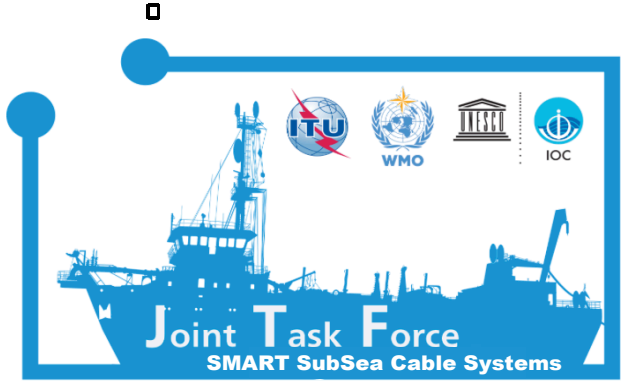
Observing the Earth and Ocean with SMART Subsea Cables: Tsunamis

***S**cience **M**onitoring **A**nd **R**eliable **T**elecommunications*



ITU WMO UNESCO IOC

Bruce M. Howe
Chair, JTF SMART Cables
University of Hawai‘i at Mānoa
And many others!

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

DEEP OCEAN OBSERVING STRATEGY

pogo Partnership for Observation of the Global Ocean

ITIC Training Program
on Tsunami Early Warning and Mitigation Systems
18 August 2023
Honolulu, Hawaii, USA

GORDON AND BETTY MOORE FOUNDATION

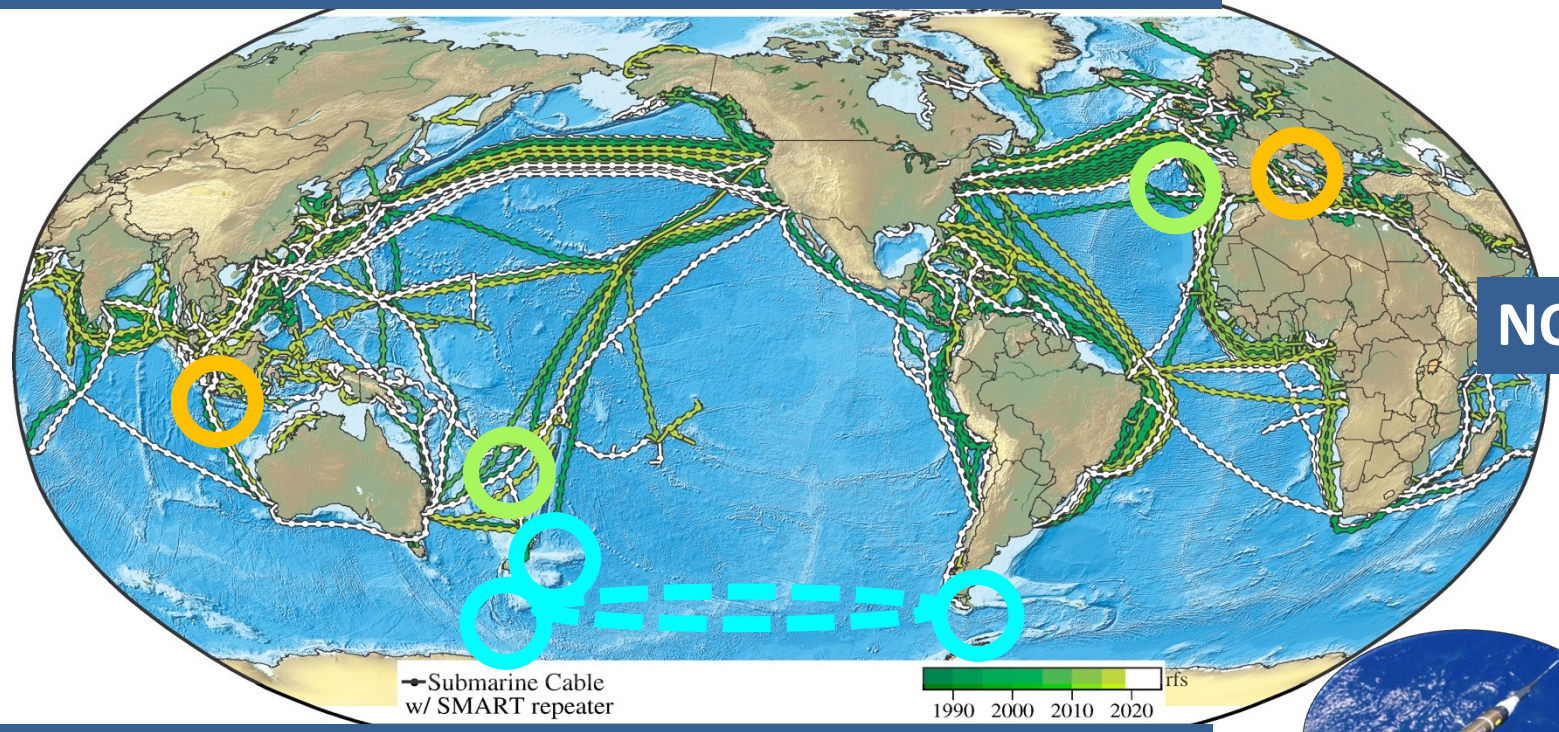
SCHMIDT MARINE TECHNOLOGY PARTNERS

SMART Subsea Cables

Global Array: Climate, Oceans, Sea Level, Earthquakes, Tsunamis

Create a Planetary sensor, power, Internet network

1st order addition to Ocean-Earth observing system



Share submarine cable infrastructure

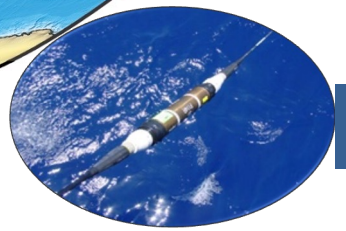
Telecom + science

NO Interference ↓€$

1.2+ GM

~20,000 repeaters

20 year refresh



repeaters ~70 km

Know the environment – protect the network

Bottom temperature, pressure, seismic acceleration

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

WMO

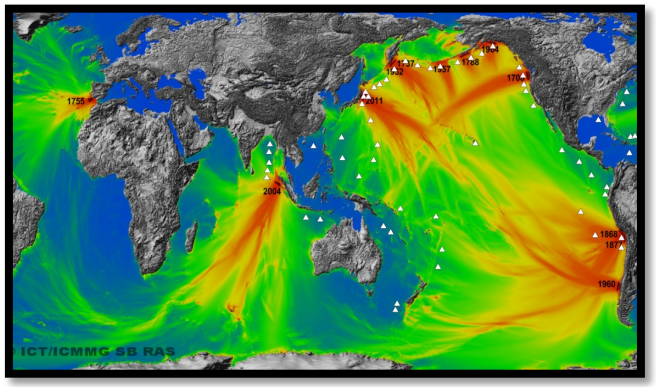
SMART CAM: 3700 km, install 2025, Gov't €154M
Continent/Portugal-Azores-Madeira ring

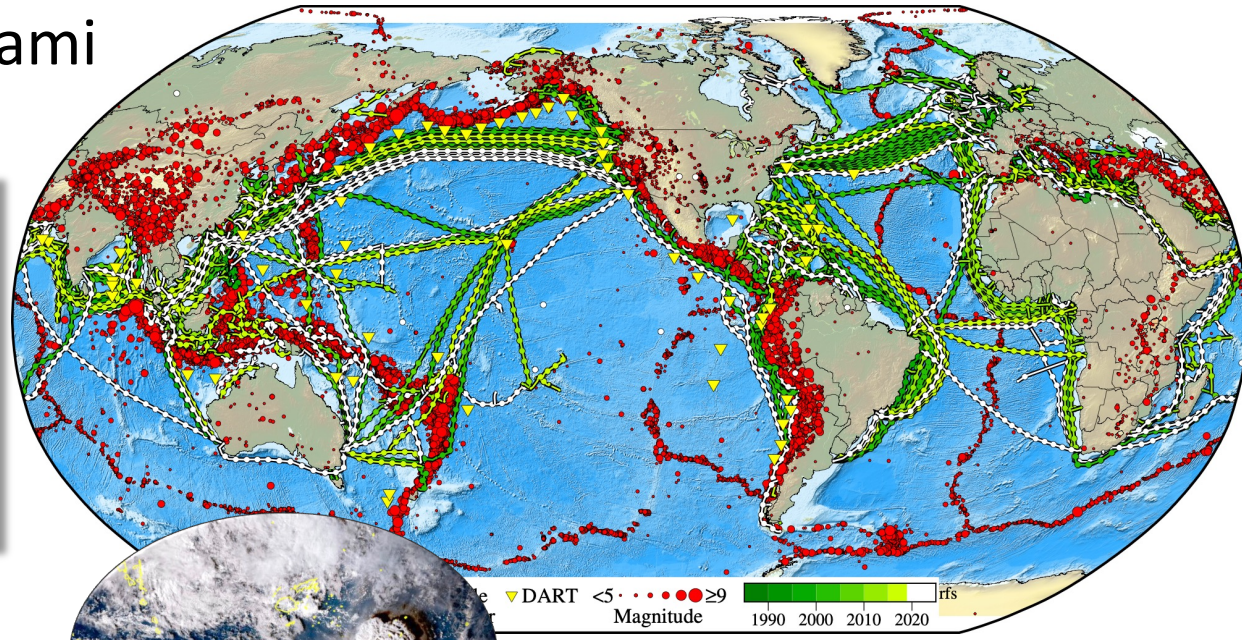
ITU

Earthquakes and Tsunamis

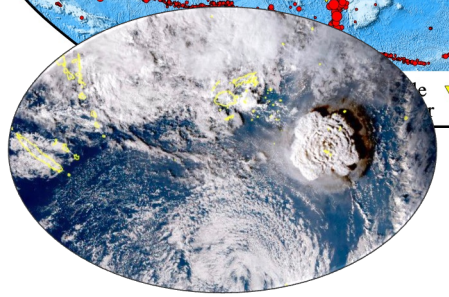
Earthquake warning: time to “Drop, Cover, and Hold On!”

Survive to escape Tsunami





Tonga 2022



DART tsunami warning buoys
Mar 2022, 38/64 working

1755

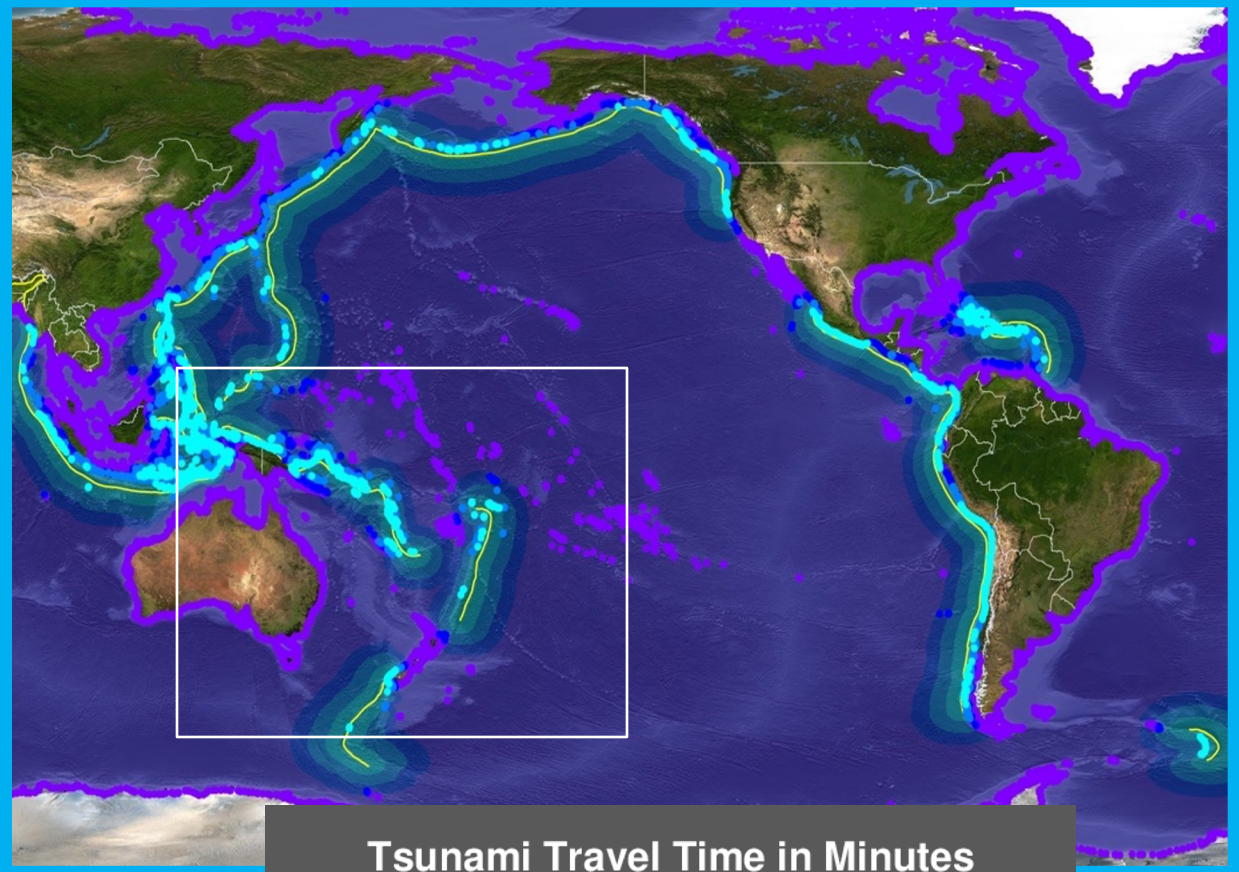
Place	Year	Mag	H (m)	Deaths	Cables cut
Algiers	2003	6.8	3	2,244	All Europe-Mid-East
Tohoku	2011	9.0	10	19,000	~10

