Sharing Infrastructure:
Climate Monitoring and Disaster Warning Using SMART Subsea Cables

Bruce Howe

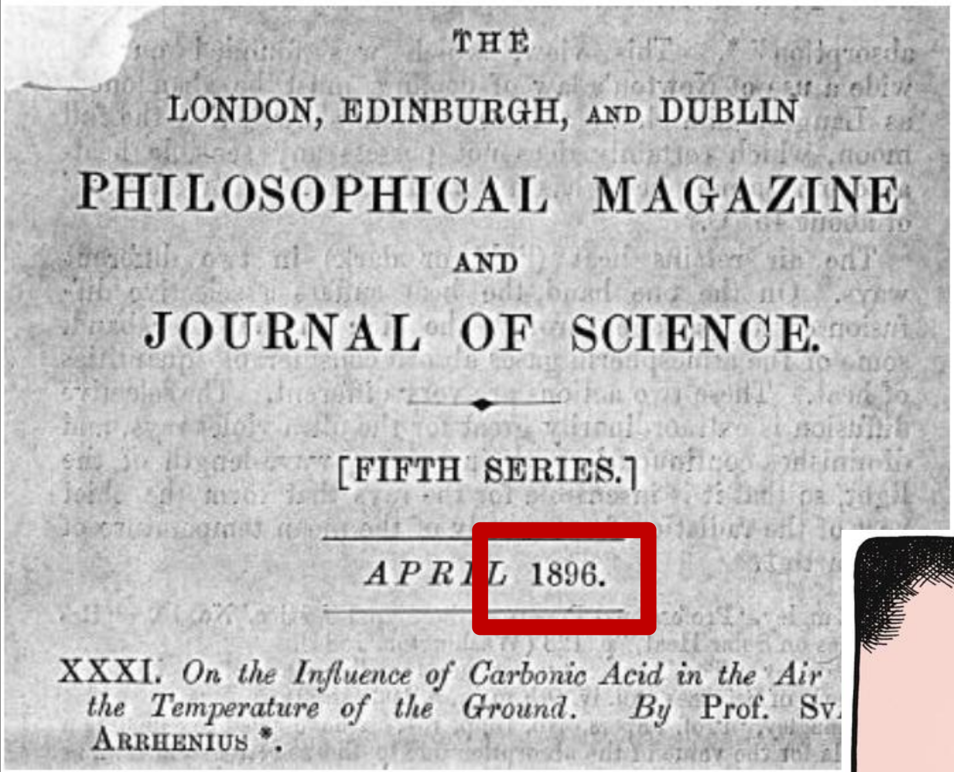
ITU/WMO/IOC Joint Task Force
and
University of Hawaii at Manoa

TICAL2019
Cancun, Mexico
2-4 September 2019

Outline

- **Motivation**
  - **Climate**
  - **Disasters**
- SMART cables
- R & E Networks
- Sharing infrastructure
- Concluding remarks

Climate


THE
LONDON, EDINBURGH, AND DUBLIN
PHILOSOPHICAL MAGAZINE
AND
JOURNAL OF SCIENCE.

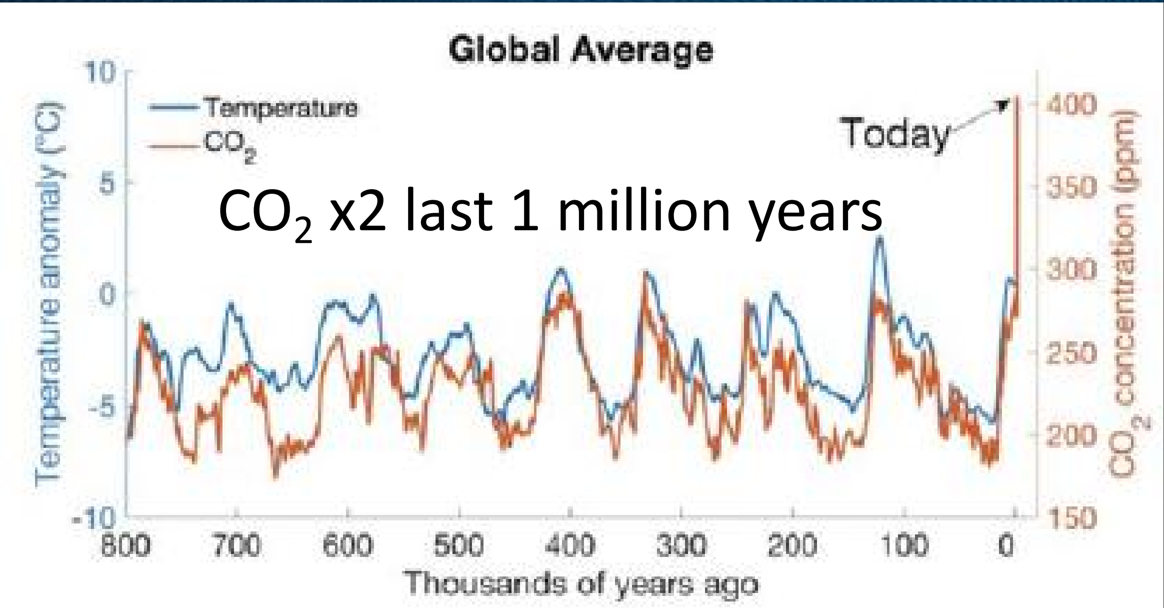
[FIFTH SERIES.]

