

Observing the Ocean and Earth with



SMART
CABLES

SMART Cables: Ocean Infrastructure for the Future



Science Monitoring And Reliable Telecommunications

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The Committee on the 2025-2035 Decadal Survey of
Ocean Sciences for the National Science Foundation
Ocean Studies Board

National Academy of Sciences, Engineering, and Medicine
24 April 2024



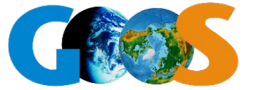
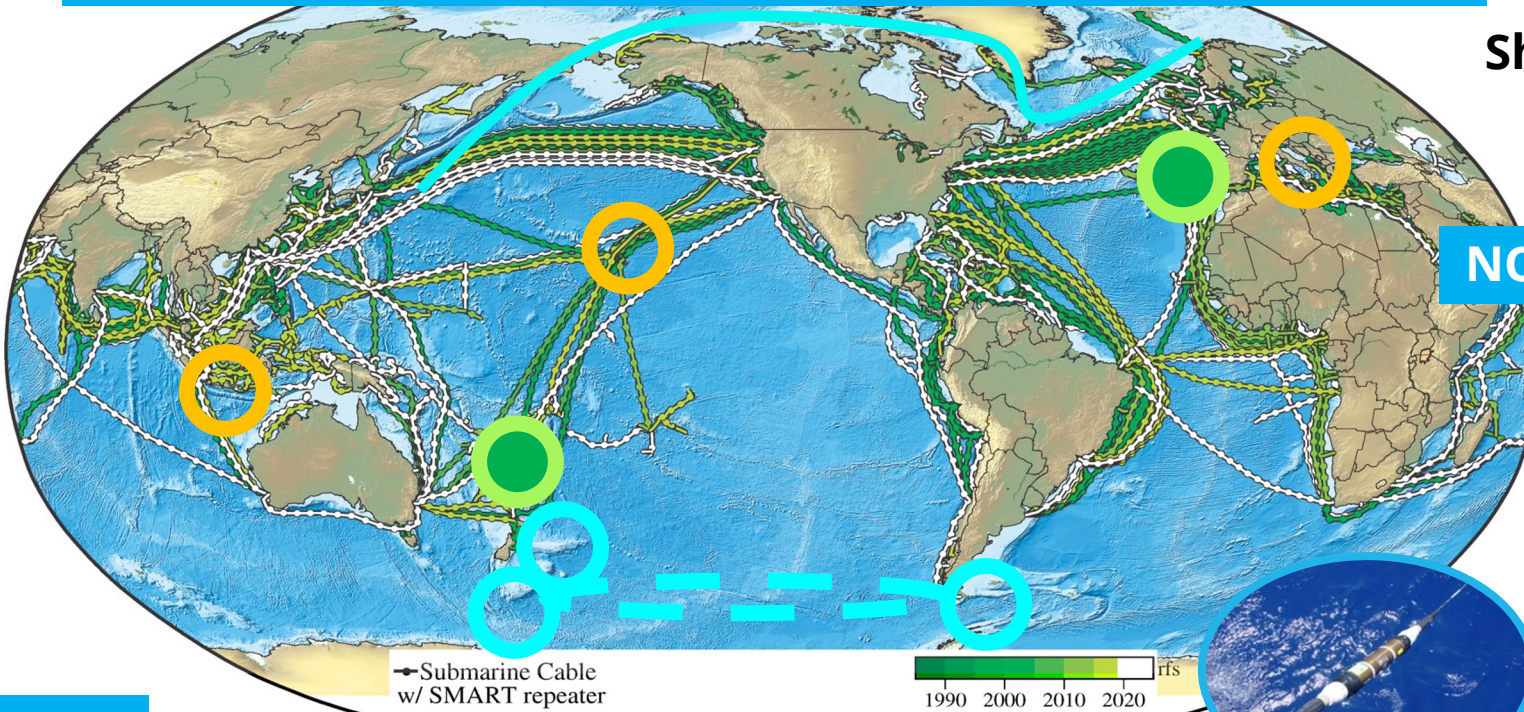
**NATIONAL
ACADEMIES** Sciences
Engineering
Medicine

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

1st order addition
to Ocean-Earth
observing system



Create a Planetary sensor, power, Internet network



Share submarine cable
infrastructure
Telecom + science
↓ €\$

NO Interference

1.4+ Gm
~20,000 repeaters
20 year refresh

spacing ~100 km

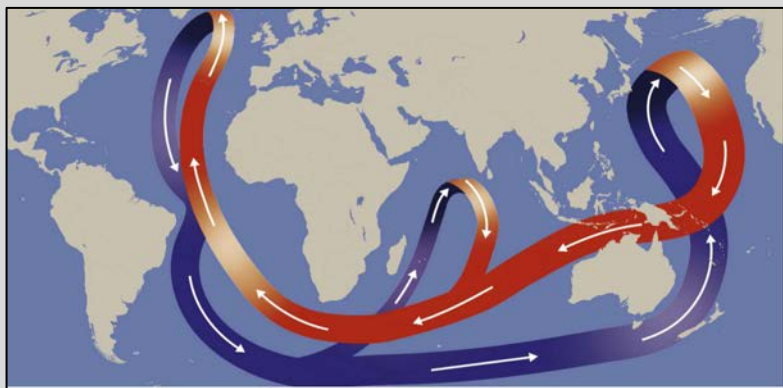
SMART Atlantic CAM
ring, 3700 km, Gov't
€154M, 2026

**Know the environment
protect the network**

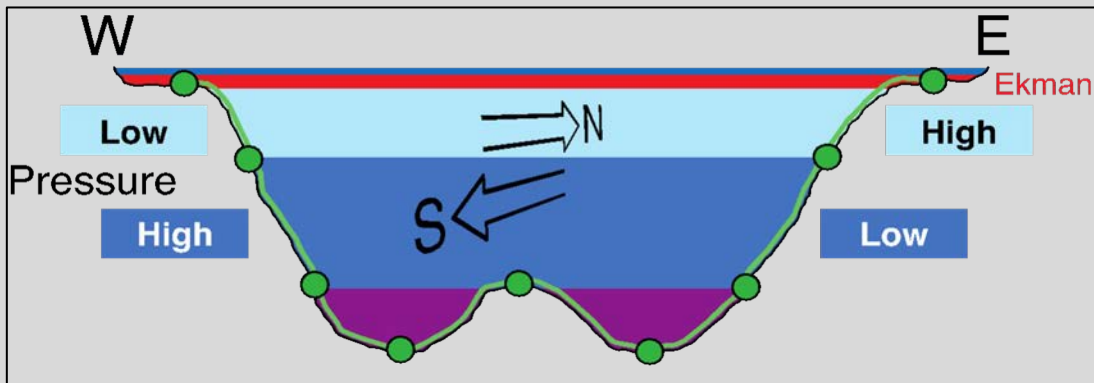
Bottom temperature
pressure, seismic sensors