Taiwan

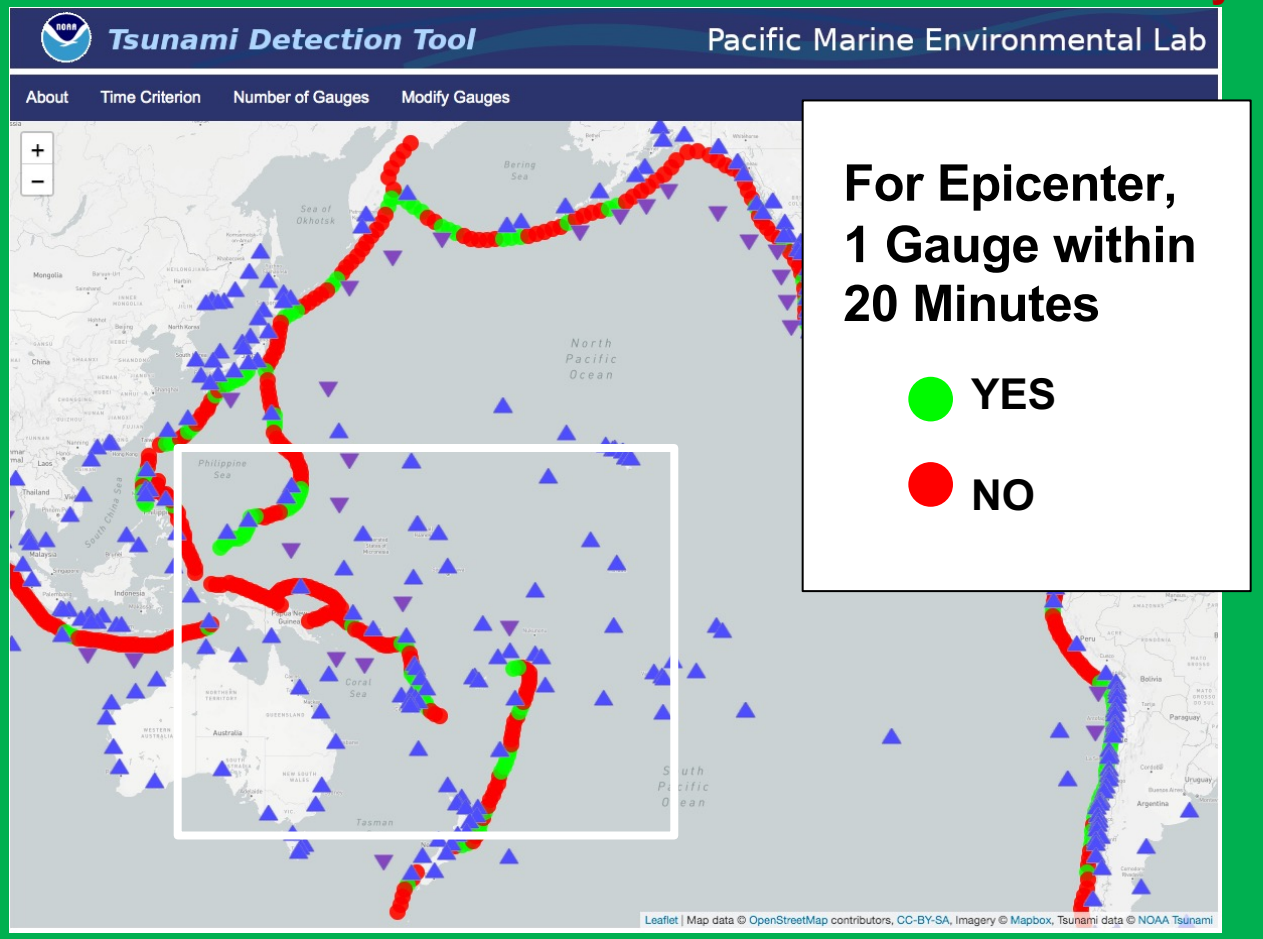
Climate change increasing typhon number and intensity (e.g., Morakot 2009)
+ earthquakes trigger submarine turbidity currents - Cut 42 cables 2006-2013

EARLY WARNING FOR LOCAL TSUNAMIS

How much time until wave arrives? <20 min



Coastal / DART Detection Latency

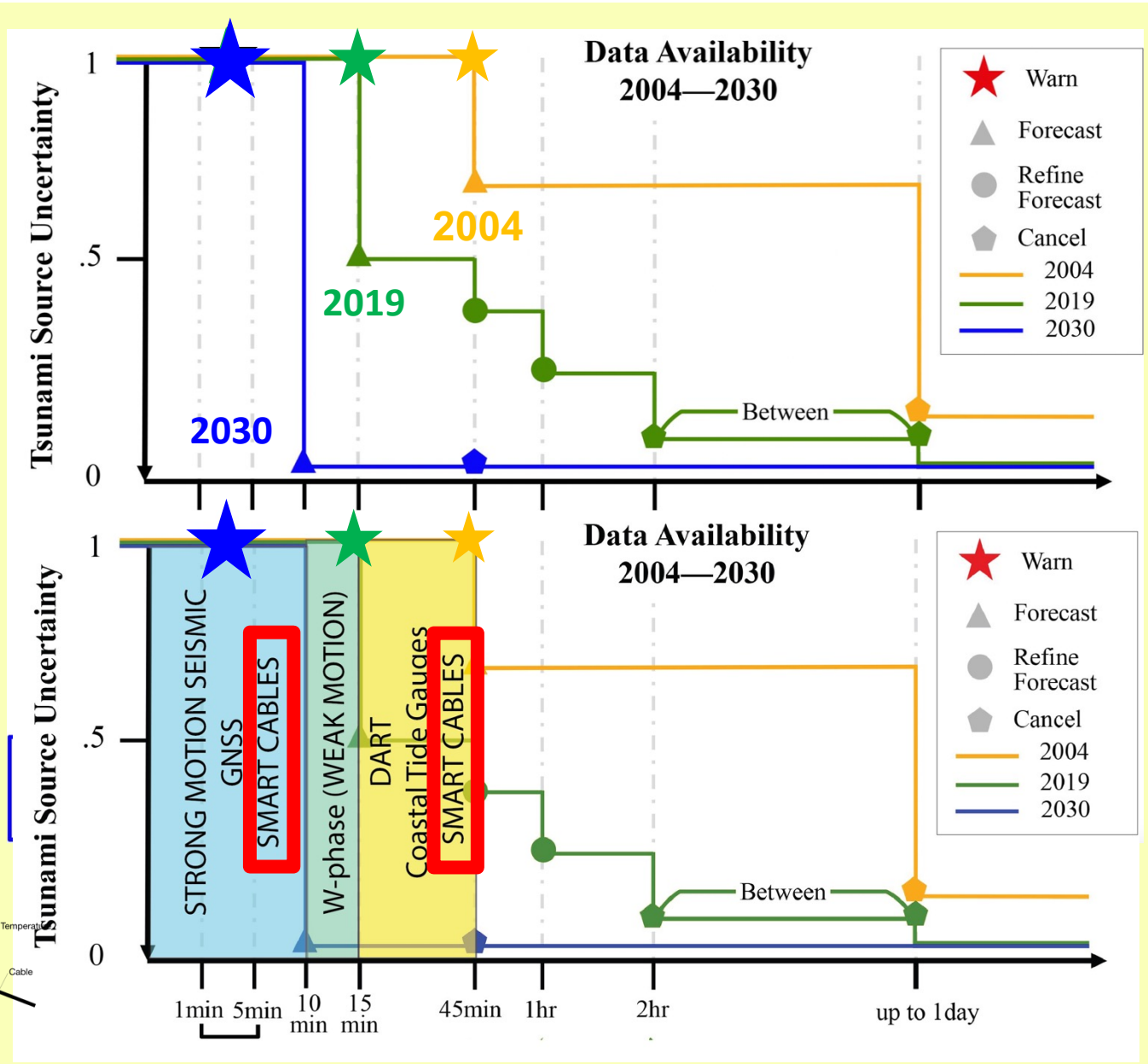


How fast you find out if wave is severe? <20 min

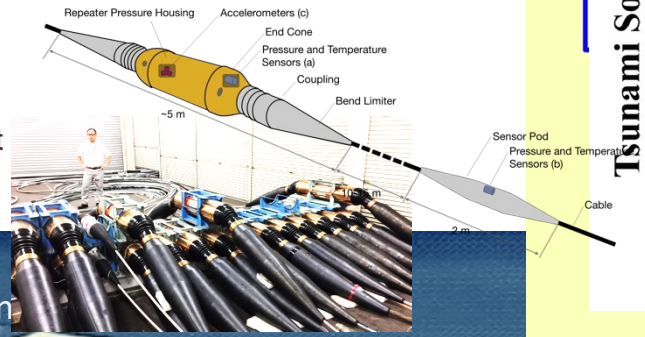
IMPROVEMENT IN EARLY WARNING (SMART, GNSS)

UN Ocean Decade Goal:

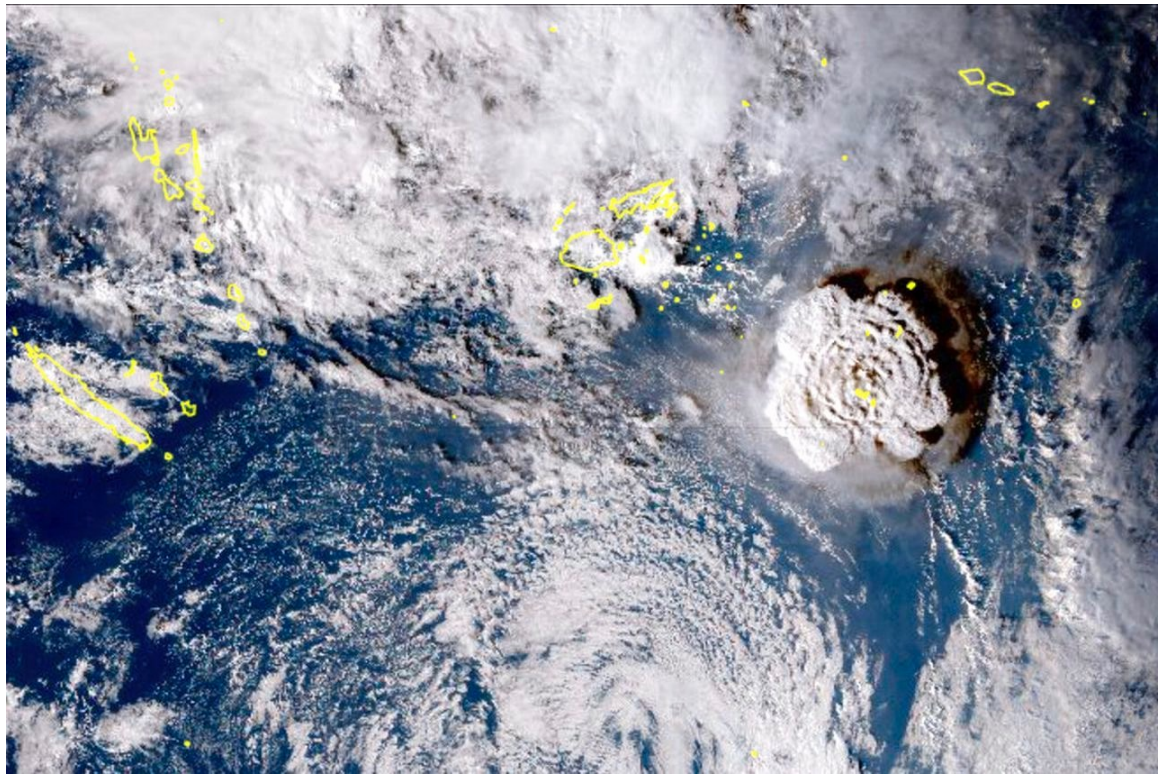
Integrate SMART Cable technology into innovative early warning systems