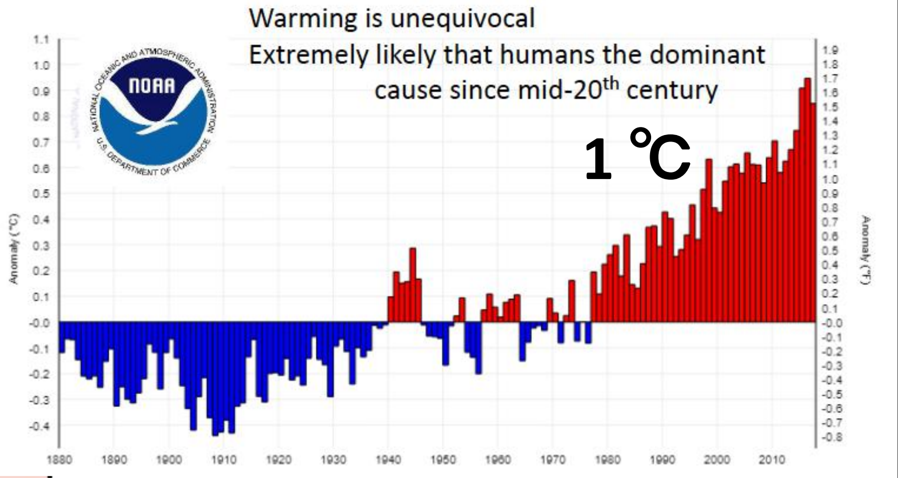
APRIL 1896.

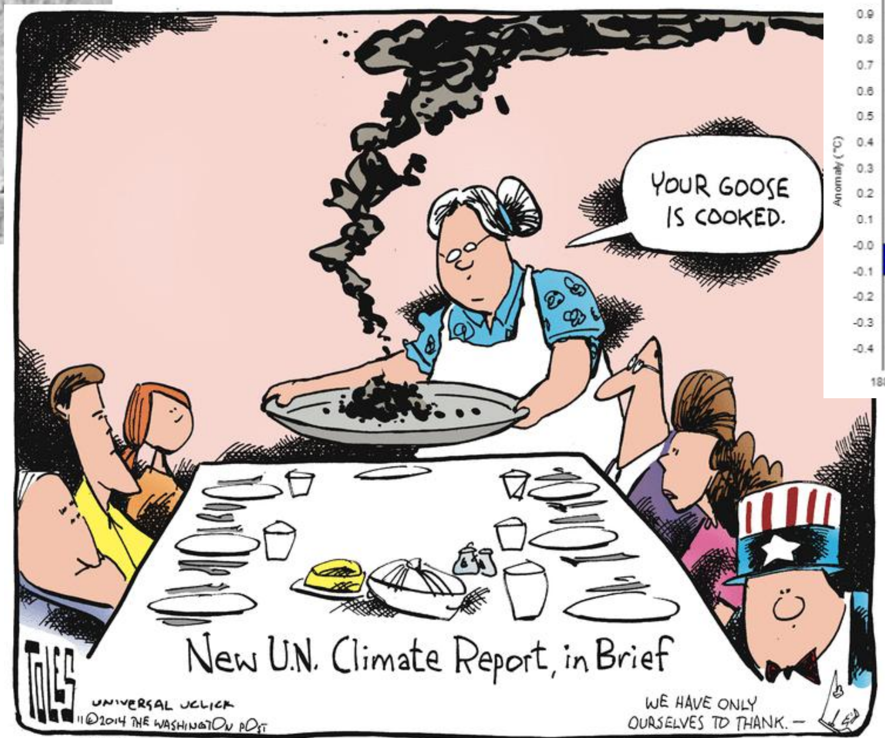
XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. Sv. Arrhenius *.