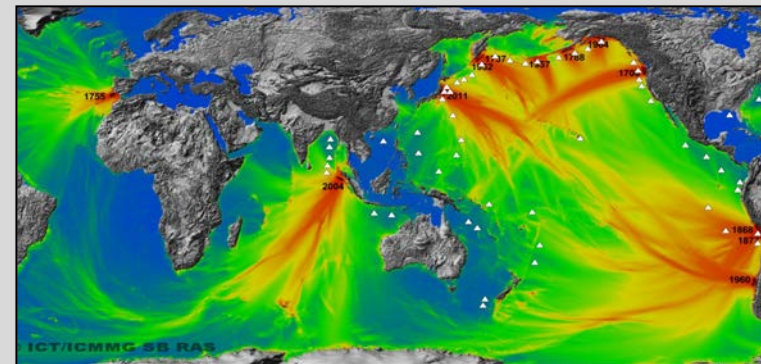
Earth System Energy Budget



Climate Change



Ocean heat and circulation, AMOC

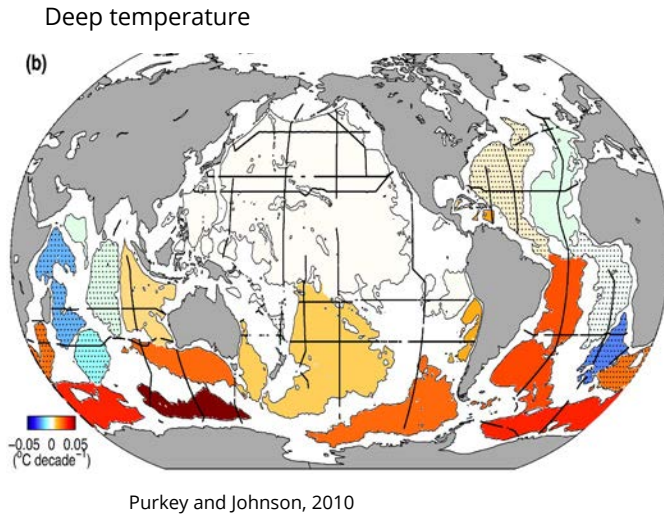


Earthquakes and Tsunamis

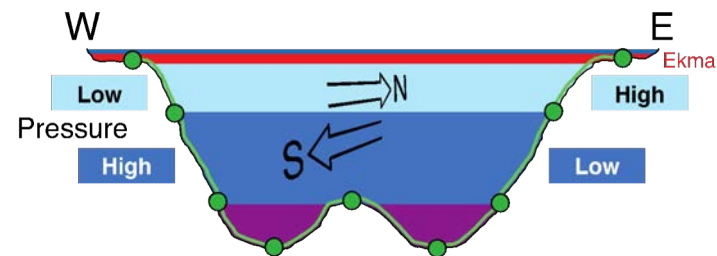
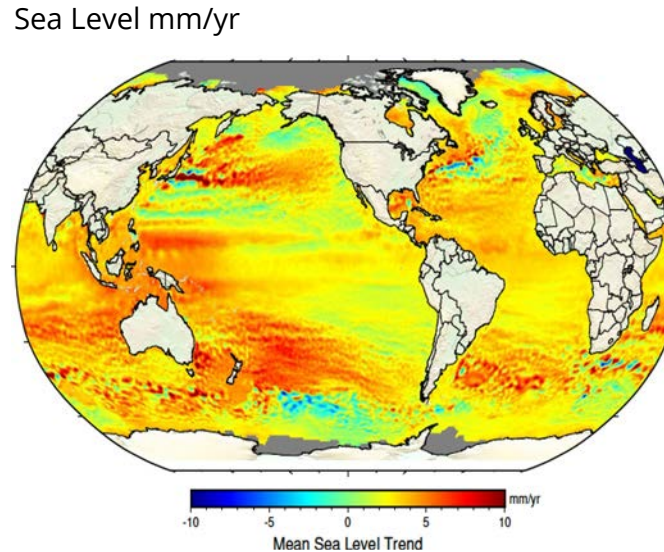
Sea Level Rise



Climate and Oceans: Temperature, Pressure and Sea Level

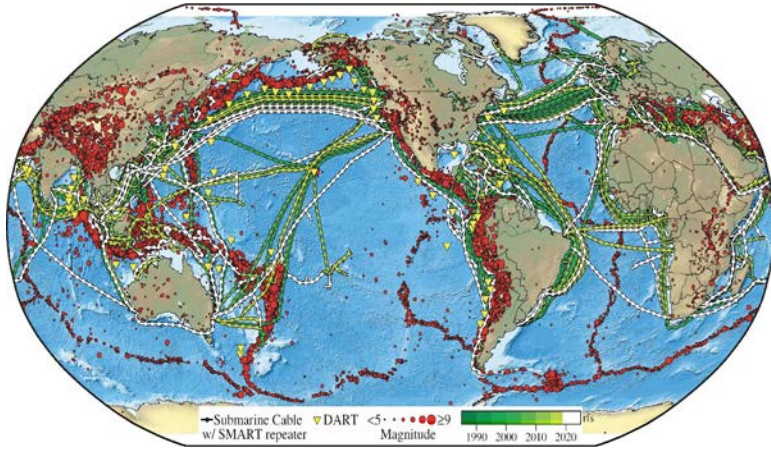


- SMART → Temperature, EOVS
- Deep ocean heat content / thermal expansion → sea level rise
- Δ deep ocean temperature → Δ circulation, Δ climate
- Earth system energy budget: deep ocean major error source



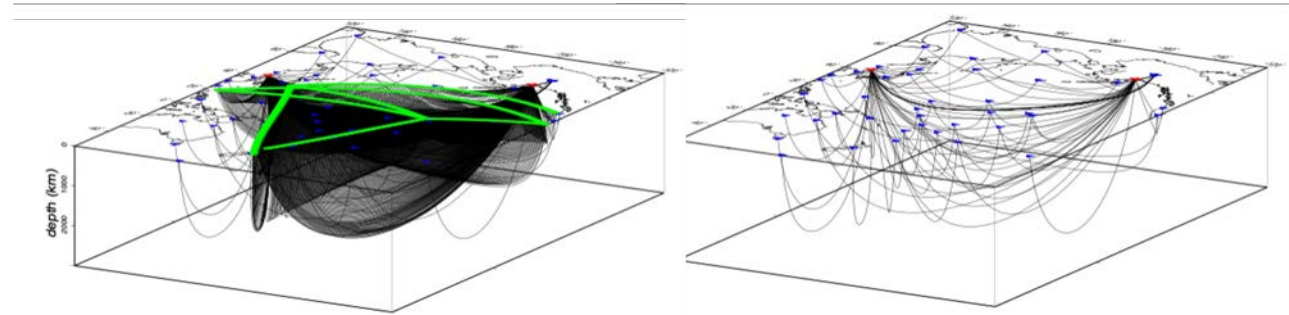
- SMART Ocean bottom pressure (OBP, EOVS) → added mass of melting ice → sea level change (x,t)
- Δx between OBP → depth-averaged currents and ocean circulation
- Reconciling Sea Level budget – steric, mass, geodesy, gravity, altimetry