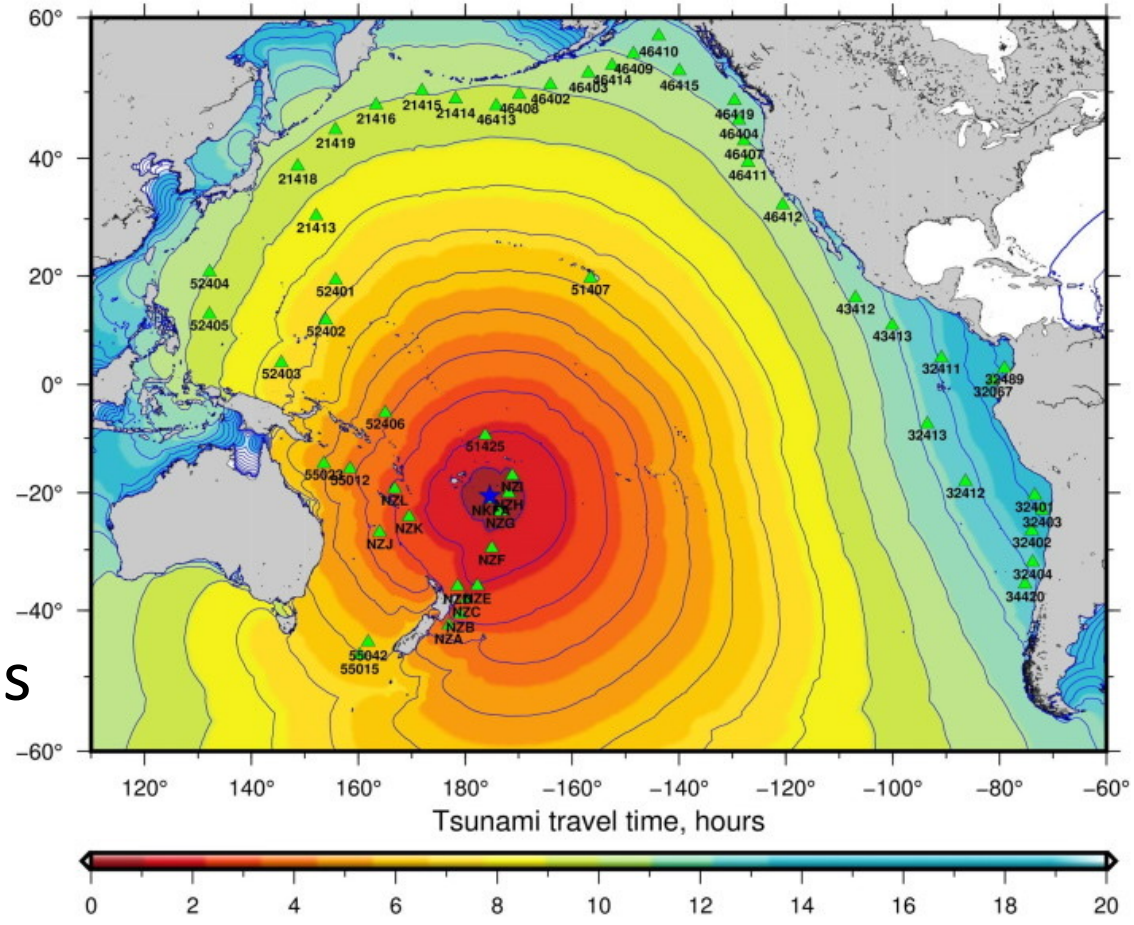
2021 2030 United Nations Decade of Ocean Science for Sustainable Development



Tonga Event

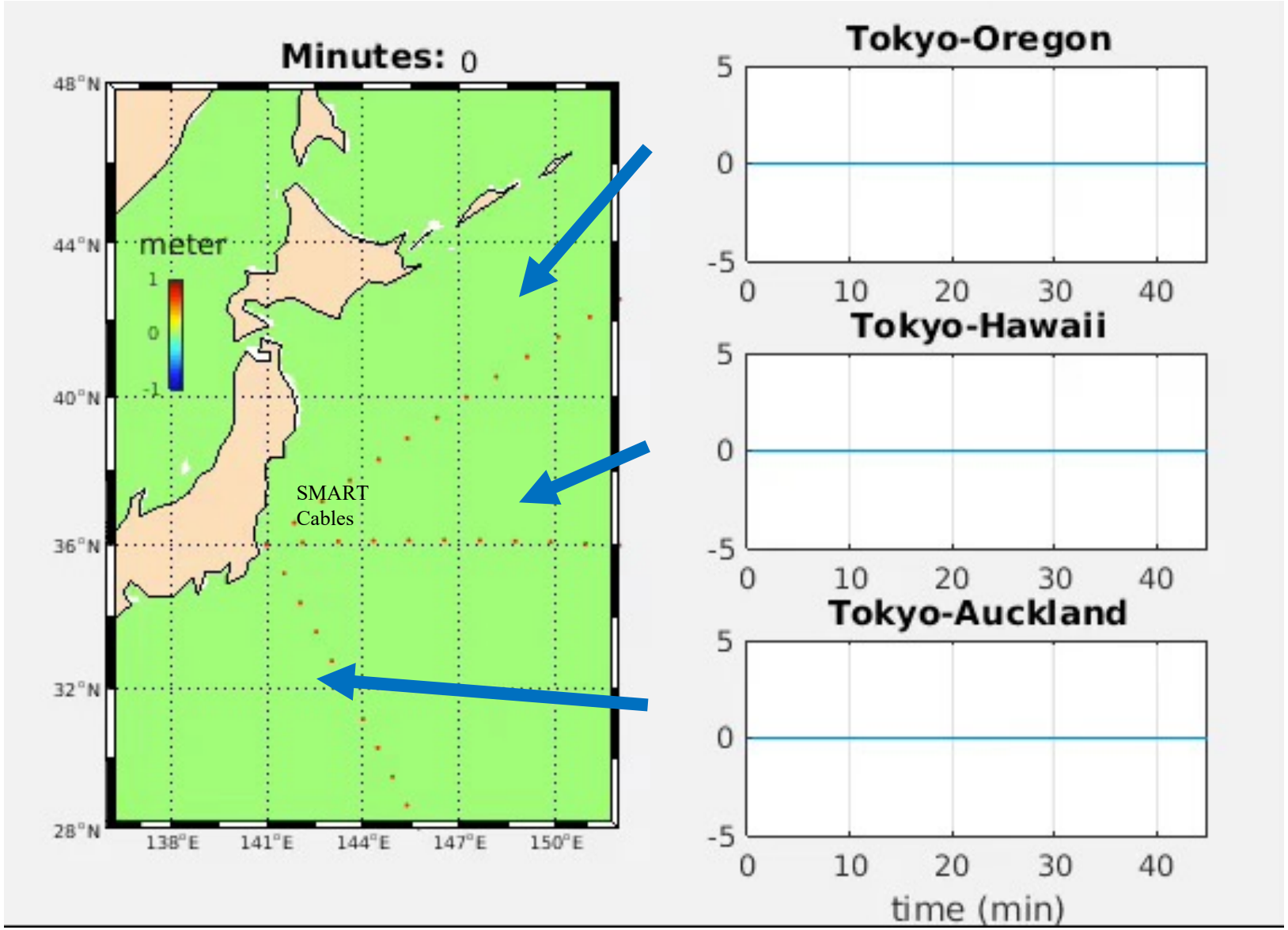


Global Scale



The earth is always presenting new surprises
– the unknown
Truly global network called for

Simulation – Tsunami Detection (bottom pressure)



Each line represents pressure sensor along cable

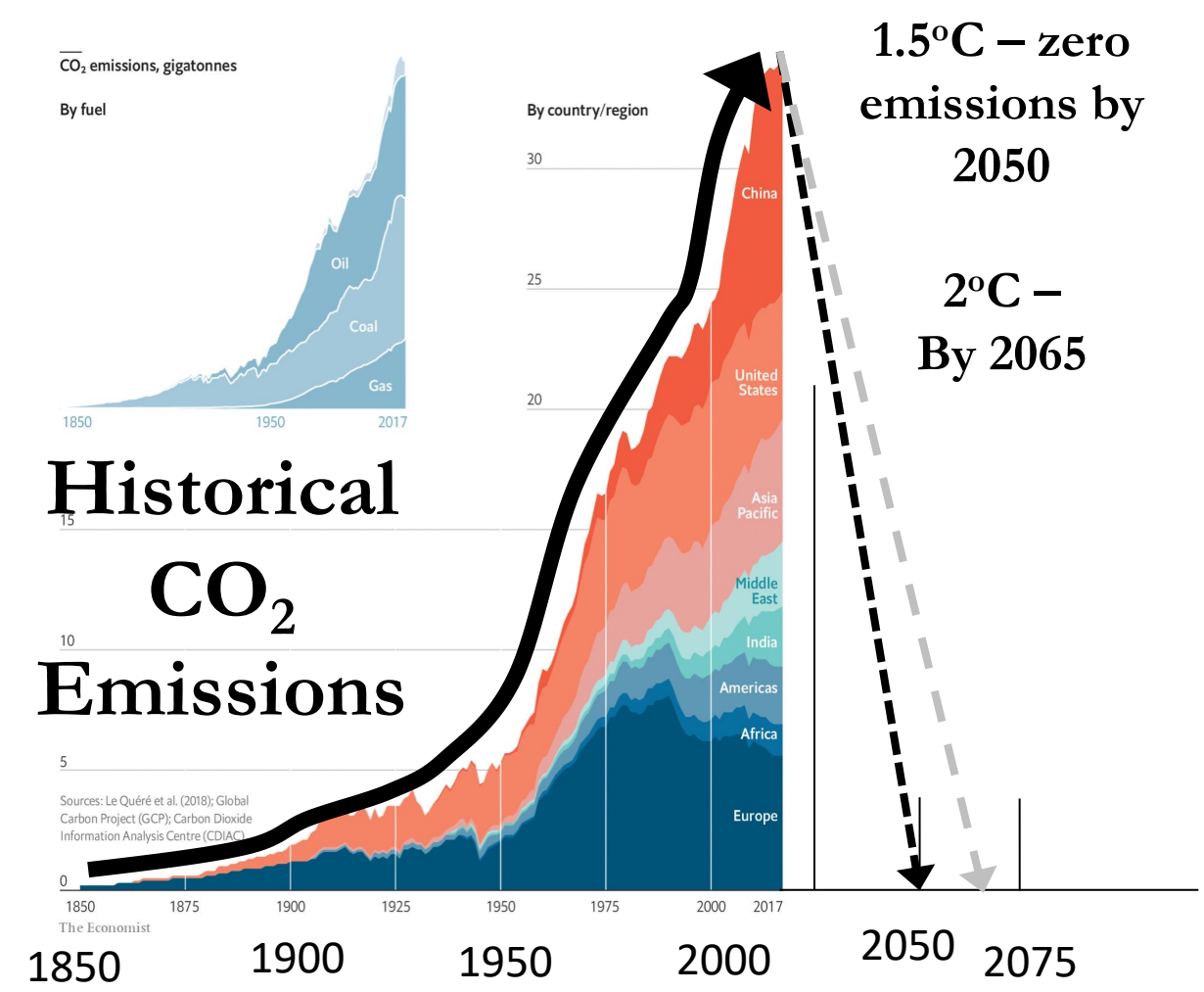
Realtime!

Reliable!

In situ

Tony Song,
JPL/CalTech

Global Warming



Historical CO_2 Emissions

1.5°C – zero emissions by 2050

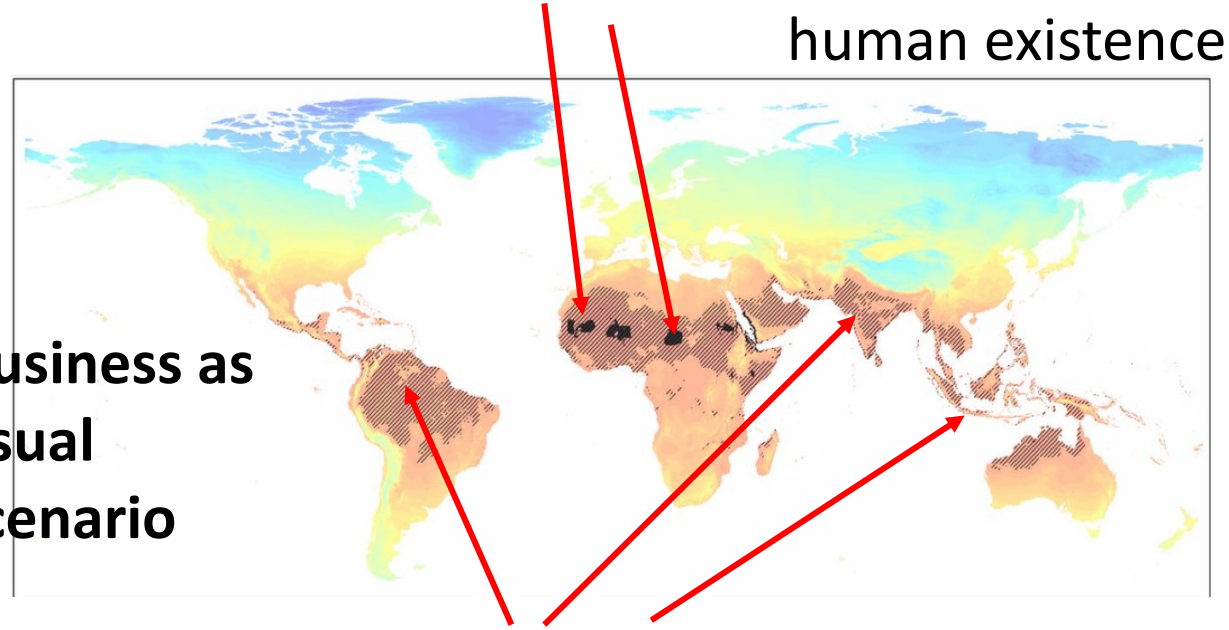
2°C – By 2065

We must remove CO_2 from the air for the rest of the century.

