy (35 tide stations)

Source	Model accuracy	RMSE	Time obtained (min after EQ)
Inv#1 (1DART)	24.0%	0.551 m	51 min
CMT	46.3%	0.432 m	52 min
Inv#2 (2 DARTs)	69.5%	0.221 m	65 min
Inv #3 (2 DARTs)	68.7%	0.239 m	68 min
Inv#4 (2 DARTs)	74.9%	0.182 m	101 min
Inv#5 (3 DARTs)	71.1%	0.234 m	116 min
USGS finite fault #1	65.6%	0.178 m	Aug 1, 2025
USGS finite fault #5	50.5%	0.372 m	Nov 19, 2025
SIFT auto-inversion (2 DARTs)	73.1%	0.140 m	In development (avail 55 min)

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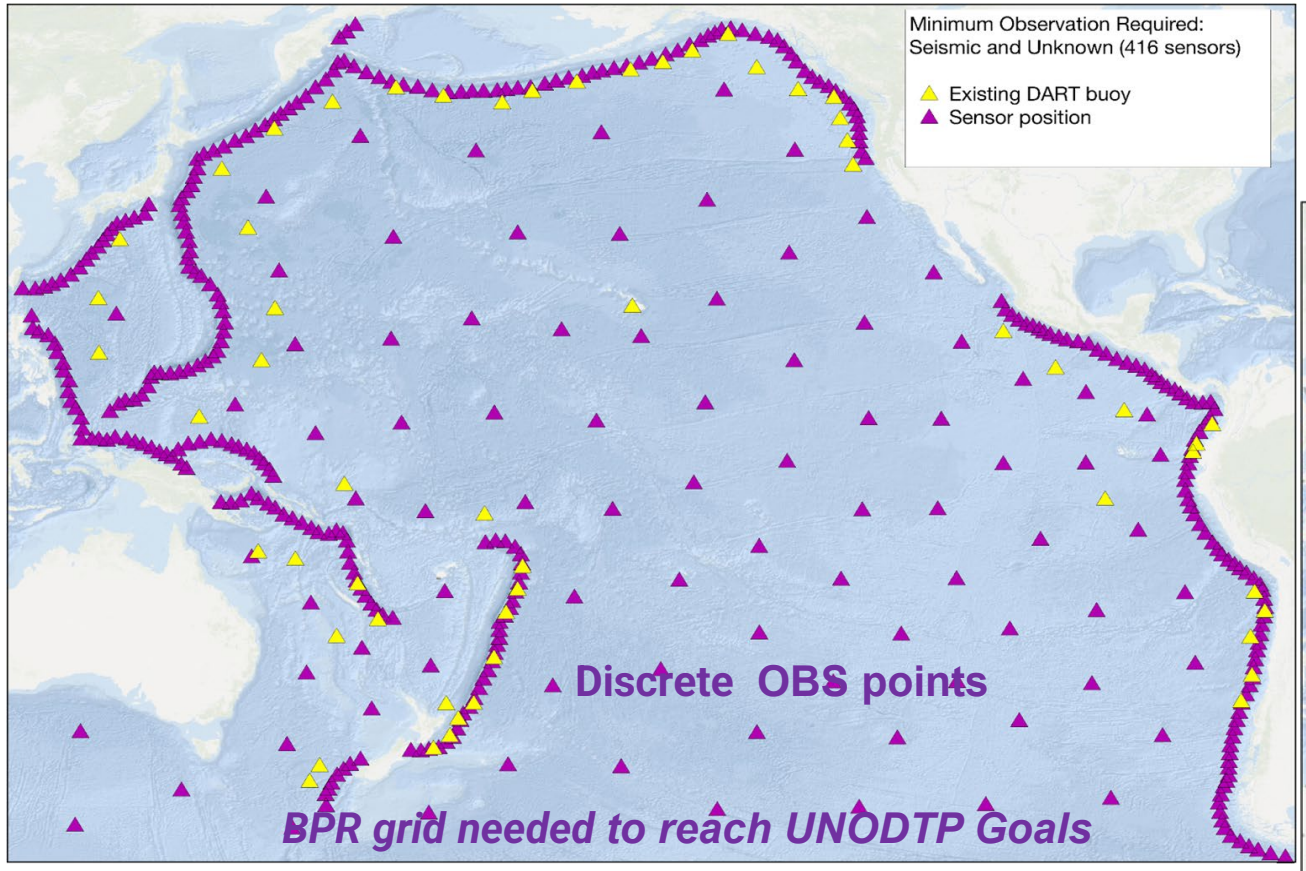
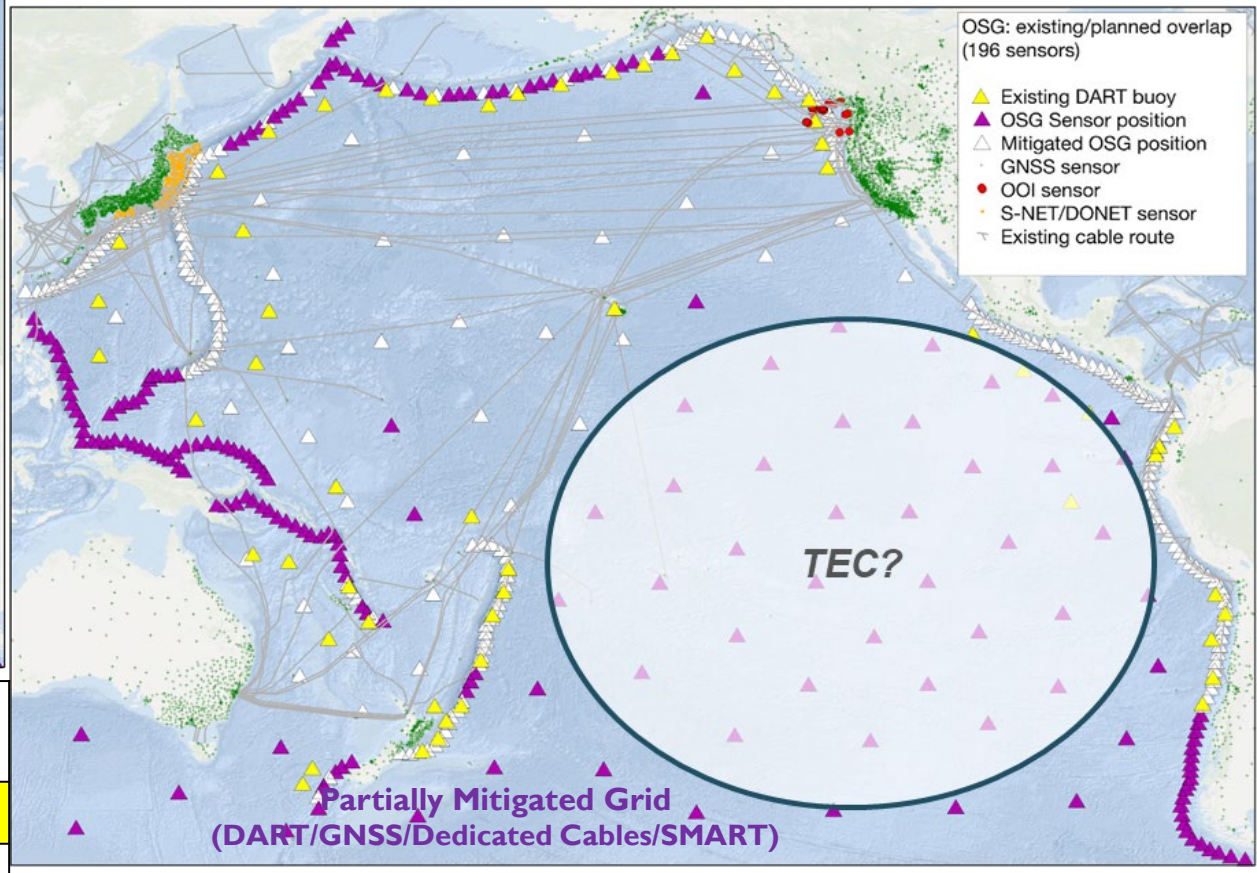
Moore and Titov