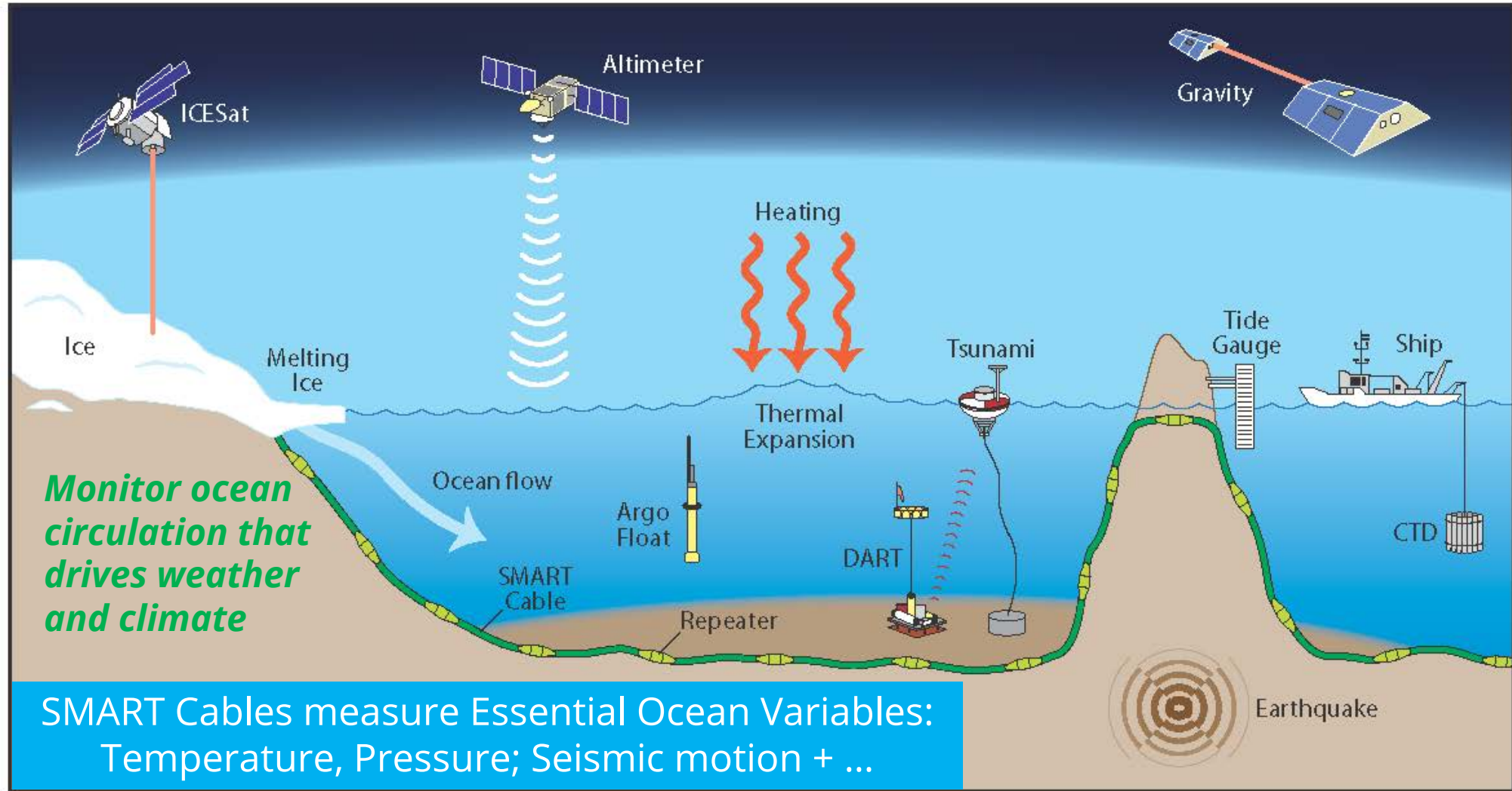
Hazards: Earthquakes and Tsunamis



- SMART Seismic sensors → advance seismology
- Detect, locate small quakes
- Rupture type and dynamics, larger offshore earthquakes
- Image the Earth's interior