Courtesy C. Fletcher

Why SMART? Ocean = Flywheel of Climate: Stores 90% Heat, CO2, Determines future Temperature

TODAY – 0.8% of land surface, too hot for human existence

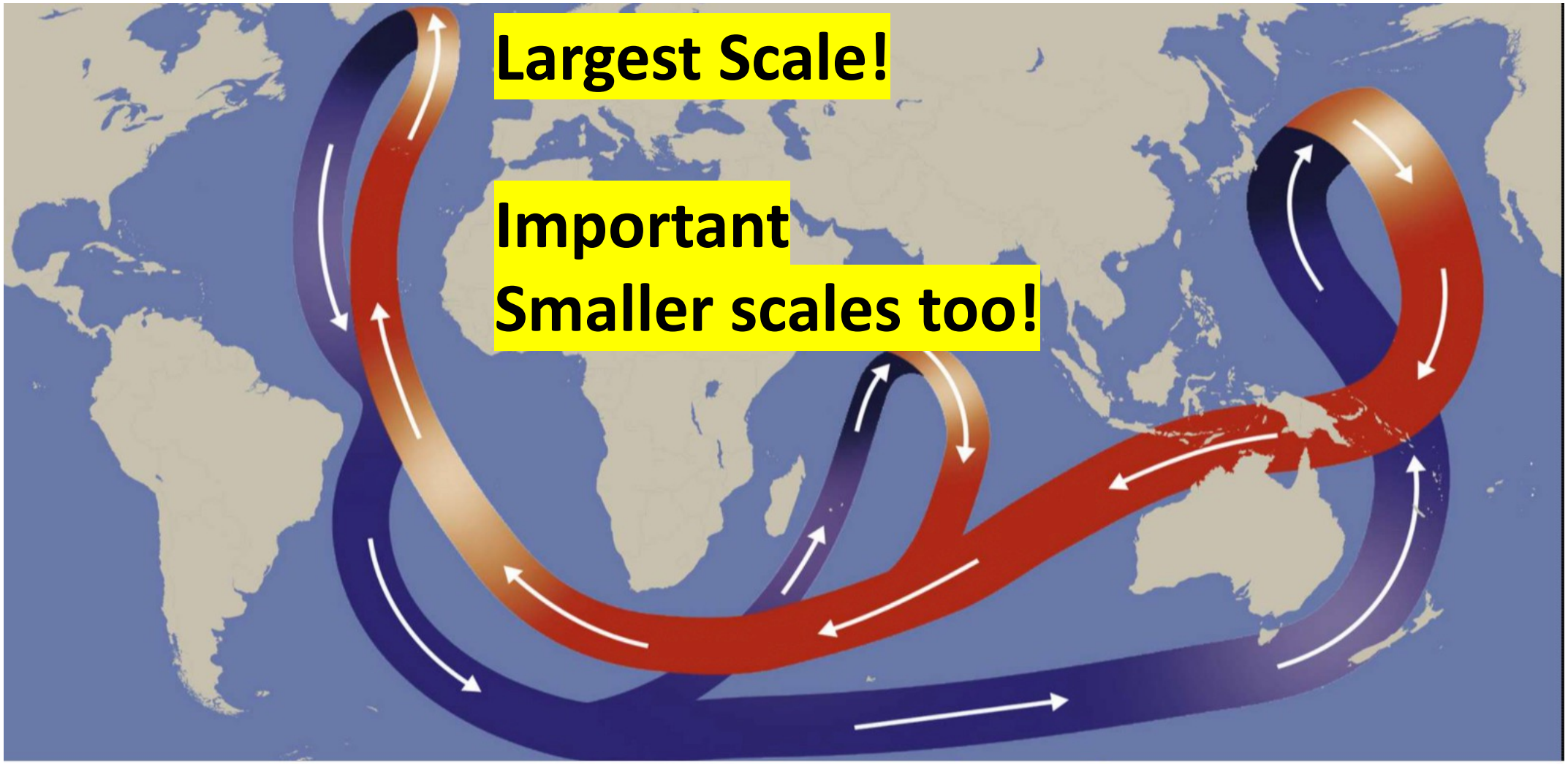


Business as usual scenario

2070 - 19% of land surface, too hot for human existence

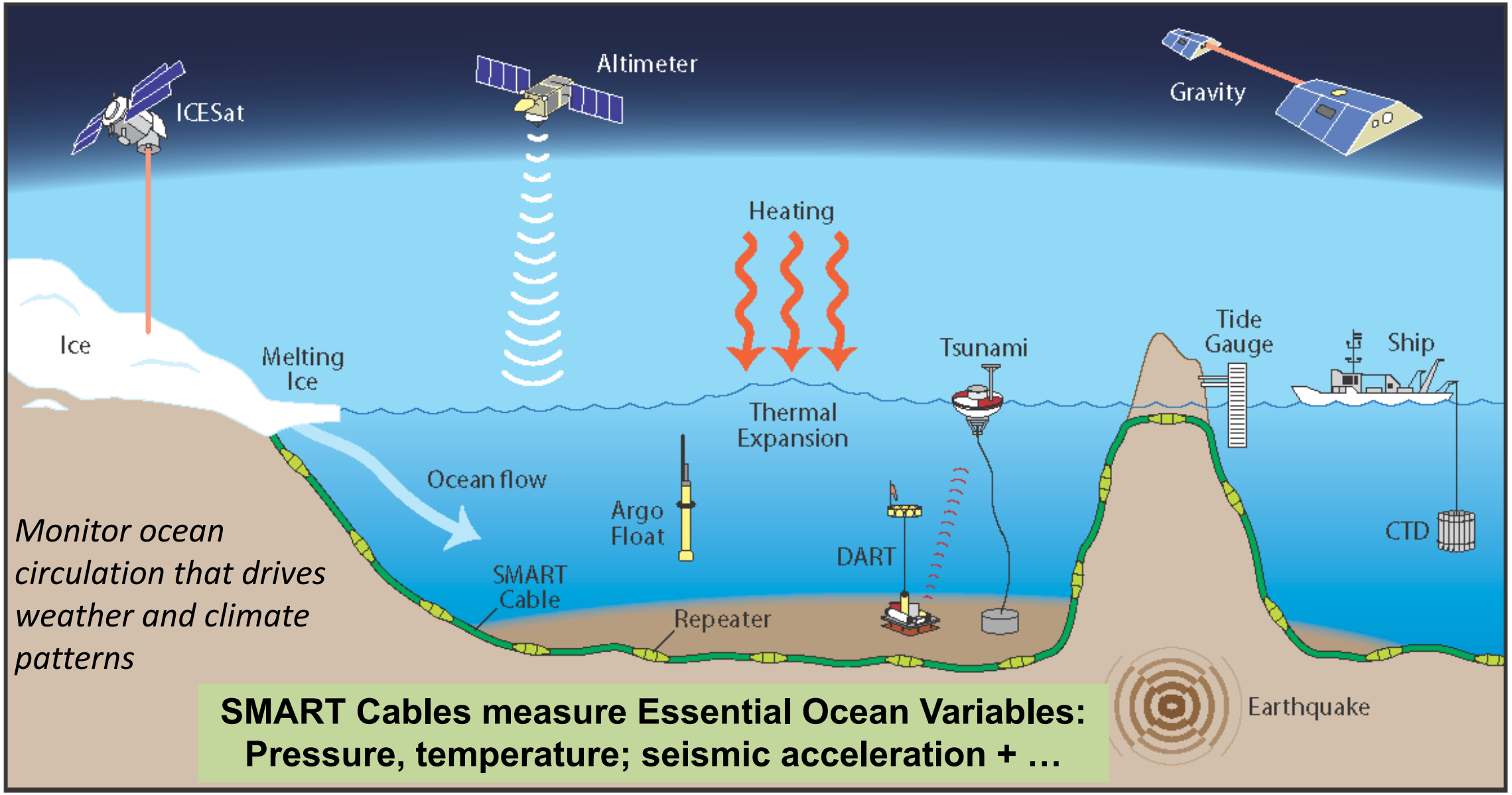
Mean Annual Temperature > 29 ℃

Ocean Conveyor Belt (a **simplification!**)



Sinking in polar latitudes - Return in upper ocean

Ocean Observing Tools



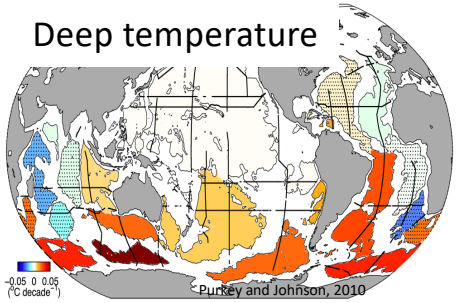
Monitor ocean circulation that drives weather and climate patterns

SMART Cables measure Essential Ocean Variables: Pressure, temperature; seismic acceleration + …

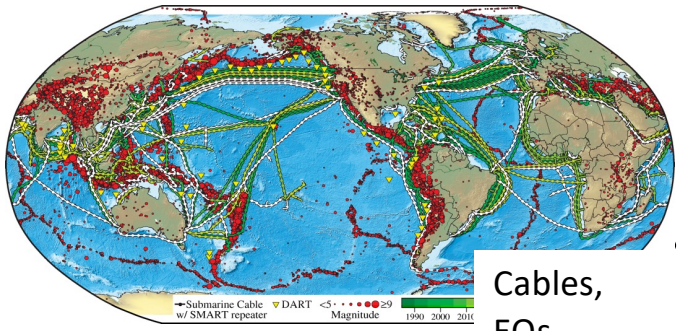
Science and Early Warning - Observables

Climate and Oceans

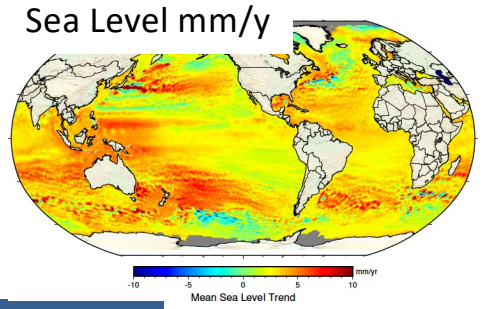
Temperature



- SMART ➜ **Subsurface temperature, EOV**
- Deep ocean warming ➜ sea level rise.
- Δ **deep ocean temperature** ➜ Δ circulation, Δ climate.

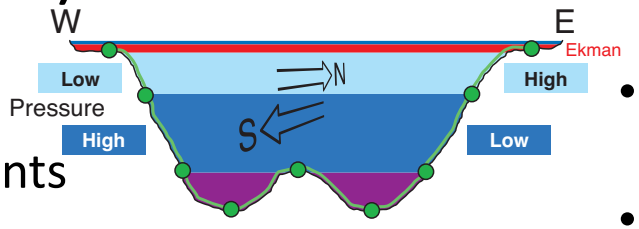


Cables, EQs, DARTs



Circulation, sea level rise, mass distribution

- **SMART Ocean bottom pressure (OBP, eEOV)** ➜ expansion, melting ice ➜ sea level change (x,t).
- Δ_x between OBP ➜ depth-averaged currents and ocean circulation.



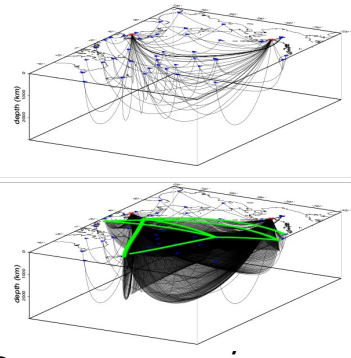
Hazards

Tsunami, Earthquake Warning

- SMART cables - vastly increase existing ocean **pressure/seismic sensors**
- Improve tsunami warning precision, Reduce unnecessary warnings/evacuations.