Arrhenius
Global warming due to CO_2

Antarctic ice cores





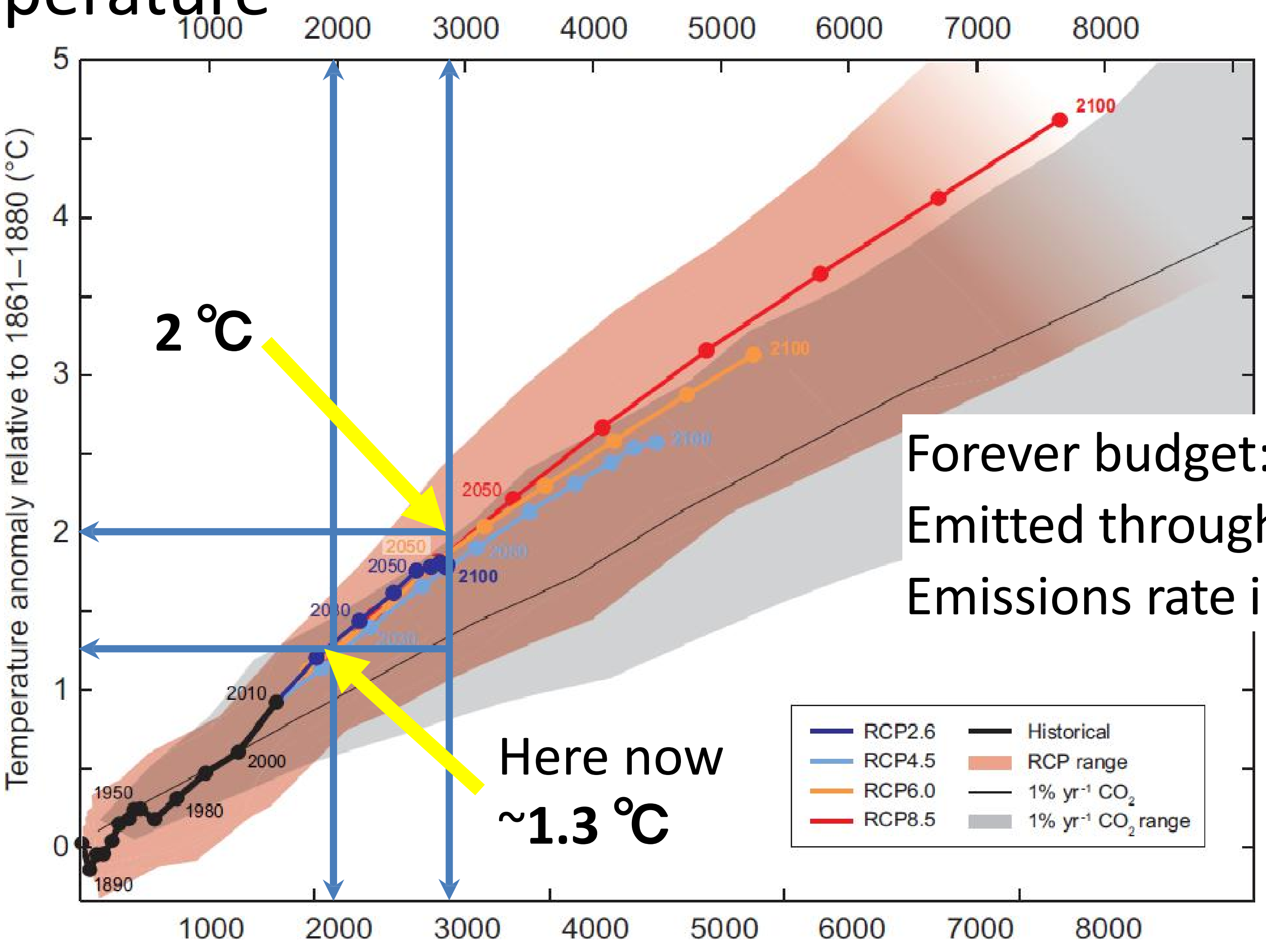


Some slides courtesy of Chris Fields, Stanford, 2018

Climate – temperature vs cumulative CO_2

Temperature

How are we planning for our 7th generation?



Cumulative emissions since beginning of industrial revolution (Gt CO_2)

Forever budget:	2900 Gt CO_2e for 66% ≤ **2ºC**
Emitted through 2016:	2150 Gt CO_2e
Emissions rate in 2016:	50 Gt CO_2e
	767 Gt CO_2e ≤ **2ºC**

15 years at present rate,
Then zero, to stay ≤ **2ºC**

CO_2 emissions

IPCC, WG I, 2013

Declining Sea Ice Extent and Thickness

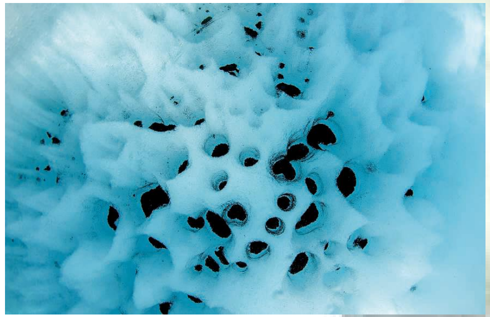
Affects global thermo-haline circulation

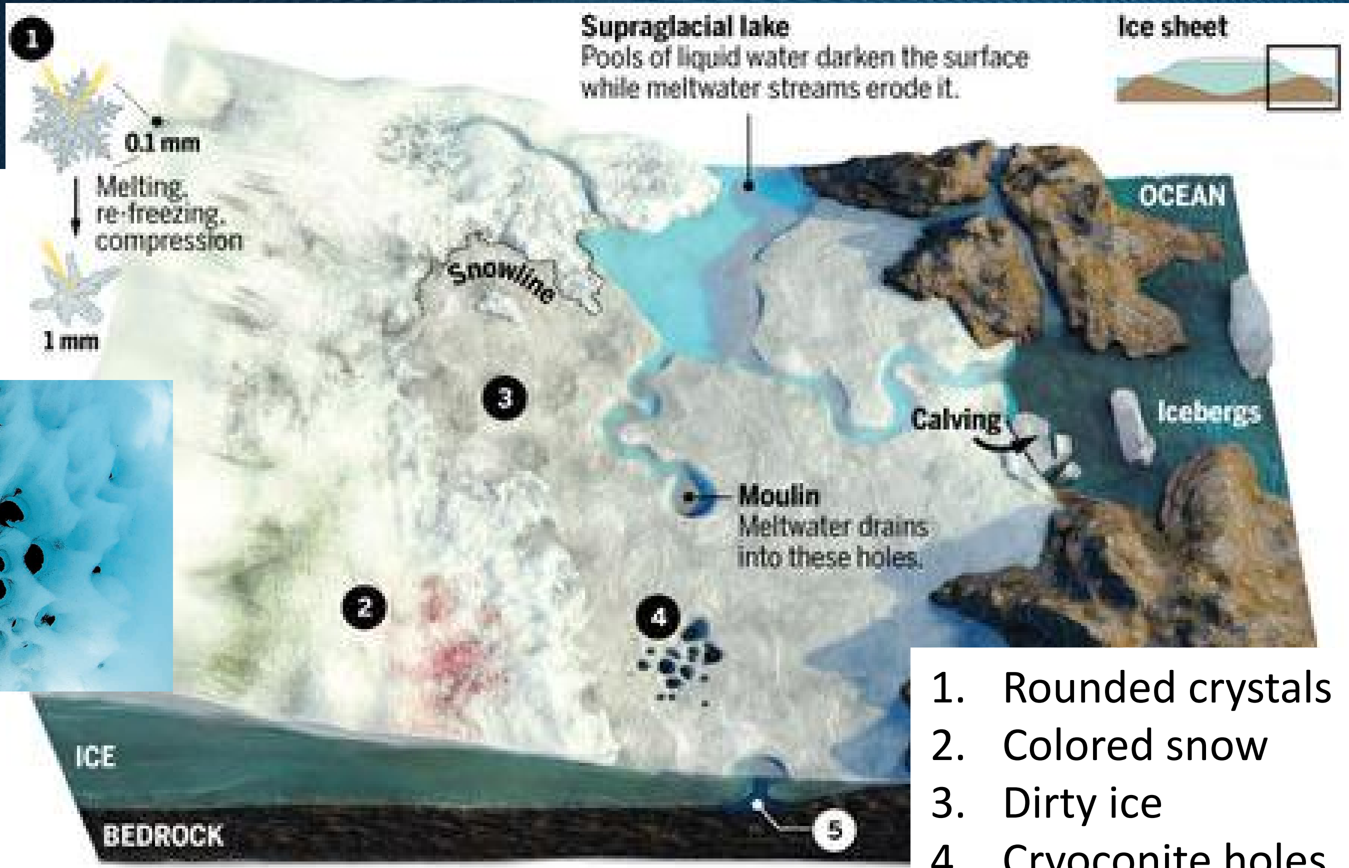
Known Unknowns?