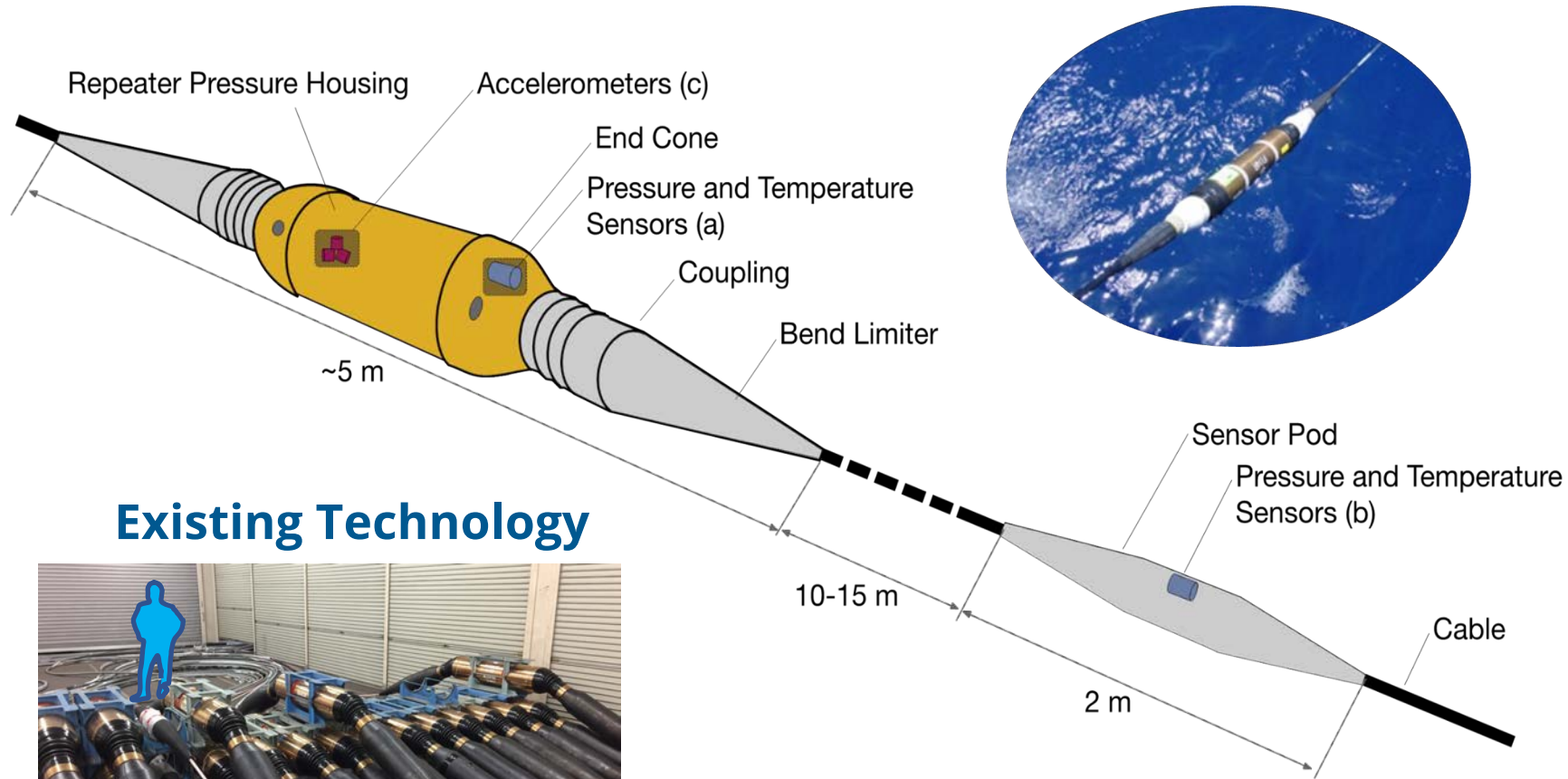
- SMART cables - vastly increase existing ocean pressure/seismic sensors
- Improve tsunami warning precision, reduce unnecessary warning/evacuations





The ocean bottom boundary condition

Shared Cable Infrastructure: Telecom + Science



Existing Technology



No Interference

Sensors:

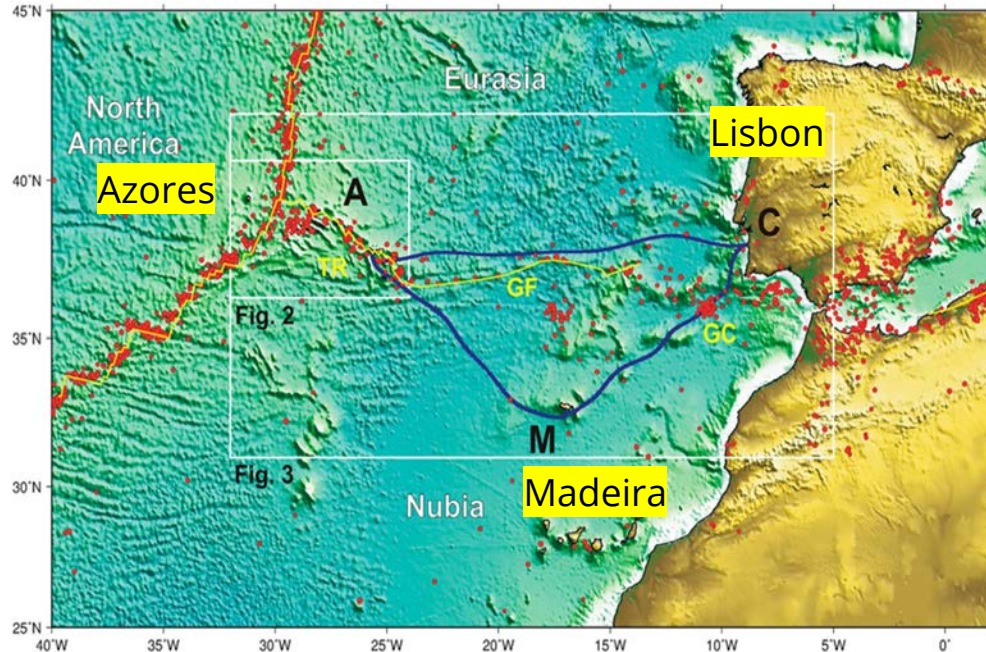
- Temperature
- Pressure
- Seismic

Key points:

- Spacing ~100 km
- Essential Ocean Variables, Global Ocean Observing System



Portugal SMART Atlantic CAM



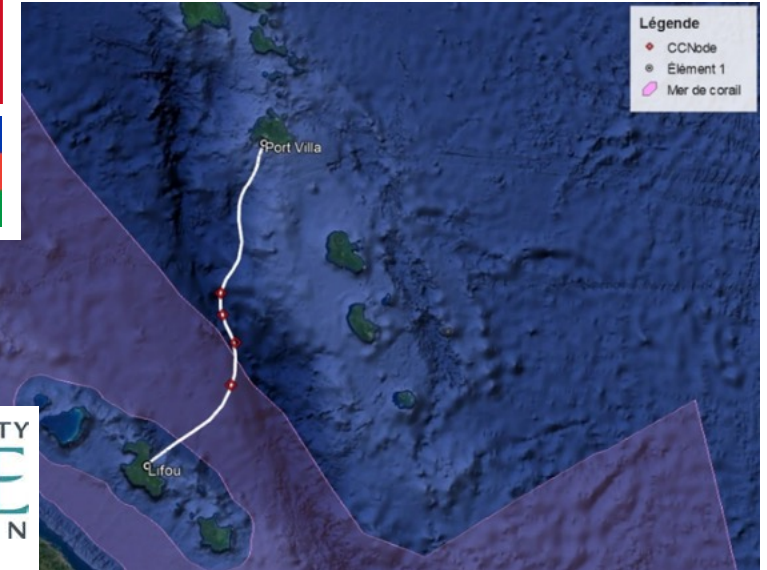
- 3700 km, ~30 SMART modules
- Gov't €154M. EU support €40M
- €154M ~ 1 ship+sensors 25 years (€6M/y)
- SMART 15% €20M ~ €2/citizen/25 y
- ~ = 1 or 2 DARTs (low reliability, slow)