Notional Global Network Design ?

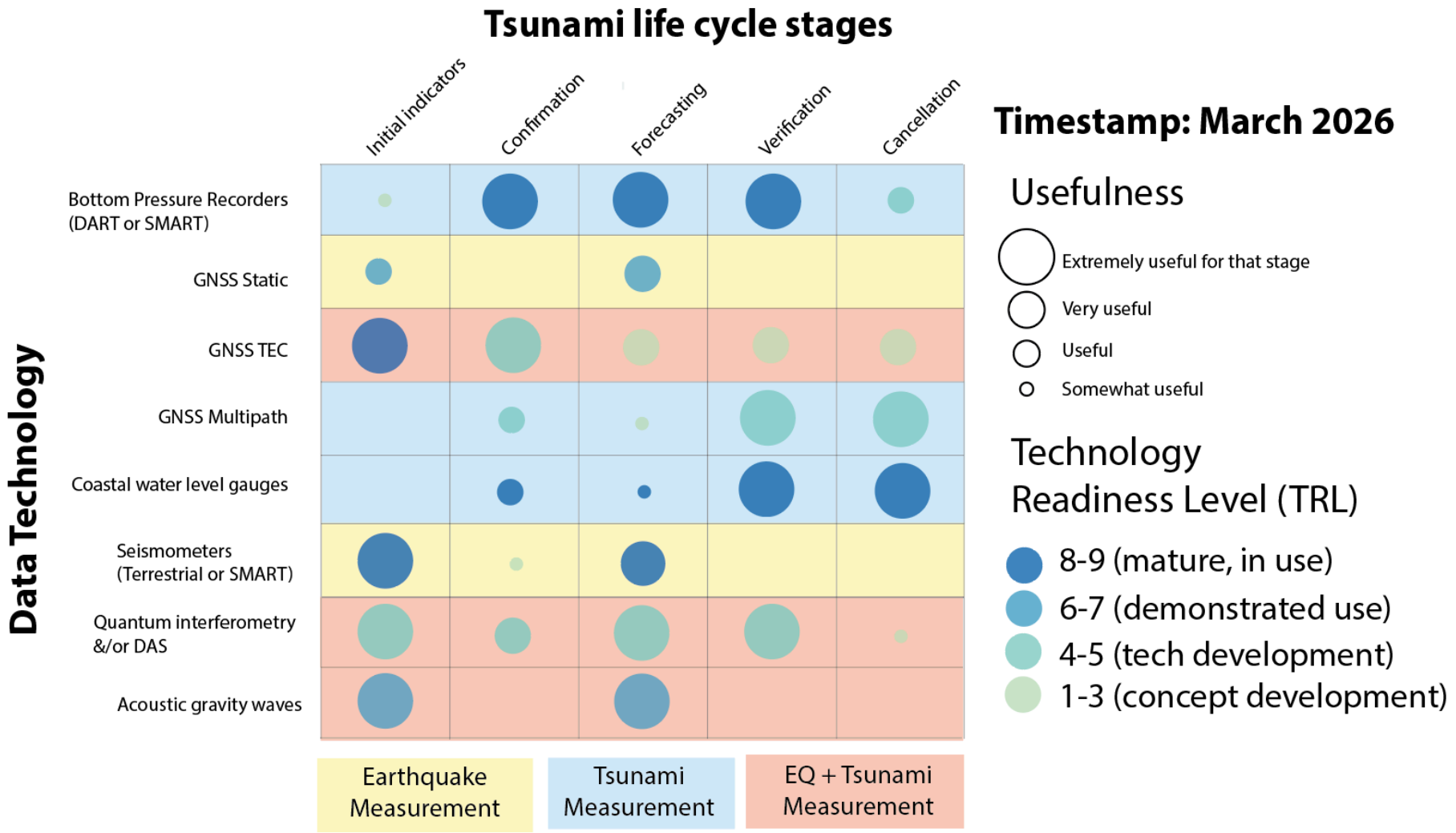


Tsunami Source Focus Area	Initial indicators (time after origin)	Tsunami detected (time after origin)	Tsunami constrained (time after origin)
Earthquake	3 min	10 min	45 mins
Non-earthquake (known)	10 mins	45 mins	60 mins
Non-earthquake (unknown)	60 mins	90 mins	120 mins