The Great Greenland Meltdown

As algae, detritus, and meltwater darken Greenland's ice, it is shrinking ever faster

E. Kintisch, Science, 23 February 2017





1. Rounded crystals
2. Colored snow
3. Dirty ice
4. Cryoconite holes
5. Subglacial water

∑small = BIG

➔Sea Level

Antarctica too – on all edges and interior

Nansen Ice Shelf

Kingslake, Nature, 2017

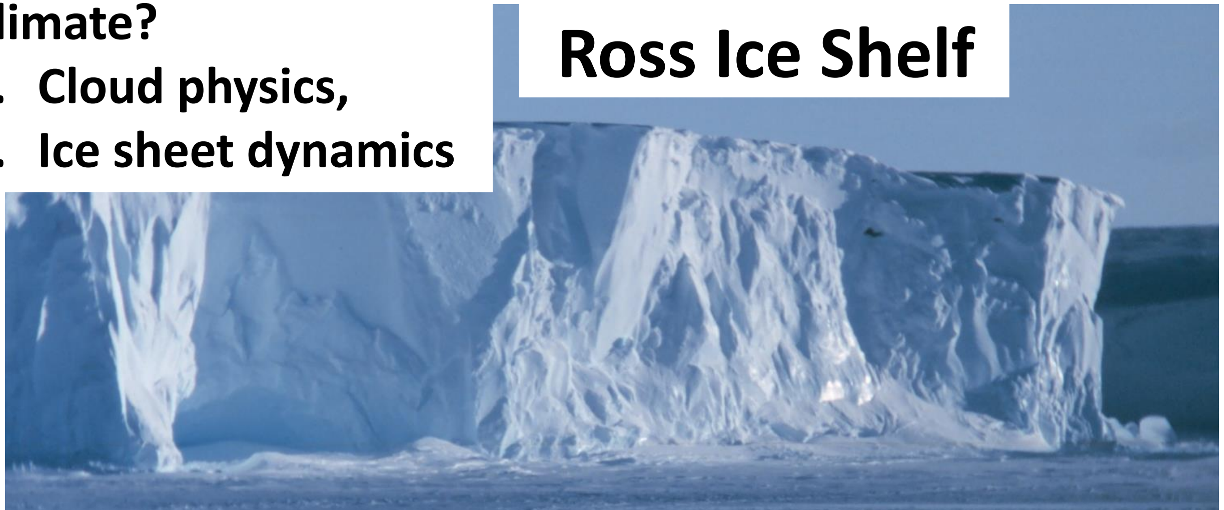
Wong Sang Lee/Korea Polar Research Institute

Climate – Antarctica

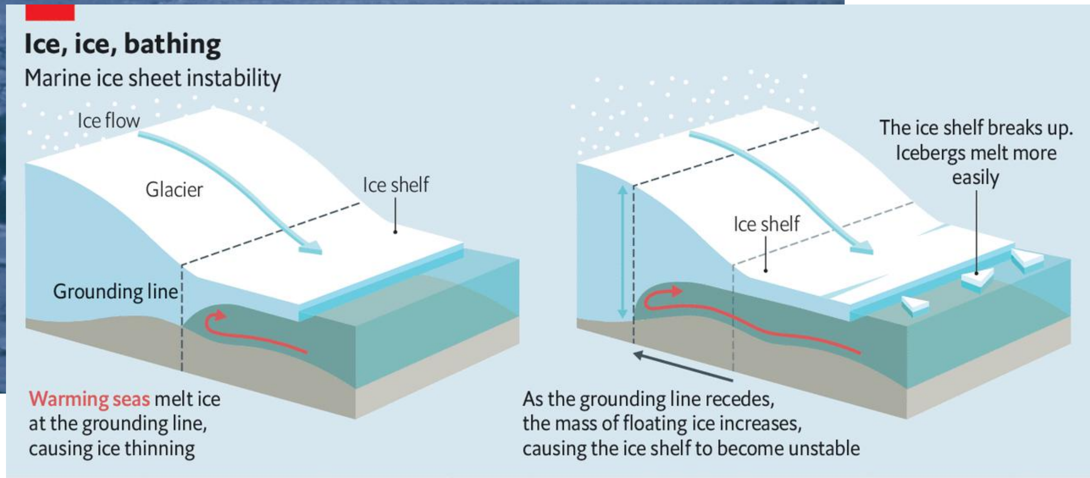
Climate?