Contracts
signed
ASN
RFS 2026

TAMTAM SMART Cable System



GORDON AND BETTY
MOORE
FOUNDATION

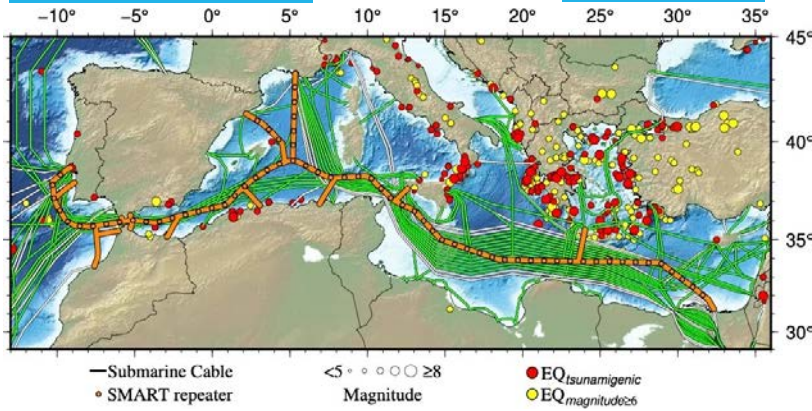


- 450 km long, 4 SMART repeaters,
- France funding SMART (telecom: AFD, ADB)

- 25+ year life, reliable, low lifetime cost
- Leverage \$5B/y industry, 180 y

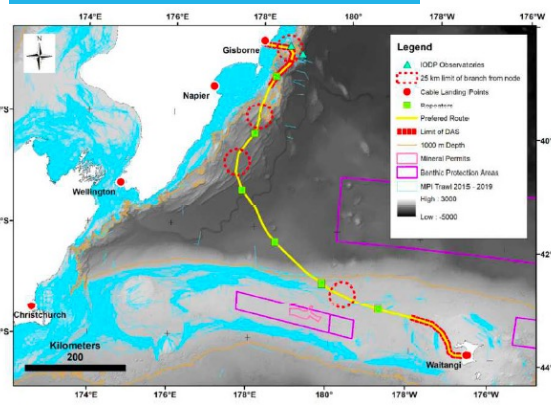
Optical Fiber Sensing in both

Medusa

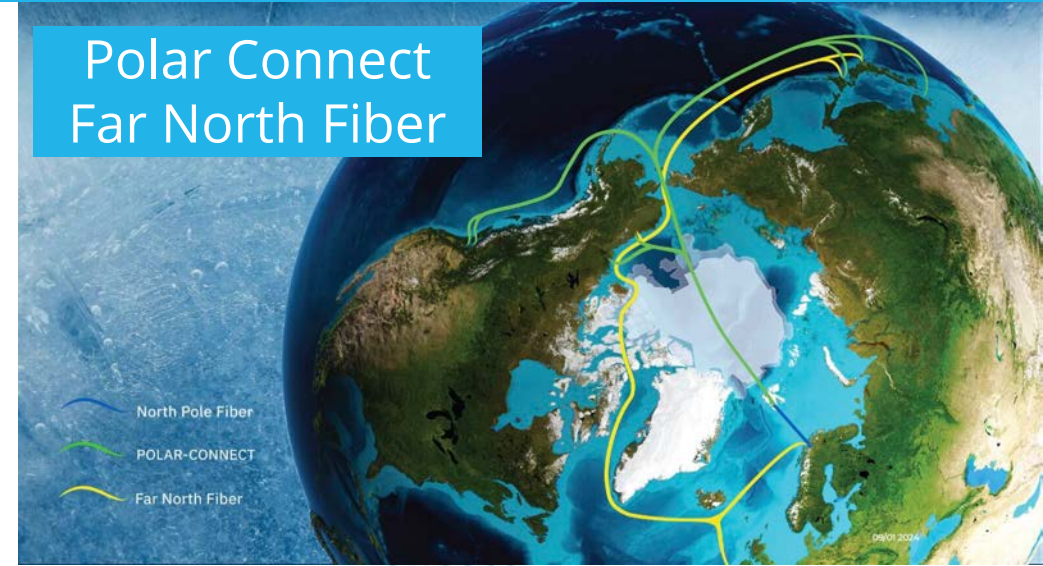


MISTS

NZ - Chathams



Polar Connect Far North Fiber



Indonesia



Koete



Antarctica

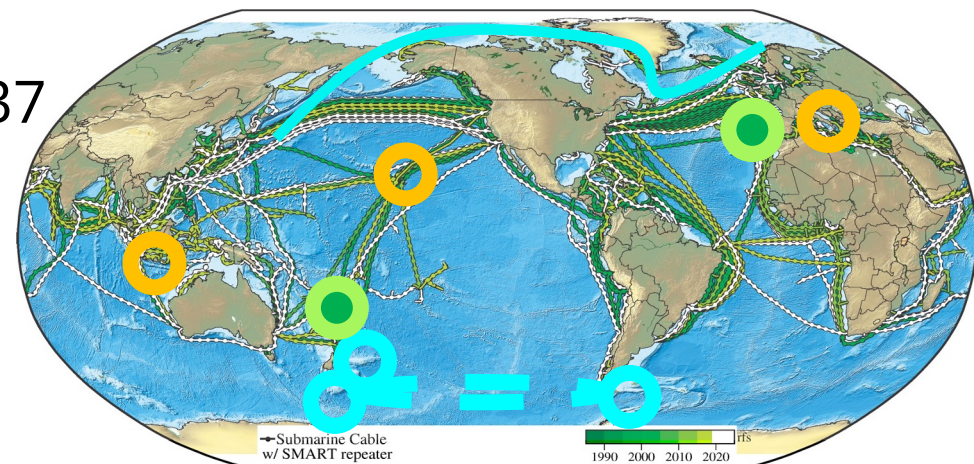


50 km, 2 module test system installed off Labuan Bajo

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

Create a Planetary sensor, power, Internet network

- SMART – marriage with telecom – connectivity, climate, DRR
– three for the price of one – saves on all fronts
- Anticipated additional 1.3 Gm of cable in water by 2037
- Leverage annual investment ~ \$ 5+ Billion
- 25+ year life, highly reliable, low lifetime cost
- EU Funding: Cables w/ SMART
- Recent successes – set precedents for future systems
- GOOS, Tsunami, Ocean Decade, DOOS
- Future – more sensors – CPIES, oxygen, carbon/pH, ...
- Challenges: \$, tech, data, permitting, legal, security, ...
- **Think globally, act locally!**



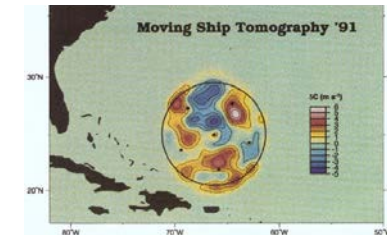
Research, Operations, Saving Lives

Change gears

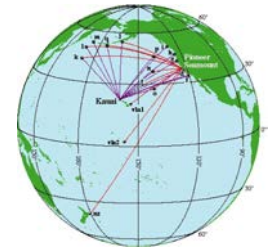
SMART → SMART+

Biased by my Background

Moving Ship Tomography



Acoustics



Acoustic Thermometry of Ocean Climate (ATOC)