Moore, Gledhill, Angove, Kumar and Fry

Novel Data – UPDATE CHART



ISN Forecasting Framework for Earthquakes

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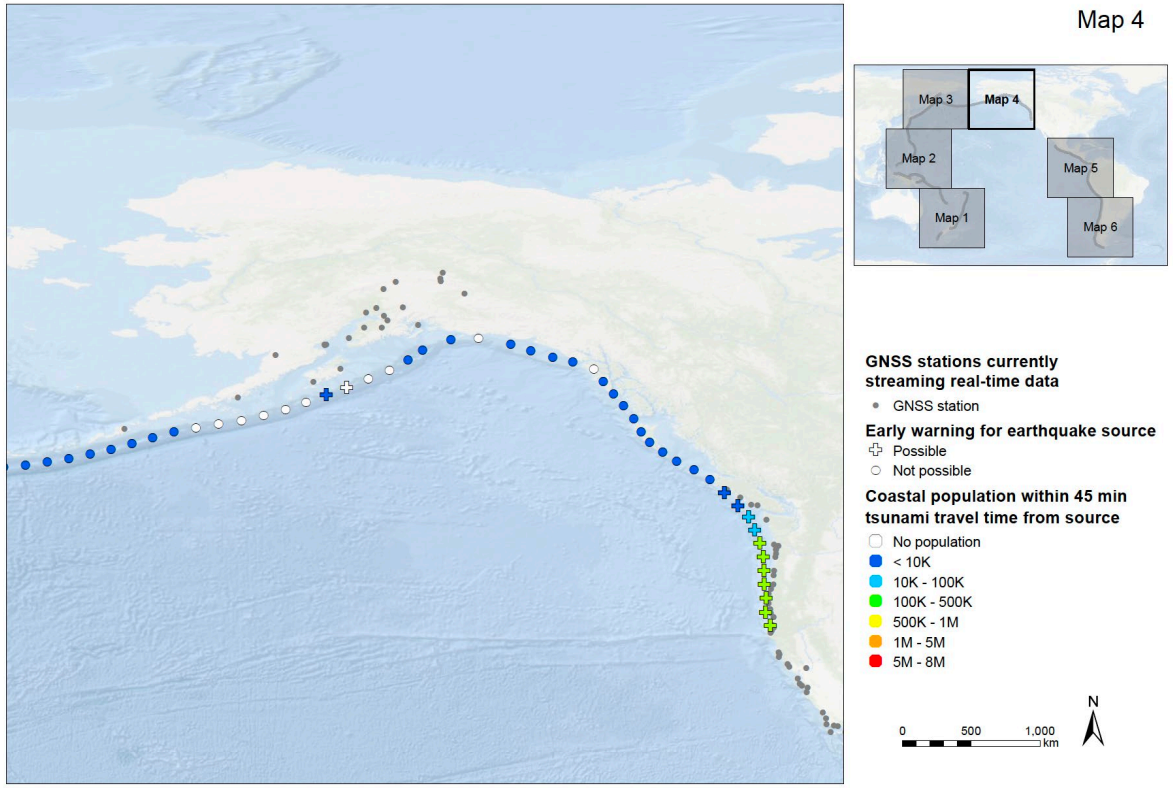
- Initial indicators – seismic, geodetic
- Seismic data exists to meet the 3-minute initial indicator in most cases
- GNSS data exists in some cases

Tsunami Source	**Initial indicators** (time after origin)	**Source partially constrained** (time after origin)	**Source fully constrained** (time after origin)
Earthquake	3min	10min	45 mins
Non-earthquake (known)	10mins	45mins	1hr
Non-earthquake (unknown)	45 mins	1hr	90mins



ISN Forecasting Framework for Earthquakes

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- Forecasting (Source partially constrained) – 10 minutes, sometimes but not very well
- Seismic wphase, Mwpd, GNSS static, acoustic gravity wave, fibre-cable