1. **Cloud physics,**
2. **Ice sheet dynamics**

Ross Ice Shelf

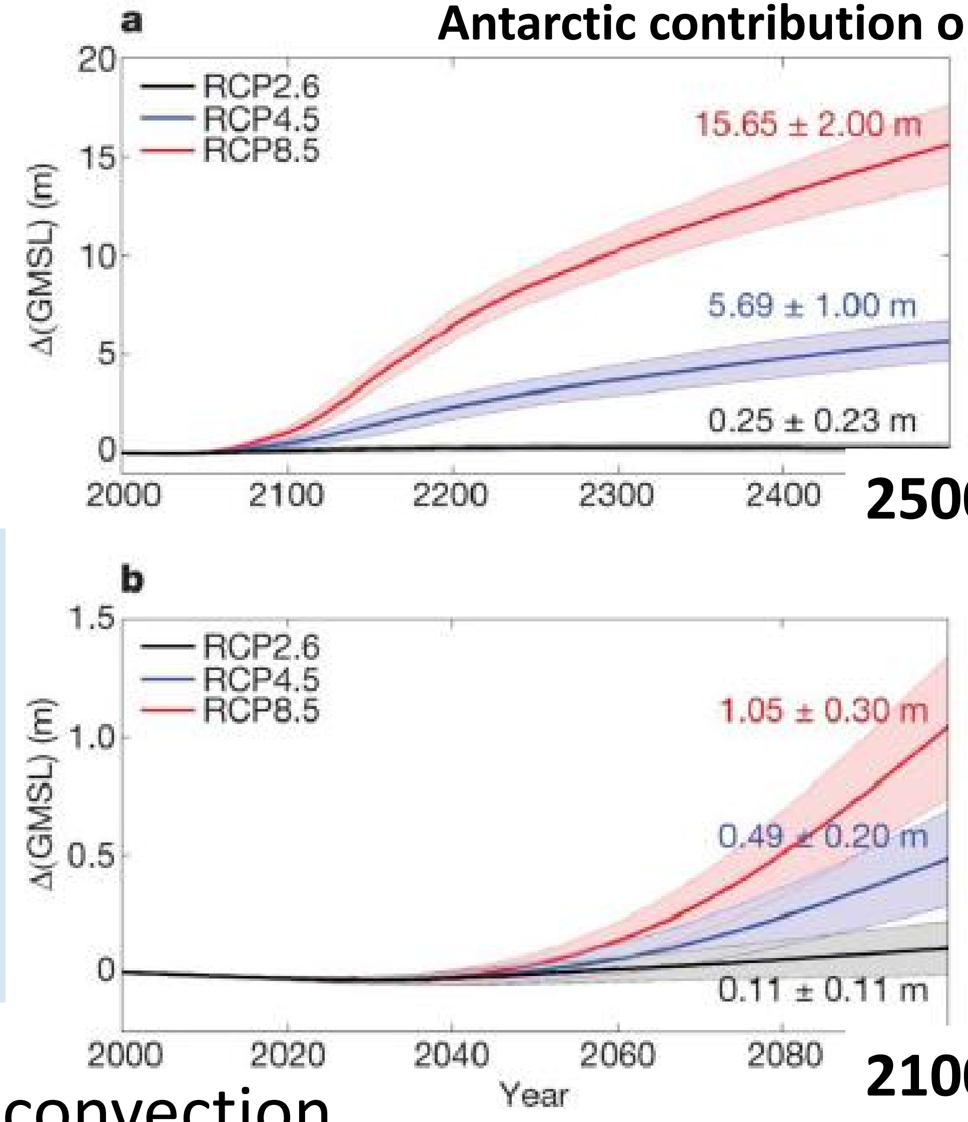


Michael van Woert, NOAA



The Economist

Antarctic contribution only



2500

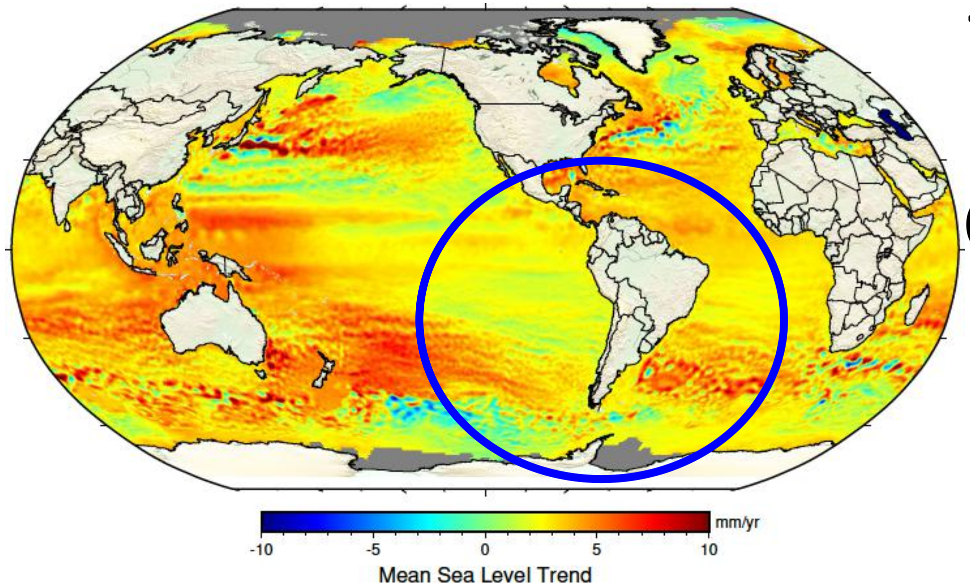
2100

Friction at base, Ice strength ~ 1/temp, turbulent convection
ice cliff collapse, much below sea level, **episodic**

R M DeConto *et al.* *Nature* **2016** nature

Sea level rise + ocean heat content

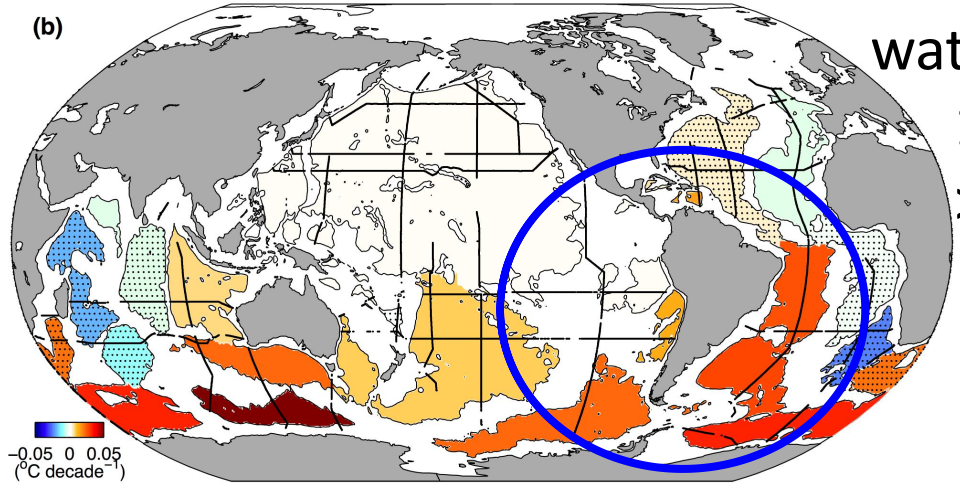
Sea level rise - Not uniform



Climate change is a remorseless threat to the world's coasts
Economist, August 2019