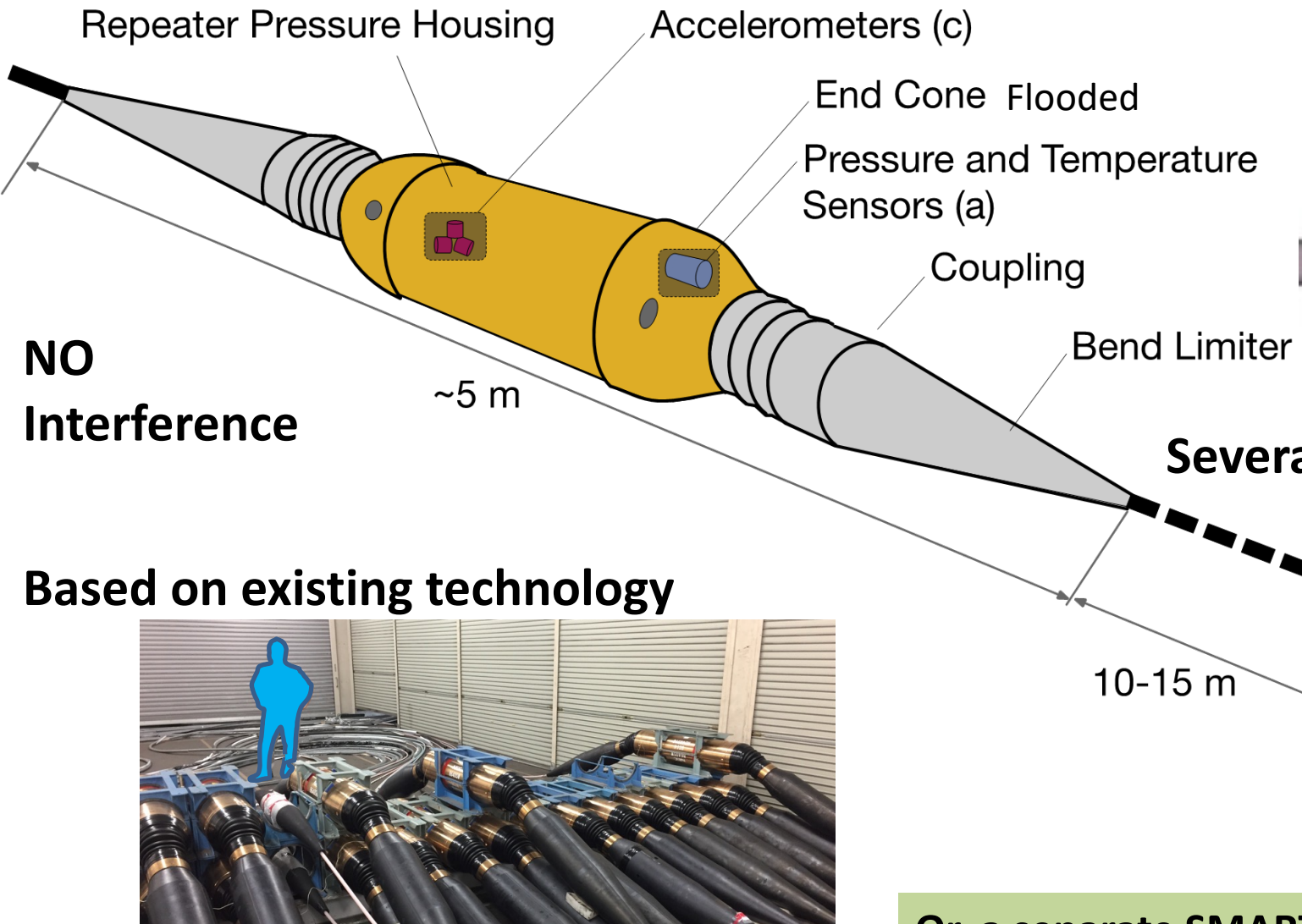
Seismology

- SMART **Seismic accelerometers** ➜ advance seismology:
- Detect, locate small quakes below ocean floor
- Rupture type and dynamics larger offshore earthquakes
- Image Earth's interior



sampling w/o, w SMART

SMART Repeaters

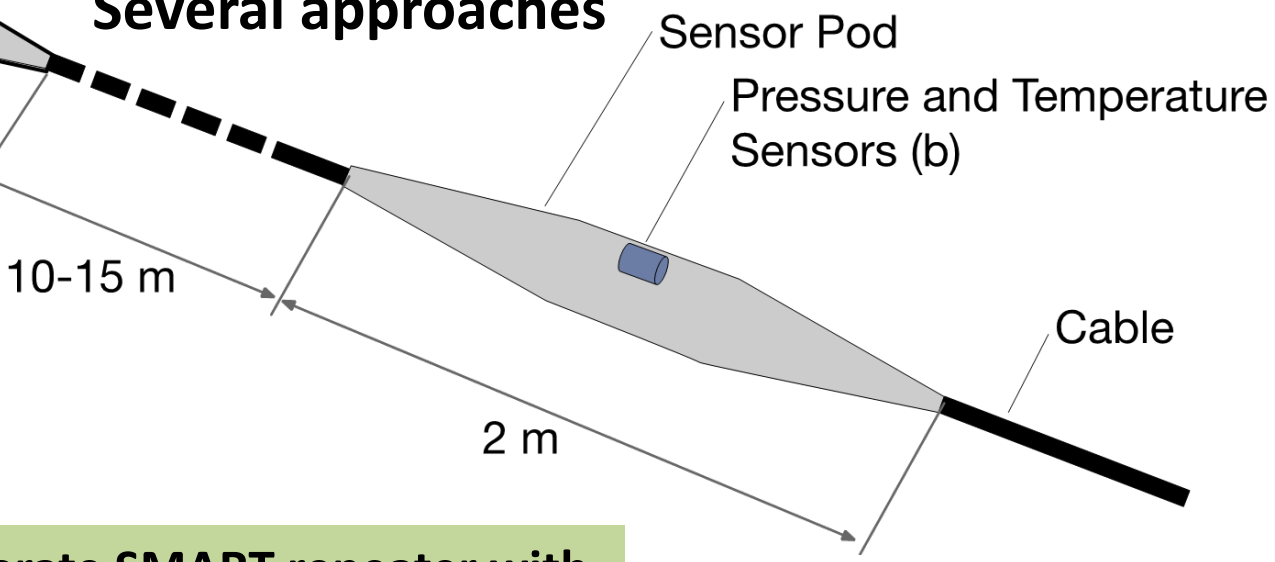


Subsea Data Systems
NSF SBIR - developing
Alcatel ASN will supply – Details TBD

Temperature sensors

NO Interference

Several approaches



Based on existing technology

Or, a separate SMART repeater with Telecom fiber pass-through

SMART Cables – Moore Foundation Project

GOAL:

SMART cables become the world standard, … global network for sustained ocean observation, … study of earthquakes, and earthquake and tsunami warning in a world with rising sea levels.

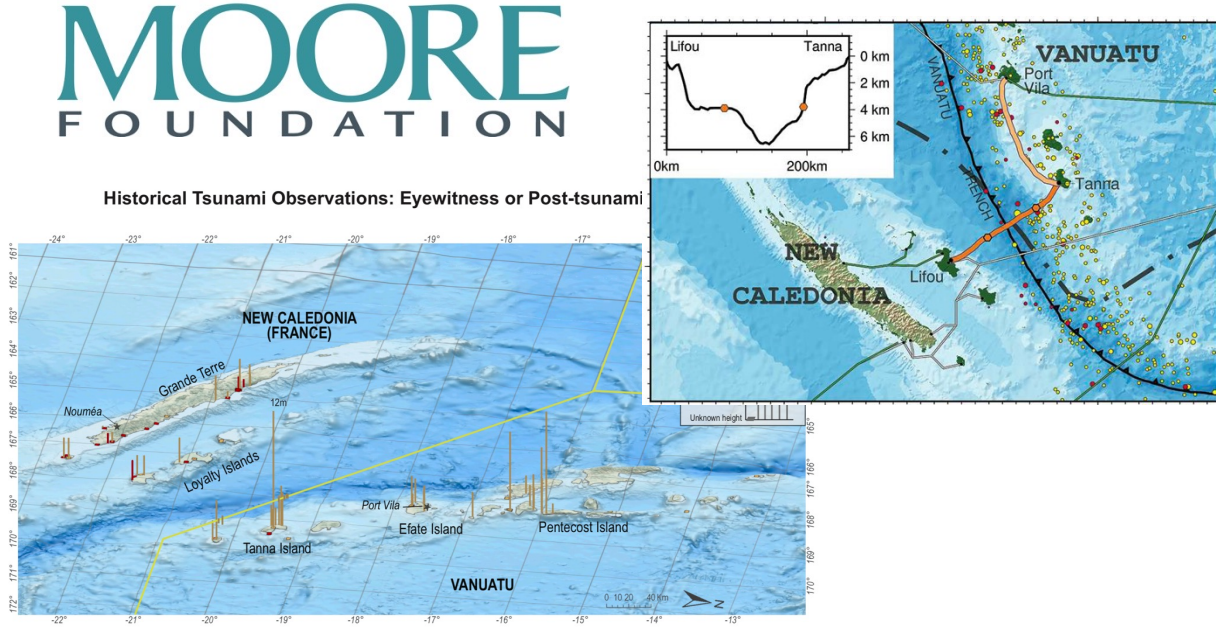
Objectives:

- **Science and early warning simulations of observing systems, data analysis, and sustained scientific operation.**
- **Vanuatu-New Caledonia, active subduction zone, dynamic ocean region, earthquake and tsunami early warning.**
- **International Project Office for Joint Task Force Scientific Monitoring And Reliable Telecommunications cables**

Team, 2022-2026

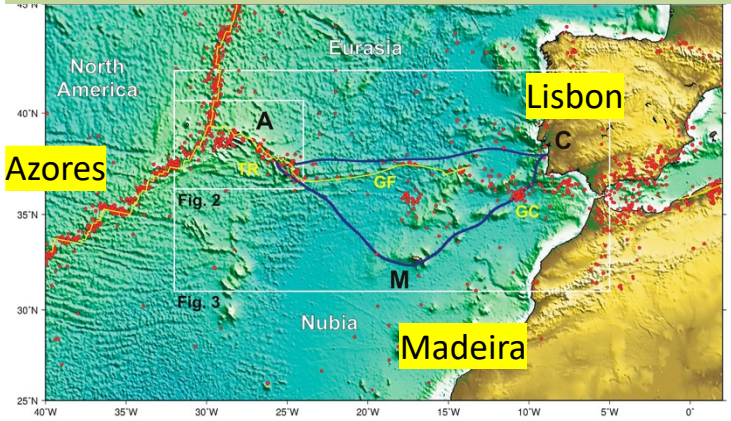
University of Hawai'i at Mānoa
Univ Texas-Austin
Louisiana State University (LSU)
University of Otago, NZ
National University of Vanuatu (NUV)
Pacific Community (SPC)
California Institute of Technology
Subsea Data Systems
Los Alamos National Laboratory (LANL)
French Institute for Research and Sustainable Development (IRD)
Vanuatu Meteorology and Geohazards Department (VMGD)
GNS New Zealand
International Tsunami information Center (ITIC)

GORDON AND BETTY MOORE FOUNDATION



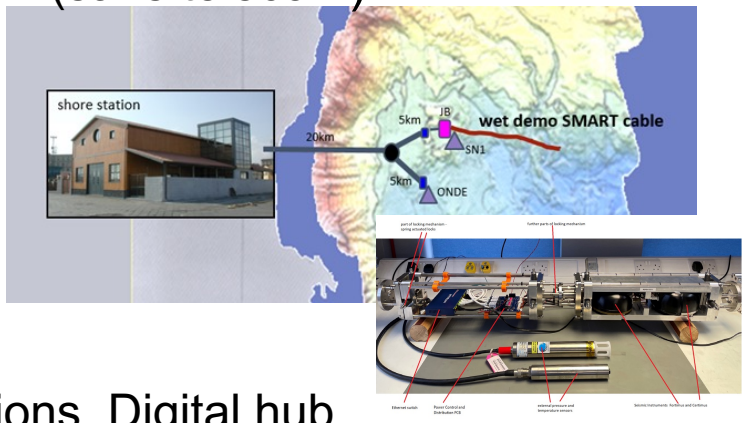
SMART Cables - Europe

Approved – underway!

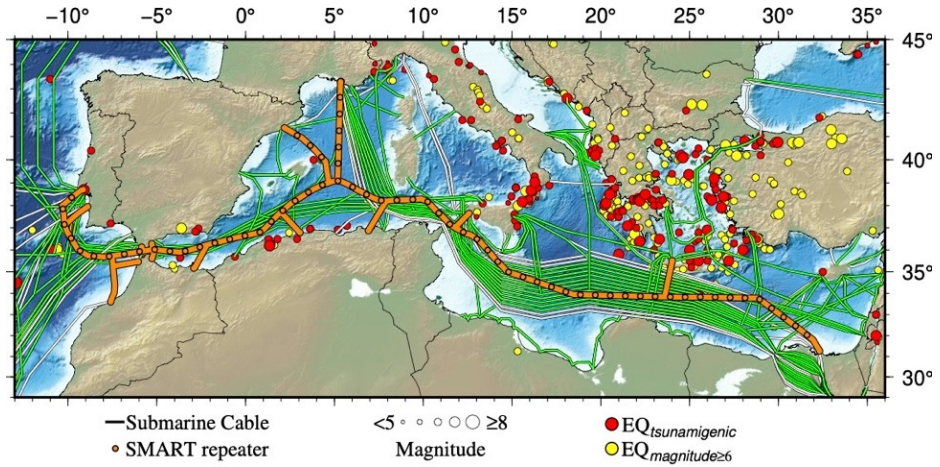


Wet Demo

- Install 2023
- Three test SMART repeaters (sans telecom)



NEAMTWS



SMART CAM

- Domestic, international connections, Digital hub
- 1755 earthquake tsunami
- Seismic, tsunami, ocean, environment
- 3700 km, 50 SMART repeaters, €154M approved
- RFP 2023Q1, Ready For Service 2025
- ANACOM connection to telecom

LEA – Listening to the Earth under the Atlantic

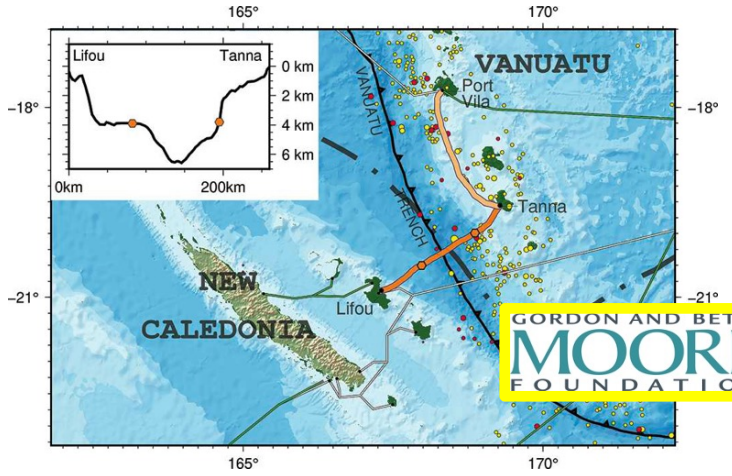
Risk analysis (V. Silva, pers. comm.)