Tsunami Source	**Initial indicators** (time after origin)	**Source partially constrained** (time after origin)	**Source fully constrained** (time after origin)
Earthquake	3min	10min	45 mins
Non-earthquake (known)	10mins	45mins	1hr
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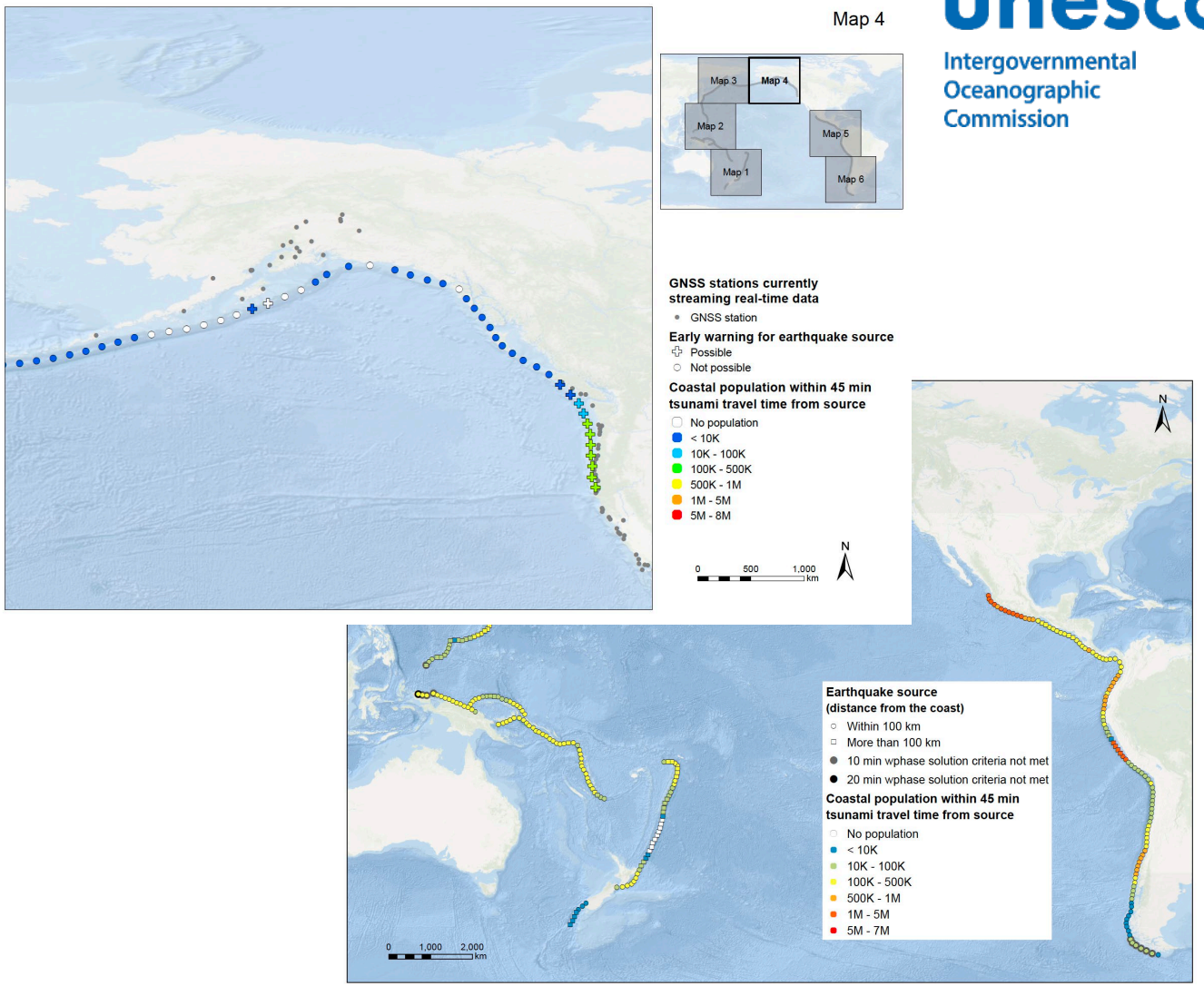

ISN Forecasting Framework for Earthquakes

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- Source fully constrained – enough data for a time-dependent forecast
- OBP (DART or SMART)
- NEED Novel Ocean Observations
  - GNSS TEC? Acoustic gravity? Fibre-optic sensing?