Global 3.2 mm/y

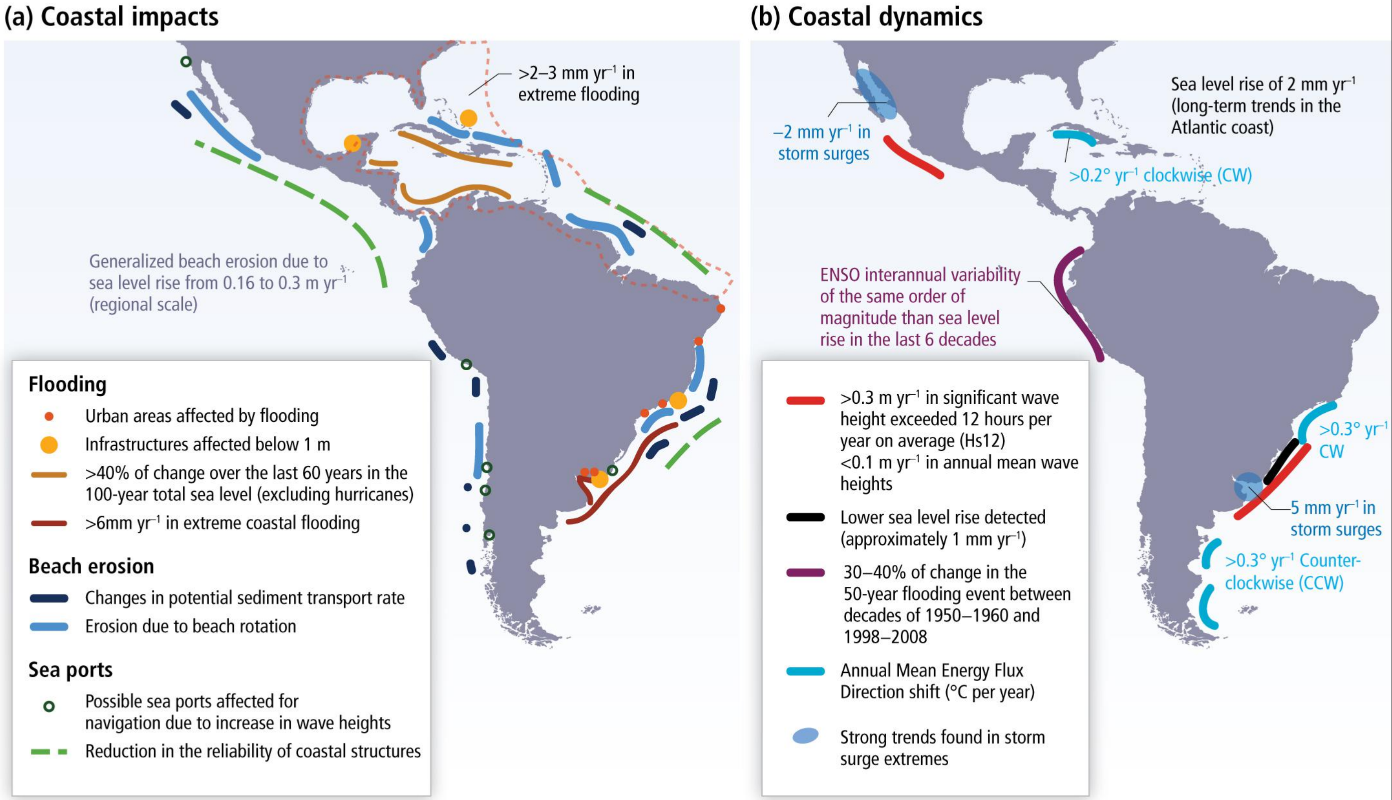
2100: 8 mm/s, 1 m



Ocean Temperature
water expanding
- 10s of mK / decade
- > 4000 m depth

Rotterdam

Coastal Ocean Changes in Latin America



Rising sea levels threaten large coastal populations

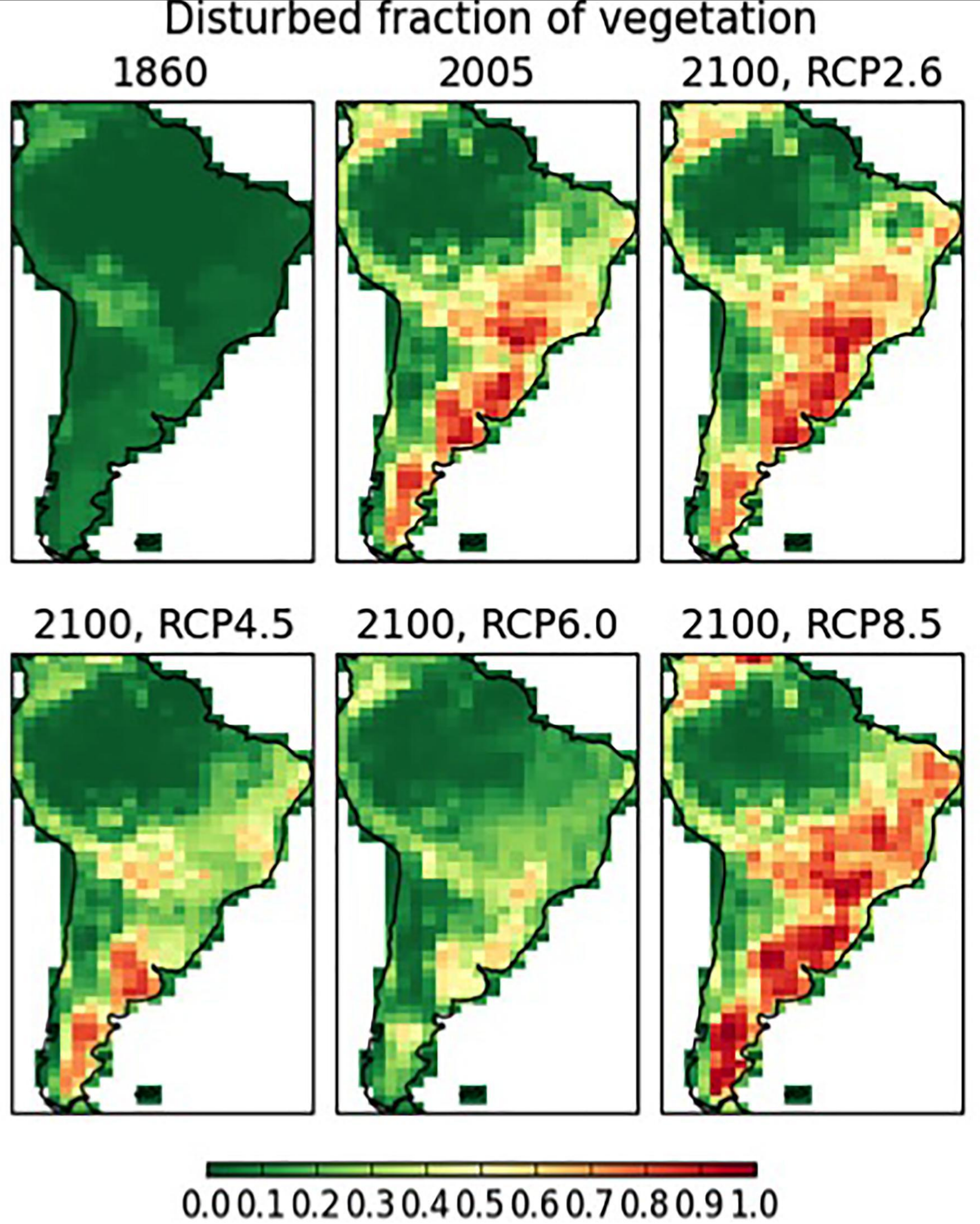
Contaminate aquifers, erode, inundate low areas, storm surge, etc.

IPCC

MesoAmerican reef and islands
low-lying, eroding, effects on marine life
coral bleaching, ocean acidification

An example