- Improved EEW (~10 s) with less loss of life will more than pay for the system
- Next: include infrastructure and tsunami inundation

MEDUSA

- Install 2024/25
- Possibly up to ~60 SMART repeaters on main cables
- Improve coverage for large regional area
- Raising funds for SMART capability now

SMART Cables - Pacific



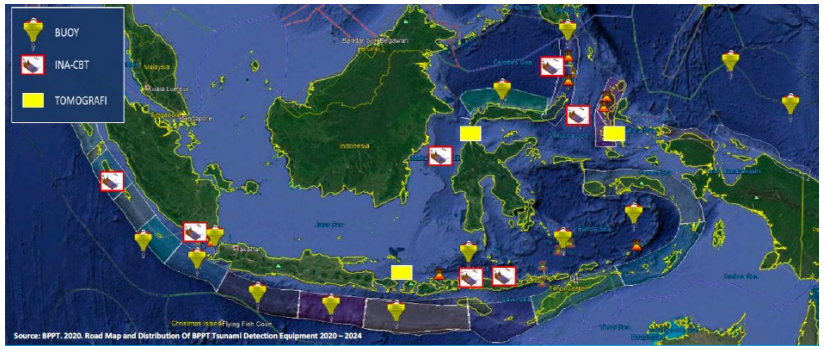
Vanuatu – New Caledonia

SMART, DAS

Intergovernmental MOU

France supporting

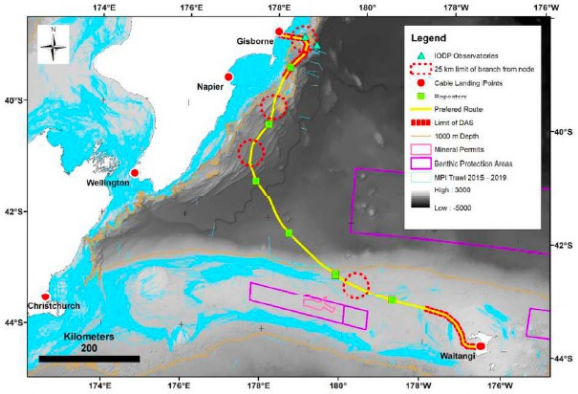
GORDON AND BETTY MOORE FOUNDATION



Indonesia

In country development Ina-CBT

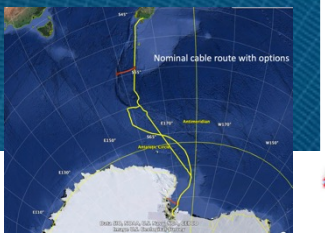
Single ended, 50 km, 2 module test system working off Labuan Bajo

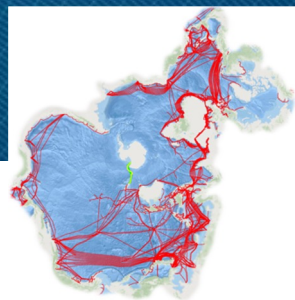


NZ–Chatham Islands

SMART + DAS + BUs/nodes

Under gov't review (MBIE)





NSF

Antarctica – NZ

Improve connectivity

SMART Cable

Workshops, NSF, NAS, Chile

Far North Fiber

14,000 km

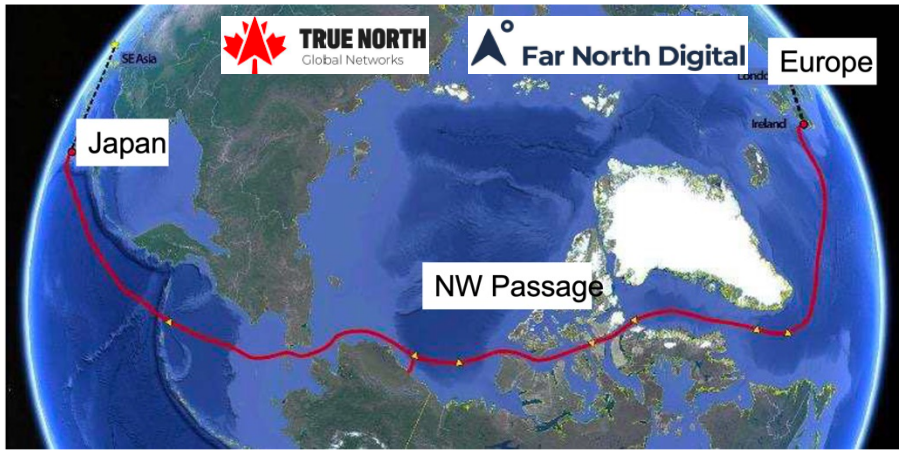
Low latency

Communities

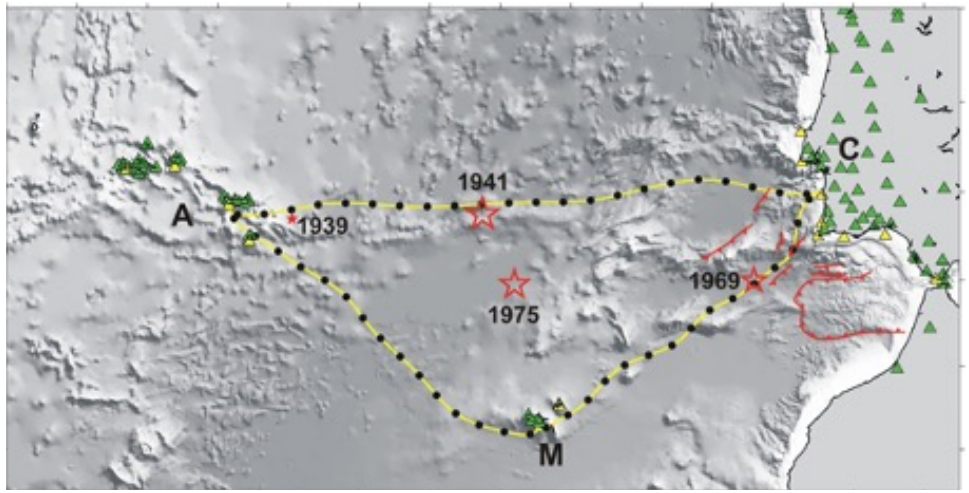
Contract 2023

RFS 2026

SMART integral

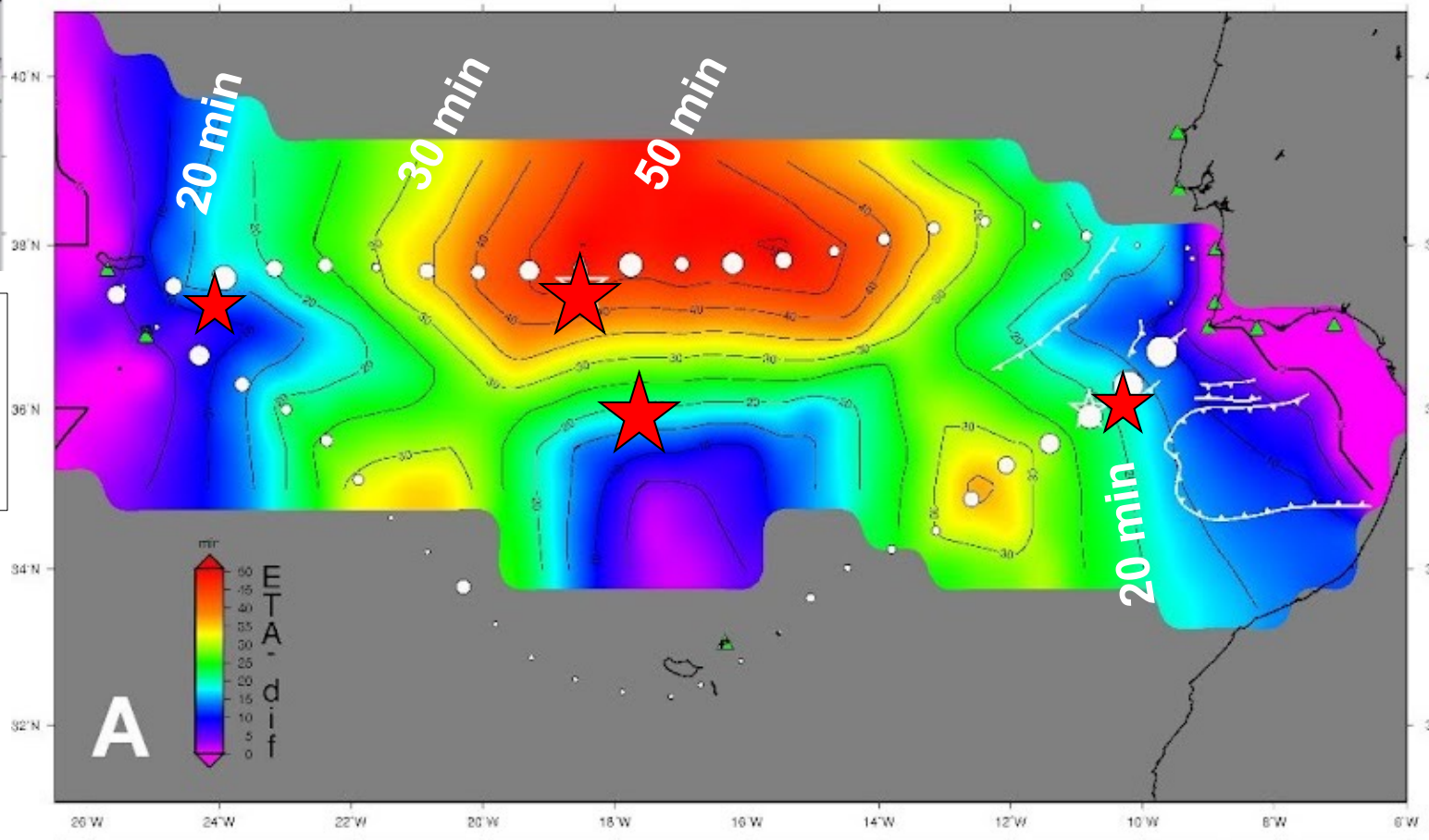


PORTUGAL: Continent/Azores/Madeira (CAM)



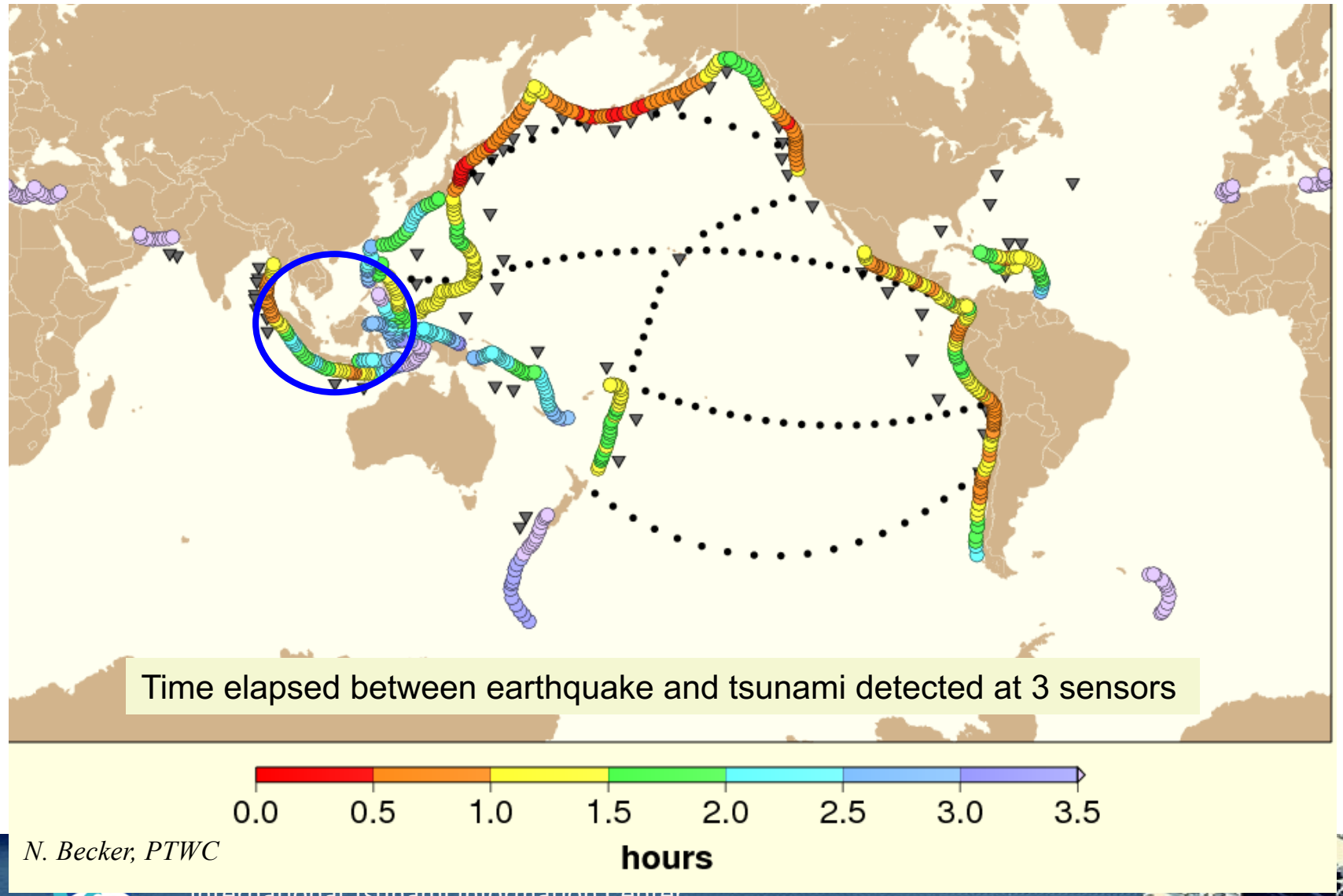
CAM submarine cable (SMART repeaters every ~70 km)
Green triangles - seismic stations (Instituto Português do Mar e da Atmosfera (IPMA).
Yellow triangles - coastal tide-gauges monitored (IPMA).
Red stars - M > 7.7 large tsunamigenic earthquakes

Tsunami warning time (min) improvement obtained by CAM-2 sensors (white circles) compared to coastal tide gauge network (**green** triangles).