Mobile

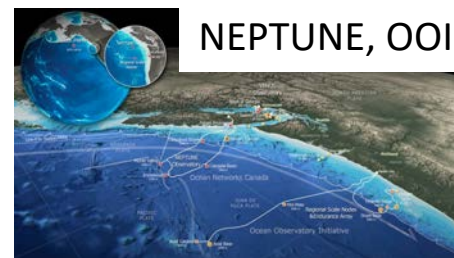
Moored profiler
Inductive
power dock
Cable connected



SeaGliders
acoustic comms and nav

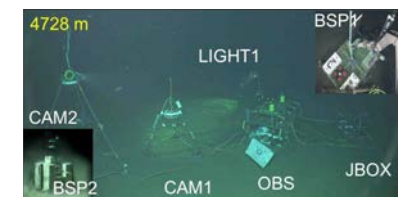


Fixed - cable



NEPTUNE, OOI

ALOHA Cabled Observatory
Deepest plug and play
power, Internet node
on planet



Essential Deep Ocean Infrastructure

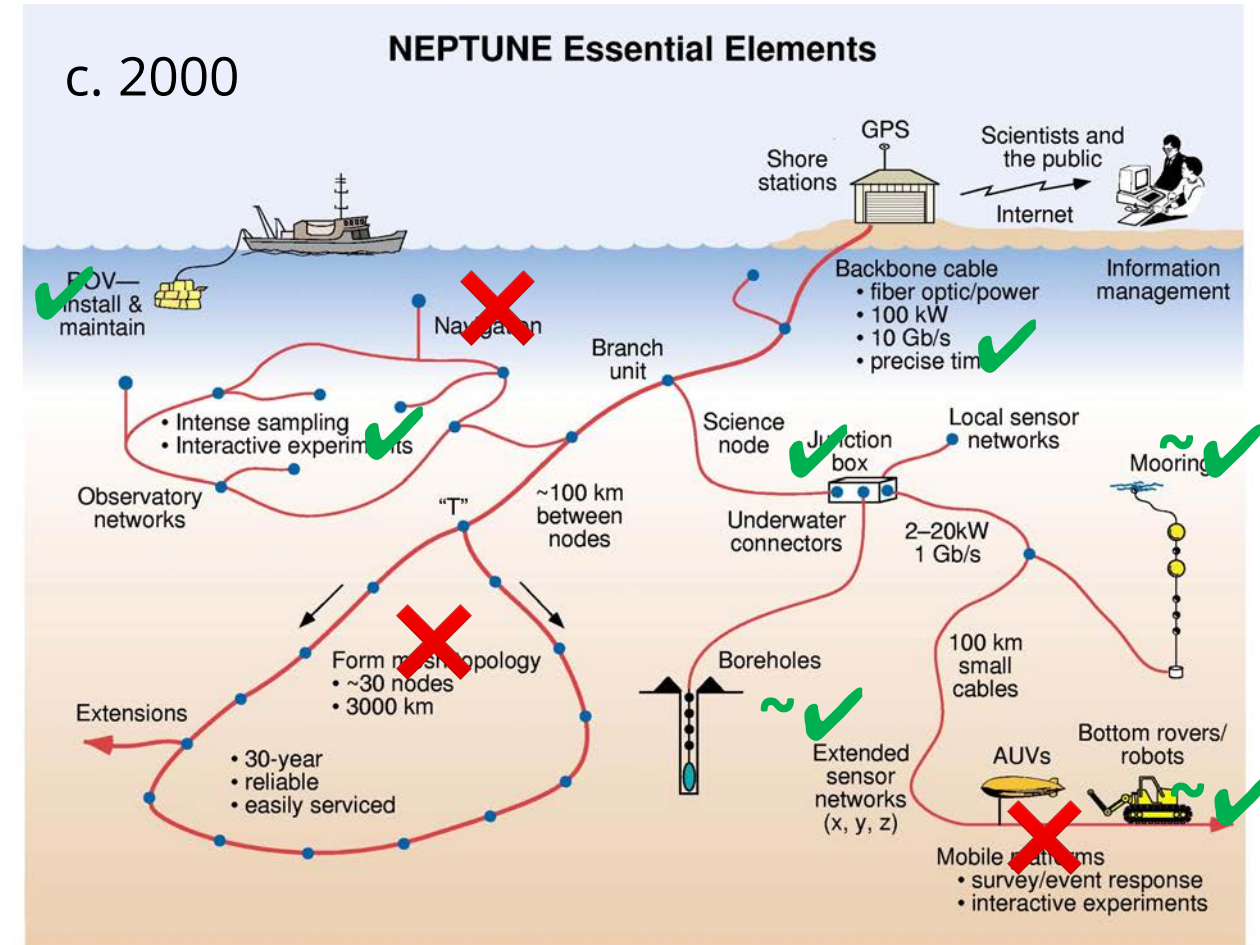
?90% ocean observing cost is infrastructure

Infrastructure Services

- POWER
- EVERYTHING depends on POWER –
- POWER enables all:
 - Communications
 - PNT – position, navigation, timing
 - + Sensing, ...

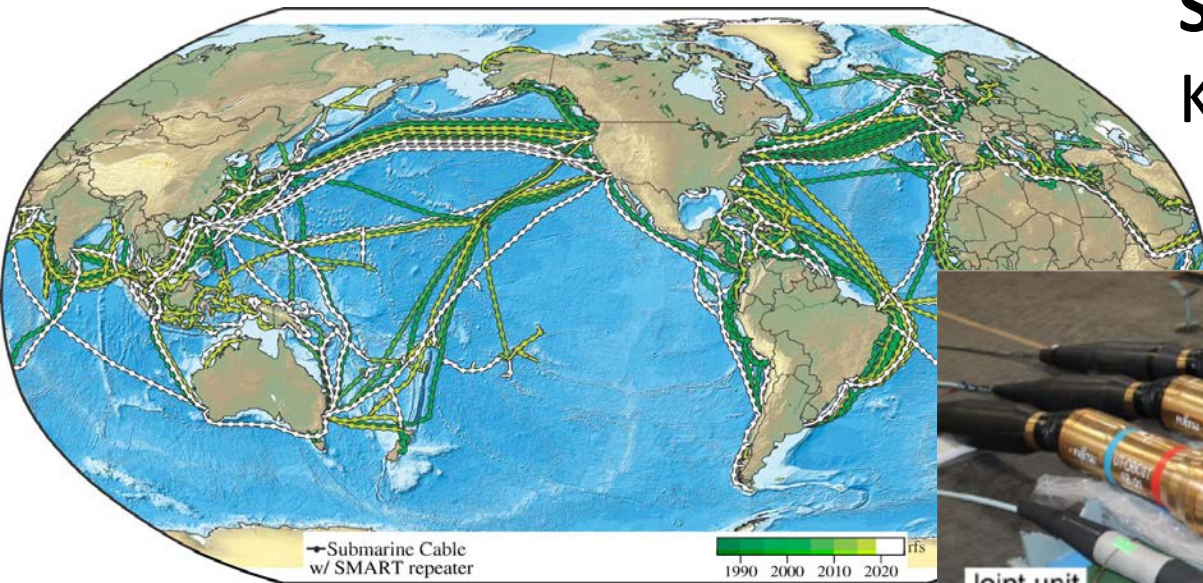
Infrastructure elements

- Cables
- Fixed platforms
 - bottom packages, moorings
- Mobile platforms
 - AUVs, crawlers, ...