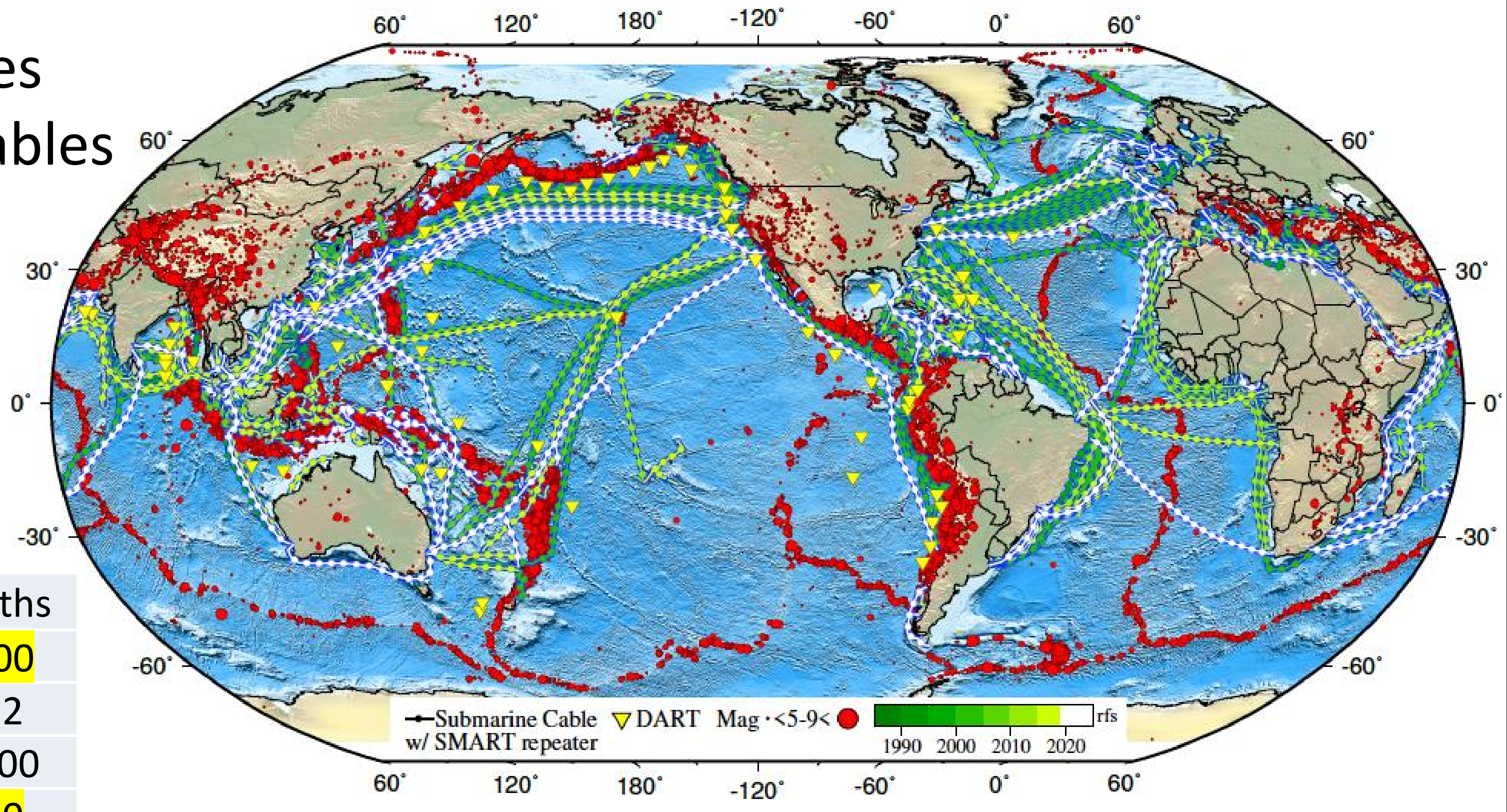
- How will vegetation change over the next century, given various green house gas trajectories – Representative Concentration Pathway (**RCP**)?
- Disturbed fraction of vegetation across South America simulated by the HadGEM2-ES Earth System Model, at 1860, 2005, and four future scenarios at 2100:
  - RCP2.6 - high mitigation
  - RCP4.5 – reforestation mitigation
  - RCP6.0 – near-zero deforestation
  - RCP8.5 - high emissions, agriculture