LEA; Matias et al., 2021)

Tsunami Detection Time – 3 bottom pressure sensors



▲ SMART sensor (500 km)

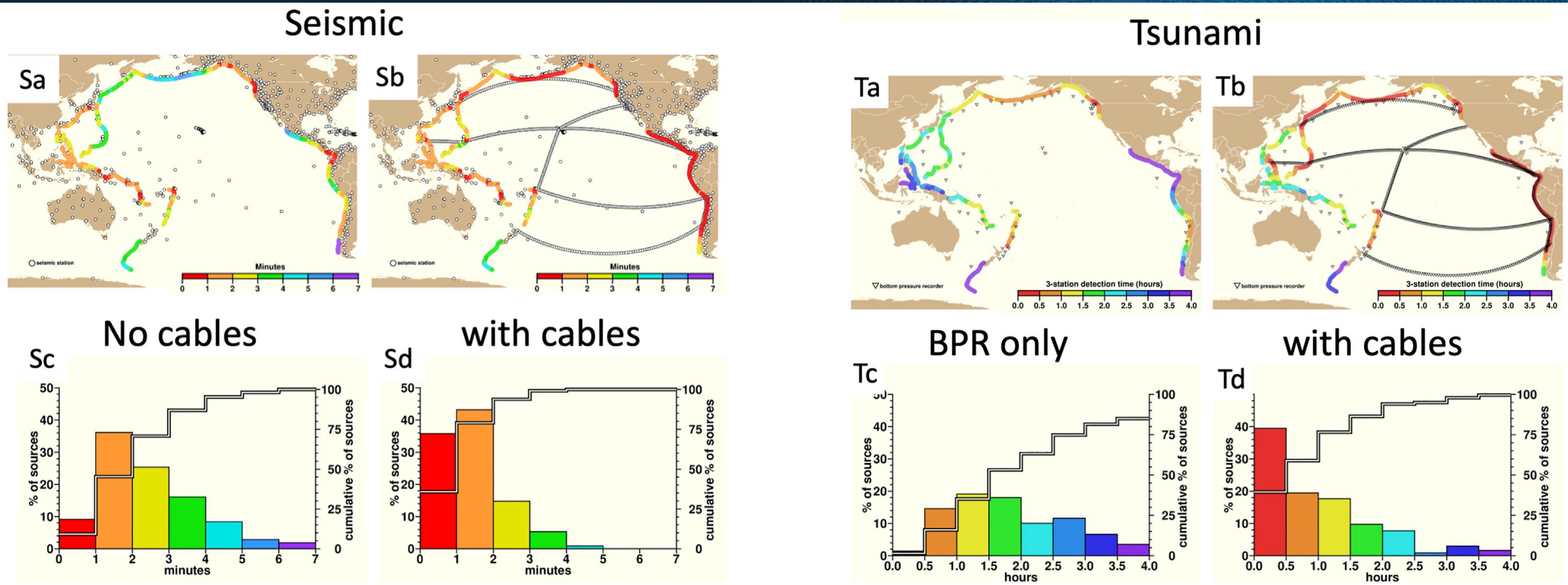
◯ Earthquake epicenter

- 25% reduction (2.1 to 1.6 hrs) in time to issue warning

  => 30 min is important for evacuation (walk speed 3 km/h)

- More time if 50 or 100 km sensor spacing

Earthquake and Tsunami Warning



Simple simulations. 905 synthetic earthquake sources located every 50 km -Pacific subduction

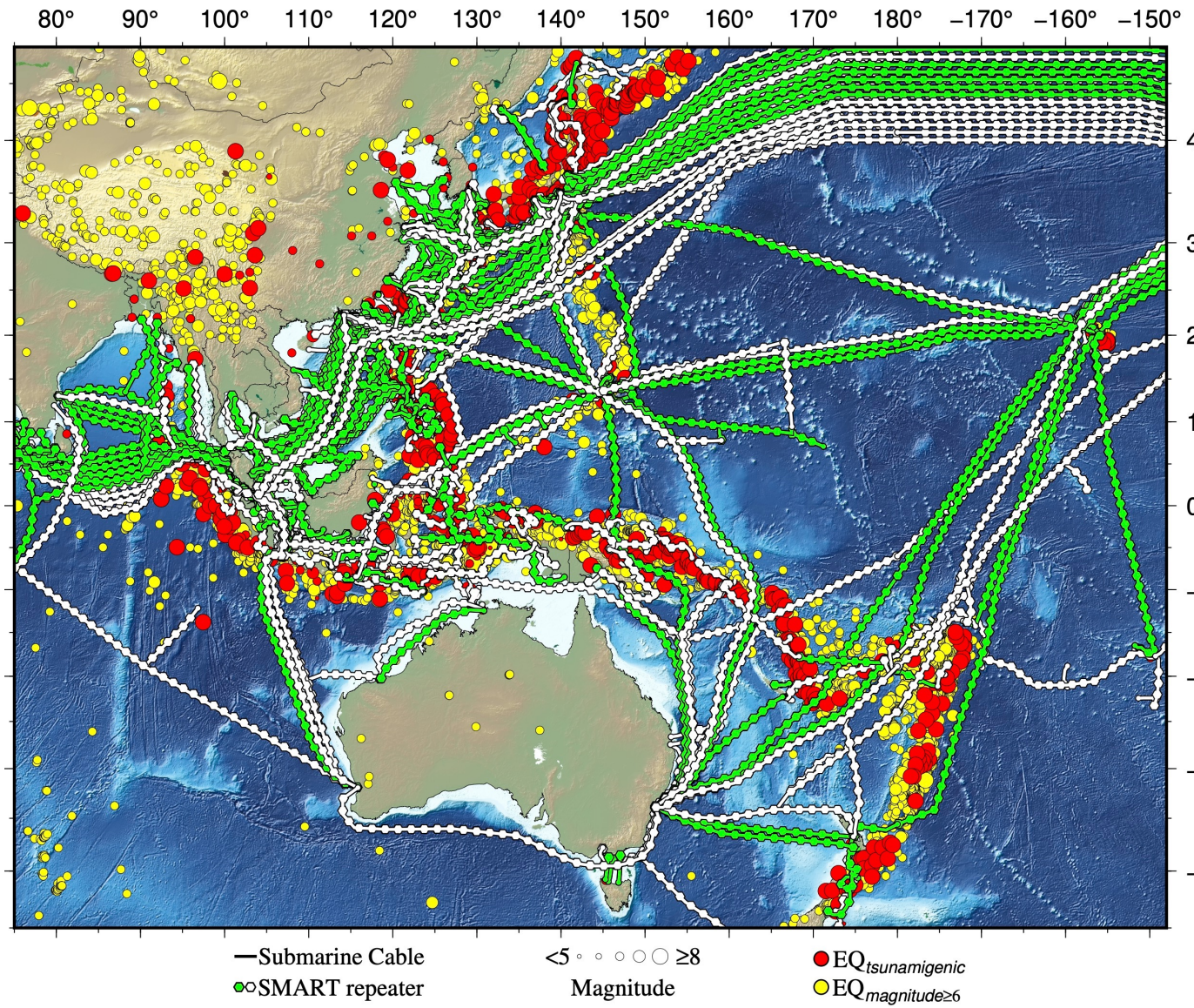
Seismic detection – 5 P-wave arrivals,
az gap < 180deg.
Earthquake detection time reduced
2.44 to 1.42 min, ~42%.

Tsunami – 3 BPR arrivals
Time dropping from
2.4 to 1.0 h, ~ 57%

Nate Becker, PTWC

A-P – Cables and Earthquakes – Risk!

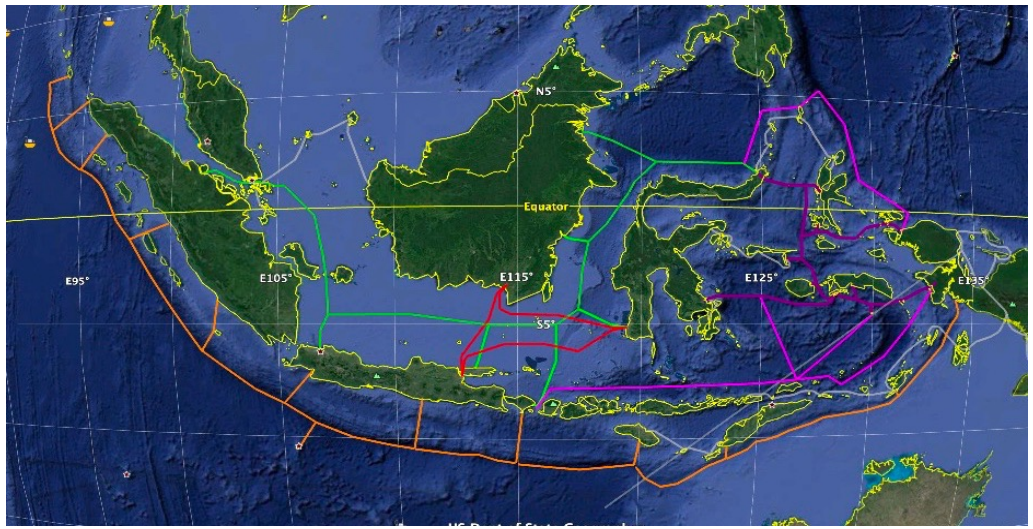
- Cables
  - Green, operational
  - White, in progress
- Yellow
  - earthquakes > M6
- Red
  - tsunamigenic earthquakes
- A disaster in the region is a disaster for all



Earthquakes and Tsunamis – Indonesia

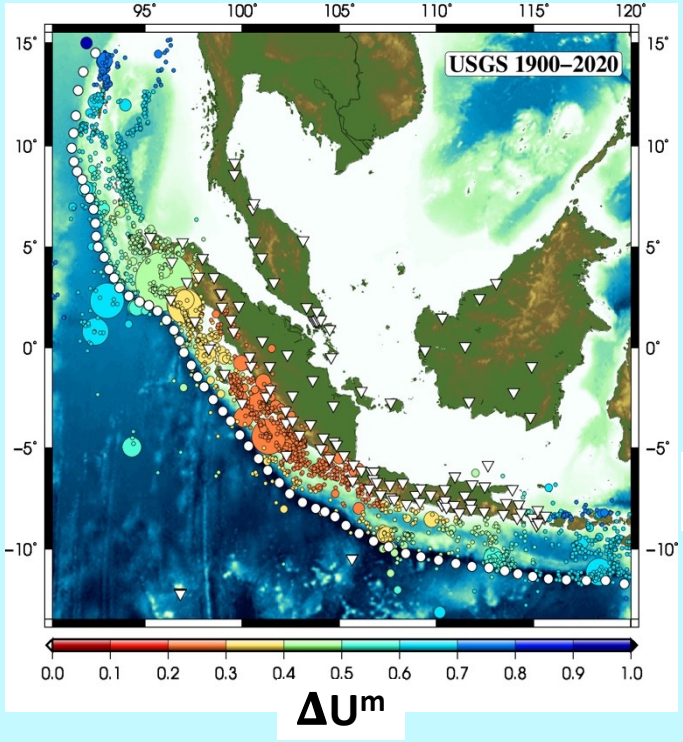
Strawman SMART Cable scenario for Indonesia
Example of SMART seismic and tsunami simulations

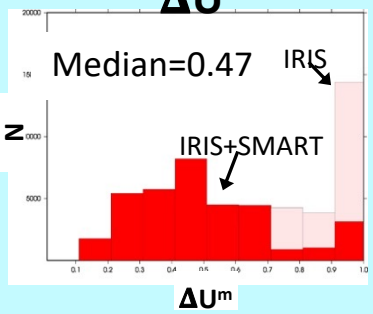
A. Salaree, et al., A numerical study of SMART Cables potential in marine hazard early warning for the Sumatra and Java regions, Pure and Applied Geophysics, 2022