Cable sine qua non for everything else – share with telecom - affordable

Deep ocean essential infrastructure elements - cables



SMART Cables

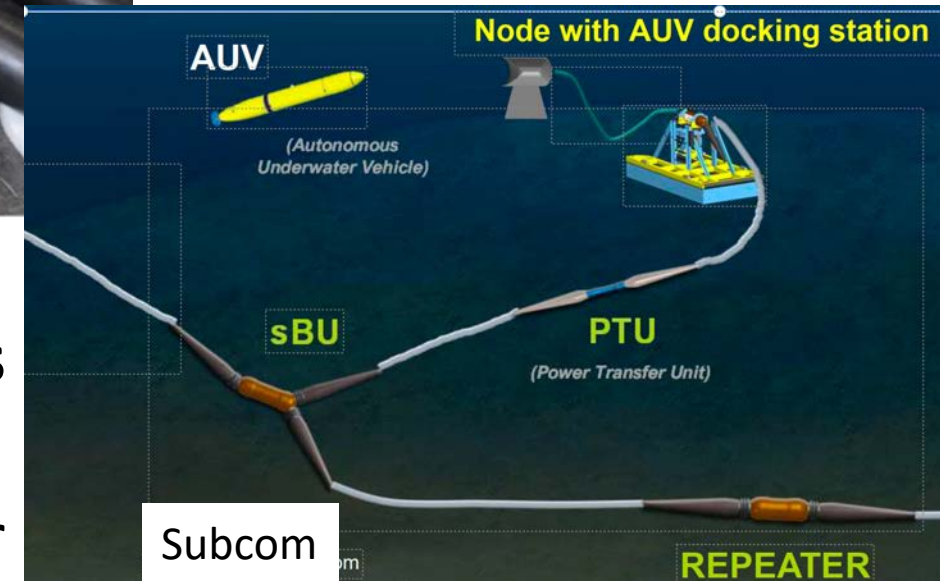
KISS, a few sensors, global coverage
now with optical fiber sensing



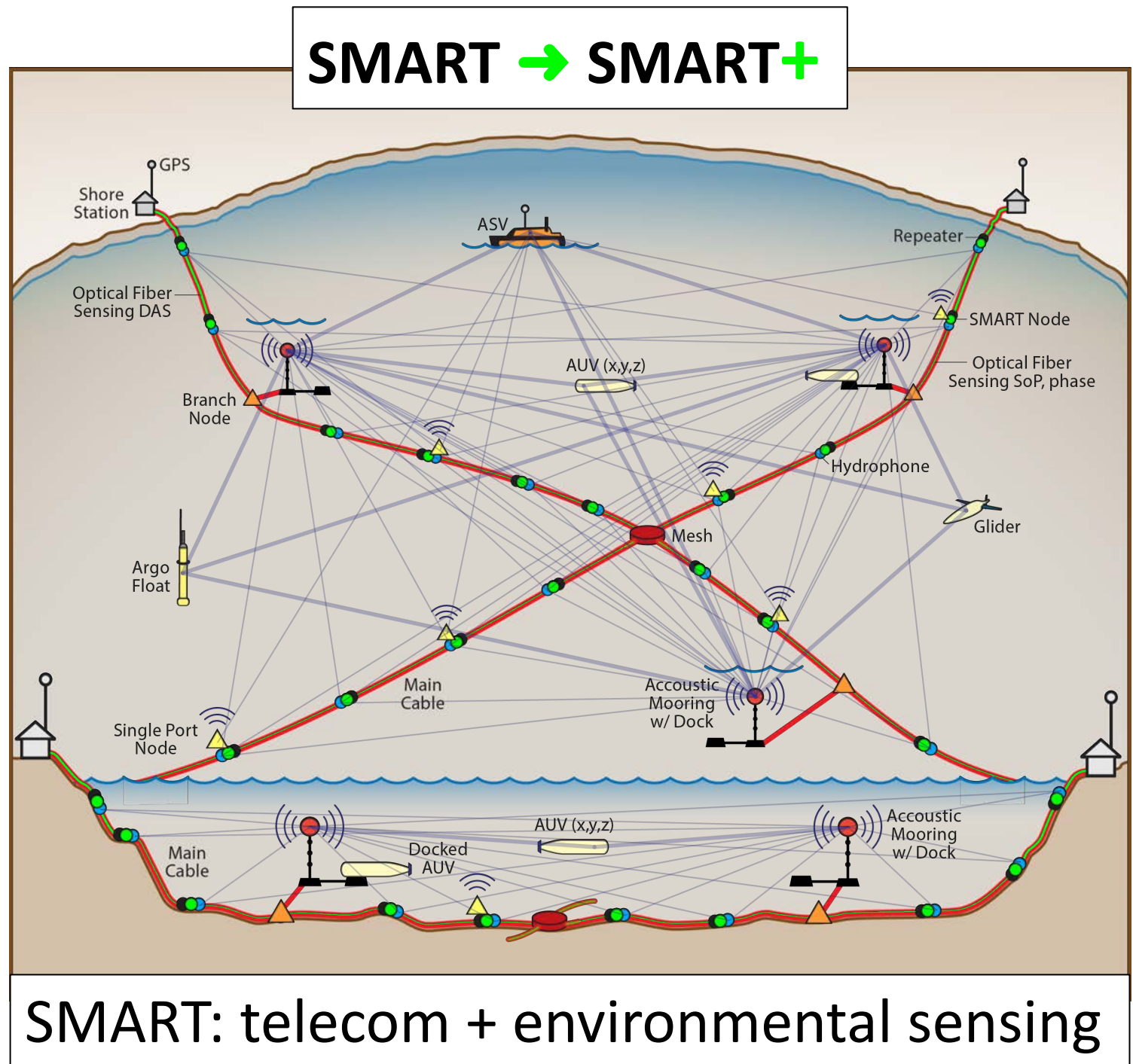
Test system, Japan
Single port, PoE

**+ fixed and
mobile platforms**

Multi-port node with power comms
Telecom rated
Support AUV docks, Moorings, other