Tsunami Source	**Initial indicators** (time after origin)	**Source partially constrained** (time after origin)	**Source fully constrained** (time after origin)
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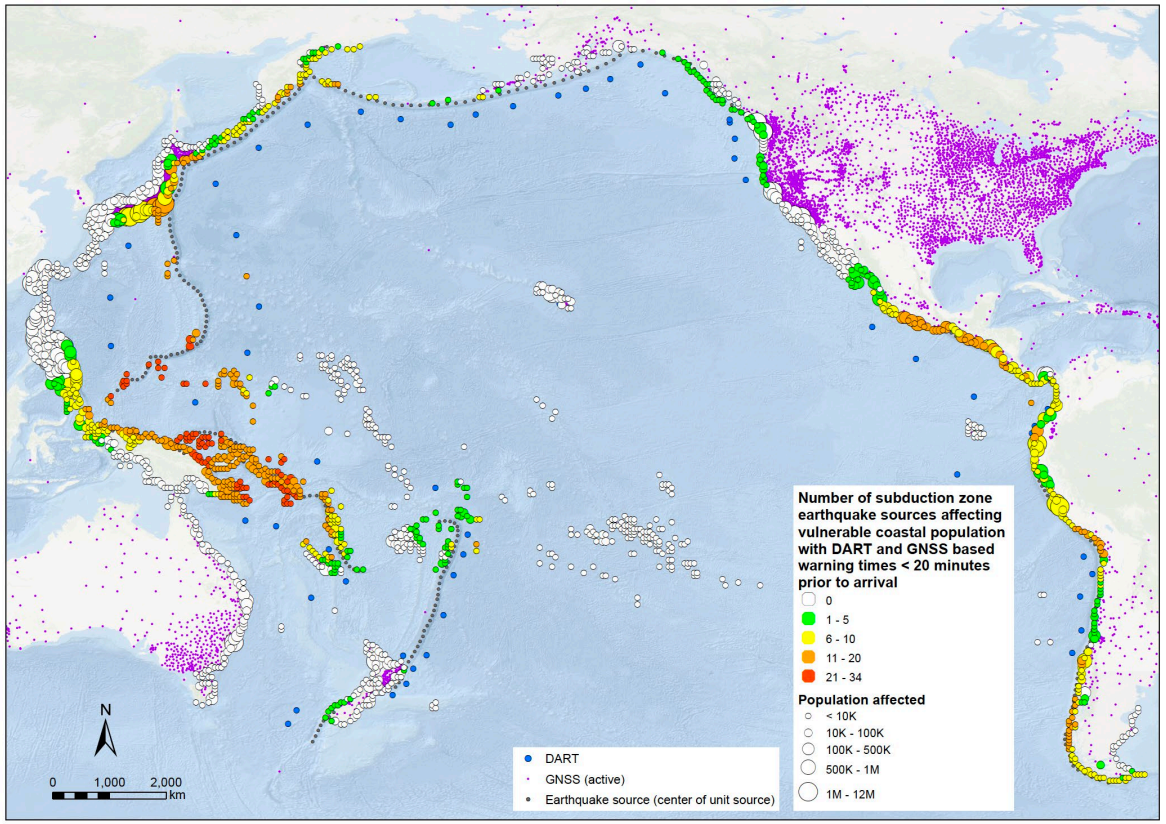
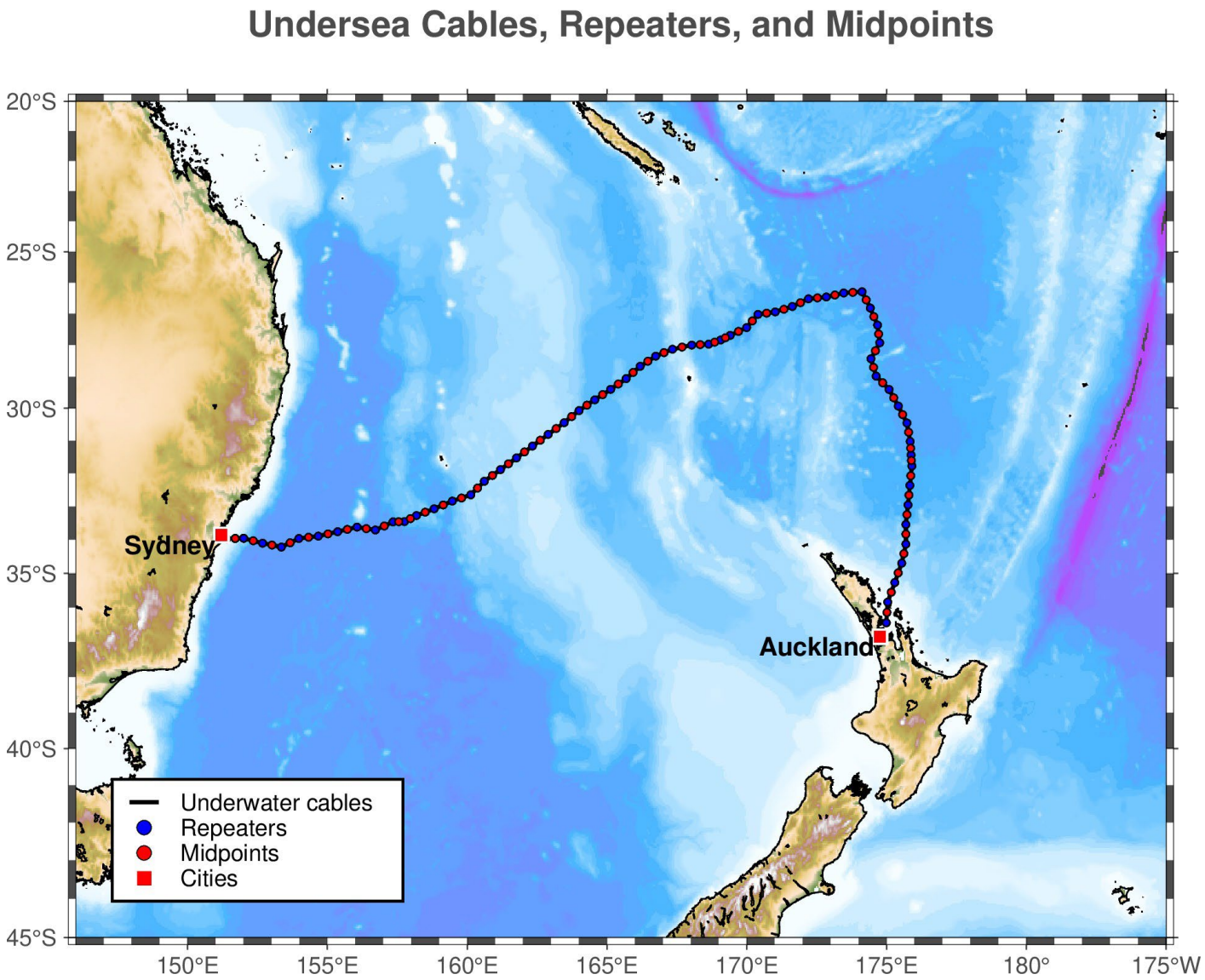