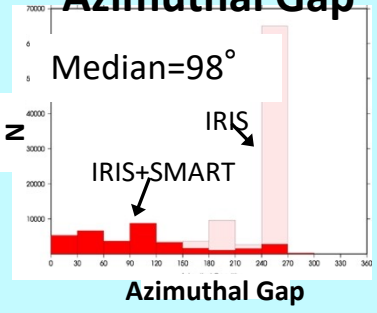


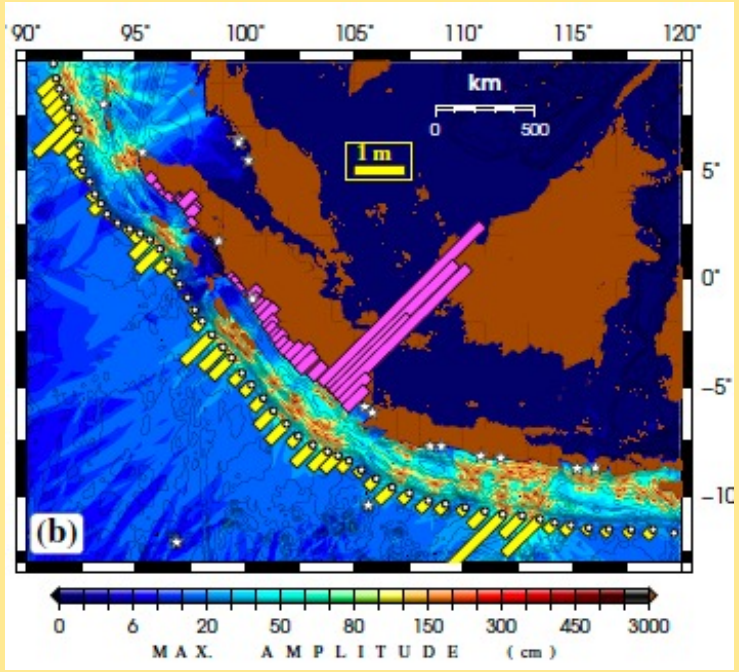
Improve geometry – Improve epicenter

ΔU^m - geometric parameter Good $0 < \Delta U^m < 1$ Bad







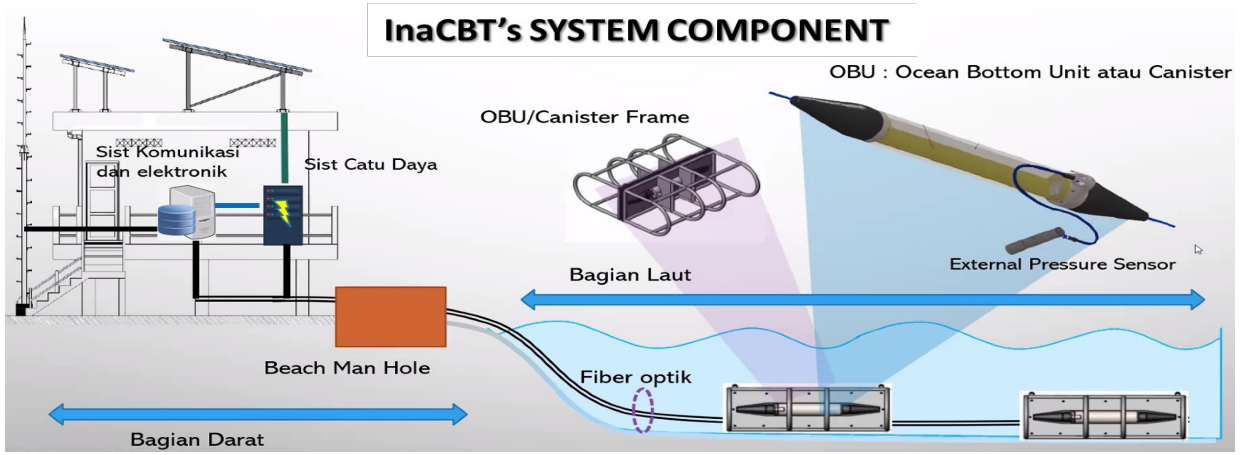


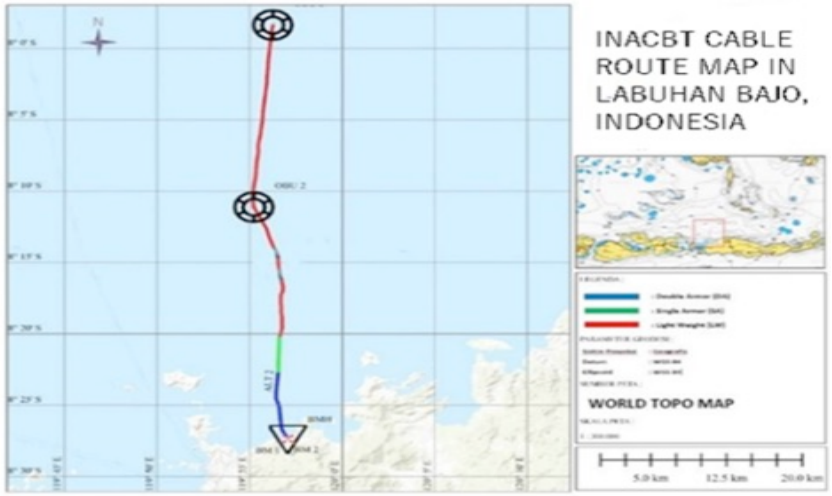
Landslides

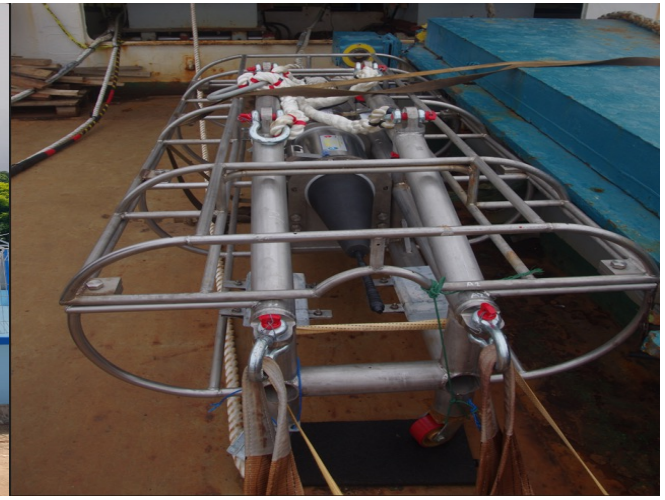
- SMART cable (yellow dots),
- 52 landslide scenarios
- Bottom slope
- Acceleration
- Tsunami height at cable
- Tsunami height near shore

Indonesian Cable-based Tsunameter (CBT)

The Indonesian government strengthened the existing InaTEWS, following an a-typical or non-tectonic tsunami (Palu and the Sunda Strait, 2018) by designating pertinent government agencies to provide support, such as the development of **InaCBT (Indonesian Cable-Based Tsunameter).**







The first InaCBT is situated in East Nusa Tenggara Province, north of **Labuan Bajo (LB),** with 2 (two) OBUs: OBU-1 is situated at a depth of 2.111 meters, 25-km from the shore, and OBU-2 is situated at a depth of 4.122 meters, 54-km from the beach.

Comments

- **Strengths**
  - Directly measures EOVs – temperature, pressure (in progress), addresses SDGs and Sendai DRR, part of UN Decade, with GOOS, part of UN structure
  - Global scale, sustained, realtime, 25-year life, highly reliable, leverages $5B/y cable industry with 170 years experience. Ultimately power, internet connections on seafloor, … relatively low lifetime cost
- **Weaknesses**
  - For now, limited to seafloor (future nodes – moorings, auv docking, acoustic nav/comms…), takes time to reach global scale
  - **Funding**. Non-traditional funding models needed; upfront cost or sustained loan payoff. Mismatch in time lines.
- **Concerns**
  - Still questions about international law (conflict - submarine cable privileges and marine science data) for the general cases – permitting and security
  - **Start with countries that want the capability – bypass concerns about legal/permitting/security issues**

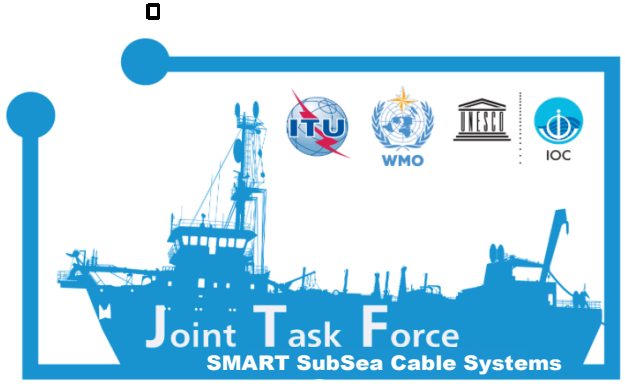
Concluding Remarks

CLIMATE, OCEAN SEA LEVEL, EARTHQUAKE, VOLCANO, TSUNAMI

- SMART – essential ocean variables and disaster risk reduction, SDGs
- Benefits to telecom - cable integrity, security and network resilience
- Global scale, power+internet on seafloor, sustained, realtime, 25+ year life, highly reliable, leverage $5B/y industry, 170 y experience, low lifetime cost
- European Union Funding: Cables, w/ SMART, outlying territories, €153M
- SMART systems: CAM, MEDUSA, V-NC, Antarctica, … will set precedents
- Work towards global scale, coverage – KISS
- **SMART – a fruitful marriage with telecom – connectivity, climate, DRR – three for the price of one – saves resources on all fronts**

Observing the Earth and Ocean with SMART Subsea Cables: Tsunamis

***S**cience **M**onitoring **A**nd **R**eliable **T**elecommunications*



Thank you!

Questions?

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

DEEP OCEAN OBSERVING STRATEGY

pogo Partnership for Observation of the Global Ocean

ITU WMO UNESCO IOC

ITIC Training Program
on Tsunami Early Warning and Mitigation Systems
18 August 2023
Honolulu, Hawaii, USA

GORDON AND BETTY MOORE FOUNDATION

SCHMIDT MARINE TECHNOLOGY PARTNERS

References
SMART Progress

- Joint Task Force (JTF), ITU/WMO/IOC SMART Cables for Observing the Ocean
  Science Monitoring And Reliable Telecommunications, Climate Monitoring and Disaster Mitigation
- SMART Cables for Observing the Global Ocean: Science and Implementation, 2019. Frontiers of Marine Science
- SMART Subsea Cables for Observing the Earth and Ocean, Mitigating Environmental Hazards, and Supporting the Blue Economy, 2022, Frontiers of Earth Science
- SMART Cables Observing the Oceans and Earth, Marine Technology Society, 2022.
- Wet Demo off Sicily to be installed 2023, INGV, Funded
- Alcatel Submarine Networks (ASN) 2020.09.29 Press release - climate change an integral part of business strategy, 2023.03.14 Press Release - developing Climate Change Solution; will supply SMART capability 2025.
- Portugal SMART Atlantic CAM system Continent-Azores-Madeira ring, 3700 km, 50 SMART repeaters, ready for service 2025, €154M. Authorized by Gov't 2022.04.13; 2022.10.20; RFP issued 2022.12.13; Description and implementation of the "Observer Part" of a SMART Cable, 2023.01.27, Science paper. Early Warning Paper.
- Vanuatu-New Caledonia - Leaders signed MOU for 2nd international cable 2022.07.29, SMART, France will support a SMART Cable between Vanuatu and New Caledonia - President Macron's speech in Vanuatu 27 July 2023 (video (minute 11) and text)
- NZ-Antarctica/McMurdo Base SMART Cable, US National Science Foundation and workshop report - desk top study just complete (awaiting public report)
- NZ-Chatham Islands - MBIE report under consideration, w/ SMART, and Science workshop report
- Norway-Japan via Arctic - Far North Fiber - under consideration, welcome SMART. NORDUNet PolarConnect Video.
- MEDUSA - Lisbon-Egypt - raising funds for SMART portion
- Indonesia – in-country development – 50 km 2 node single ended system; SMART Cable Potential in Indonesia, Salaree et al, Pure Appl. Geophys, 2022
- Moore Foundation has awarded Joint Task Force/UHawaii $7M to facilitate SMART, globally, regionally, as well as Vanuatu-New Caledonia, proposal
- ITU - Circ. Letter Member States, Assemblies (WTSA-20, WTDC-22, PP-22); Study Group 15/Q8 G.SMART. Forwards - Submarine Telecom, 2019/20, 2021/22
- SMART endorsed as Project of the UN Decade of Ocean Science for Sustainable Development 2021-2030, Supporting Docs, Web page, with GOOS, Tsunami
- Global Ocean Observing System (GOOS) accepts Ocean Bottom Pressure as an Essential Ocean Variable; and SMART as a GOOS Project. 2022.11.28.
- European Union Funding: CEF-2 Digital Global Gateways, Submarine Cables, Call 2 2022.10.12, w/ SMART, outlying territories, €153M, 30-70% of project cost; (see DG Connect ppt); Call 3 summer 2023
- JTF SMART Cable Workshop 19-20 January after PTC23 in Honolulu, followed by Moore SMART Cable project meeting 21-23 January.
- Asia-Pacific Countries with Special Needs Development Report, 2023: Strengthening Regional Cooperation for Seamless and Sustainable Connectivity, ESCAP
- Workshop, SMART Cables, Science and Society, University of Aveiro, 22-23 May 2023
- New SMART Cables web site (in addition the ITU site at top), https://www.smartcables.org/ and video.

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