1. Start with telecom network – 1.4 Gm, 20,000 repeaters, every ~70 km
2. In existing and new systems, SMART optical fiber sensing (DAS, SoP, phase)
3. In new systems, SMART nodes: temperature, pressure, seismic accel
4. Include hydrophones – Passive Acoustic Monitoring, soundscapes
5. Single ports on select repeaters – acoustic modem, more basic sensors
6. Branch nodes: AUV docking, acoustic moorings, instrument arrays
7. Mesh SMART subsea power grid
8. Add mobile platforms with sensors
9. Acoustics – tomography, sound speed, temperature, heat content
10. Acoustics – long range nav + comms for autonomous platforms

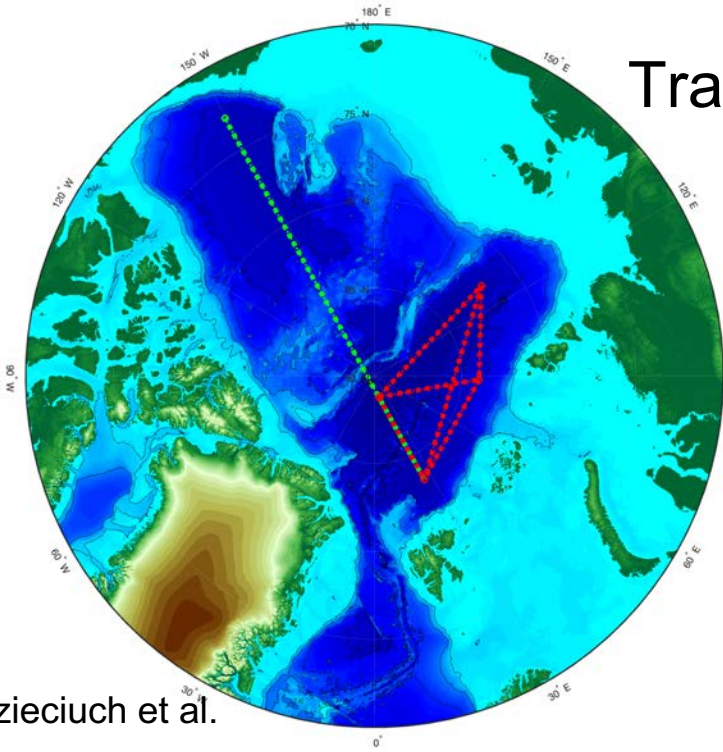


Acoustic tomography and navigation

Hydrophones on
Mermaids/EarthScope Oceans and
Seatrec infiniTE™ Float
ASN – integrating acoustic modems

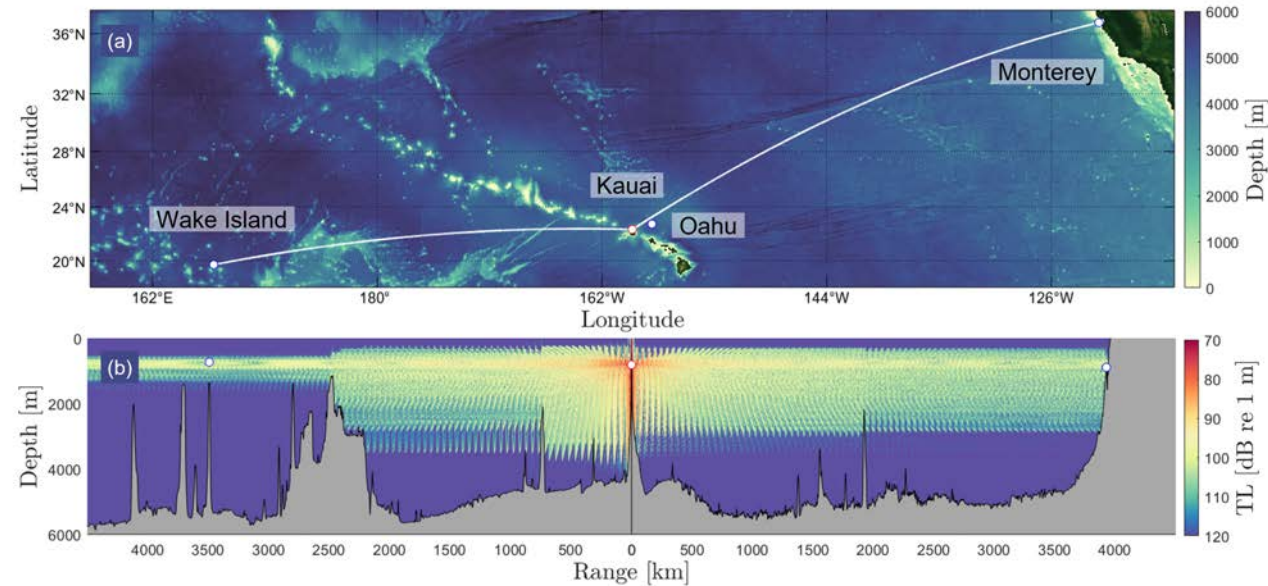
Trans-Arctic

Ocean
Temperature
at the speed
of sound



Dzieciuch et al.

North Pacific



- High Arctic Acoustic Thermometry and Soundscape
- EU partnership with NERSC, 2024-2026
- Thermometry of Atlantic layer
- Soundscape monitoring of multiyear ice
- Float and glider navigation

- Kauai Beacon, ONR
- Transmitting regular 2% duty cycle
- RX on OOI, MARS, CTBT/Wake, ACO
- Gemba et al. NPS, UW, UH, ...

SMART AND SMART+

SMART and SMART+ are within reach in the coming Decade, ...

- Deep ocean – largely unknown, essential for science
- Needed elements, test beds and long duration demos
 - AUVs multi-purpose, with docking (all sizes) Cabled Connected Moorings
 - Acoustic moorings (TX, RX), PNT Smart Subsea Power Grid
 - Modeling/data assimilation – ALL data types, Bottom boundary layer, fluxes
 - Sensors – 25 year life, low drift, ...
- Incentivize US industry, capacity building, sustainable Blue Economy
- Prepare, implement Antarctica, Arctic, NPac, Southern Ocean, AMOC ...
- ONR and NOAA for collaboration and transition, BOEM, NOPP, ...
- Perfect for Directorate for Technology, Innovation and Partnerships (TIP)
- Must be an international collaboration



SMART CABLES



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MOORE
FOUNDATION



Schmidt Marine
TECHNOLOGY PARTNERS

SMARTCables.org

[ITU/WMO/UNESCO IOC Joint Task Force](#)

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