Fibre-optic sensing trial

- Trial since 2024
- Have successfully recorded many earthquakes and a submarine volcanic eruption
- Inexpensive to retrofit (~800k Euros)
- Data volumes manageable
- Works far offshore



RCET-NEW, UK NPL, NZ MSL collaboration

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Data assimilation (method of Maeda et al.,) on *perfect* cable data

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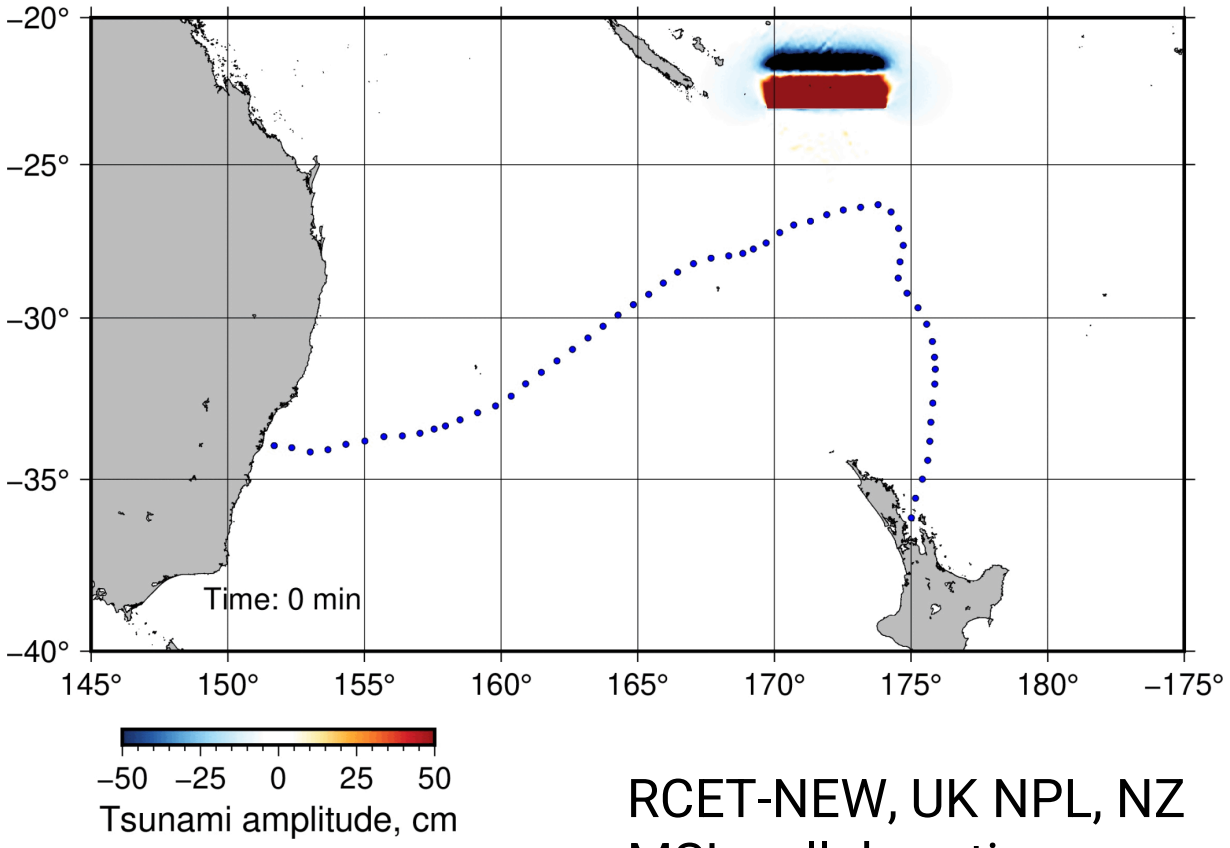
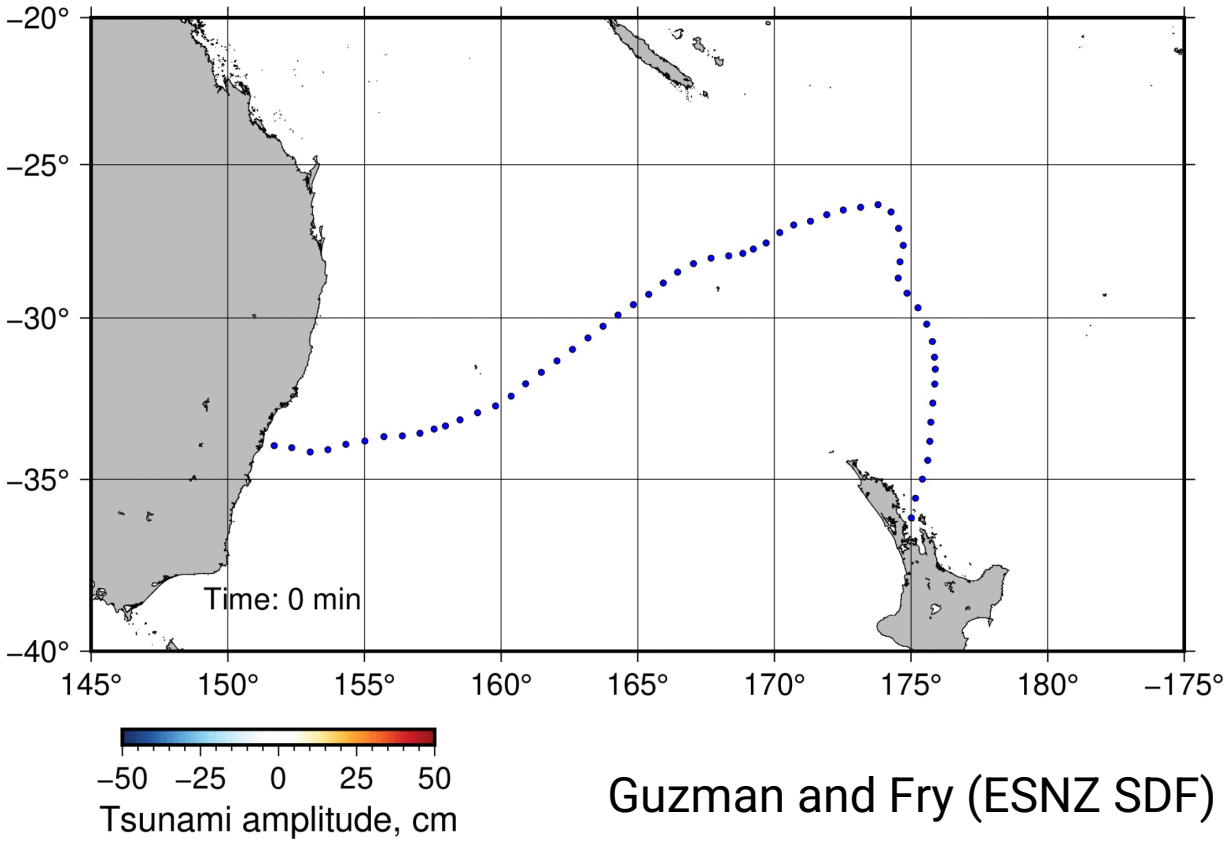
True wavefield



RCET-NEW, UK NPL, NZ MSL collaboration

Data-assimilated wavefield



Guzman and Fry (ESNZ SDF)

Generalised ISN Forecasting Proposal

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- 3-stage
- Initial Indicators based on seismic data (3-minutes for EQ)
- Initial forecast based on seismic (Mwpd or Mww) and INGV PTF approach (until we can generate a FOO or acoustic-gravity provides a better operational alternative) 10-minutes for EQ
- Cancellation-grade forecast based on OBP + fibre-optic sensing
  - Realistic potential to be financially viable and provide

Summary

- We must utilise direct ocean observations in our forecasting to achieve ODTP targets
- We can achieve significant progress toward the goals with improved operational procedures and the existing observational network
- All cancellation-grade forecasts and all forecasts for non-eq events require direct ocean observation and in most cases a proliferation of observational density.

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Thank you very much for your generous attention!