Changes in Climate and Land Use Over the Amazon Region: Current and Future Variability and Trends, Marengo, et Al., Front. Earth Sci., 2018

Tsunamis

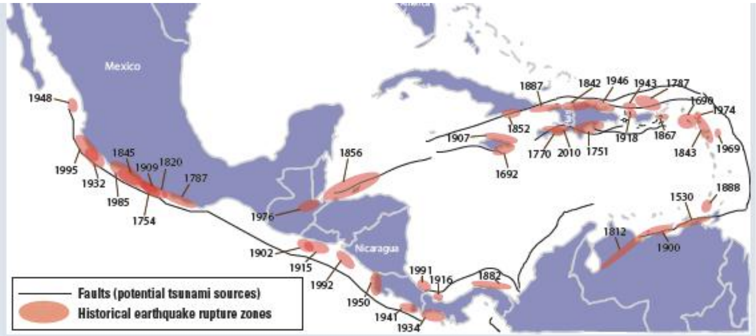
Red earthquakes
Green/white cables



Place	Year	Mag	H (m)	Deaths
Valdivia, Chile	1960	9.5	25	6000
Alaska, USA	1964	9.2	30	132
Mindinao, Philippines	1976	7.9	9	7,800
Tumaco, Columbia	1979	8.1	6	350
Hokkaido, Japan	1993	7.8	30	250
Papua New Guinea	1998	7.1	15	2200
Sumatra, Indonesia	2004	9.2	33	230,000
Solomon Island	2007	8.1	12	52
Samoa	2009	8.1	14	189
Maule, Chile	2010	8.8	3	525
Tohoku, Japan	2011	9.0	10	19,000
Palu, Indonesia	2018	7.5	7	~2000?

DART – tsunami warning buoys
7 August not working:
Global: 22/59
LAC: 9/17

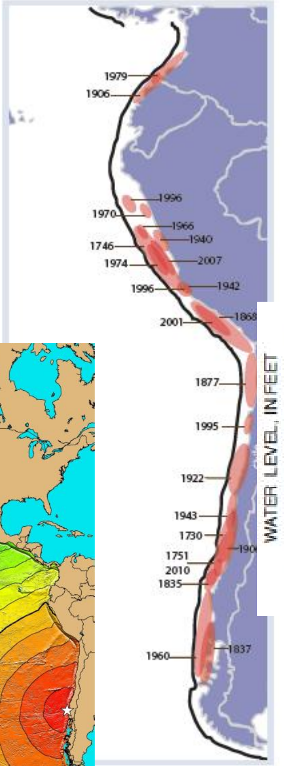
Chile 1960, 2010

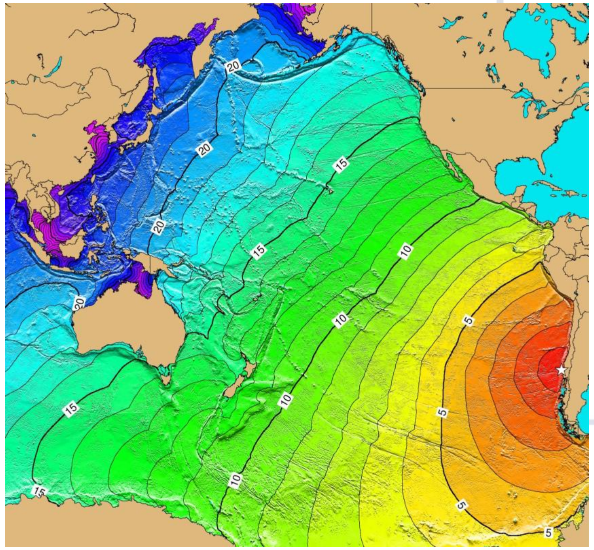


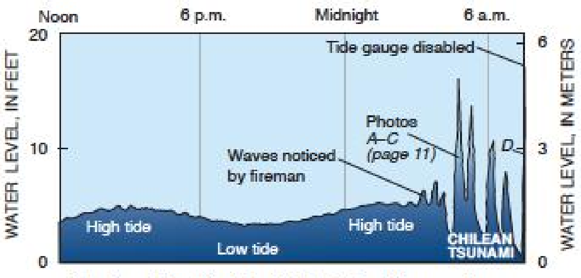
Chile, Maule
27 Feb 2010 525 dead, 25 missing

Tsunami
Local,
Juan Fernandez Island,
Hawaii
Japan

Valdivia, Chile,
1960
Largest ever
recorded
earthquake M=9.5







Tide-Gauge Record for 23 and 24 May 1960, at Onagawa, Japan

Concepción, 100 km S
Moved 3 m W
Length of day -1.3 us

Outline

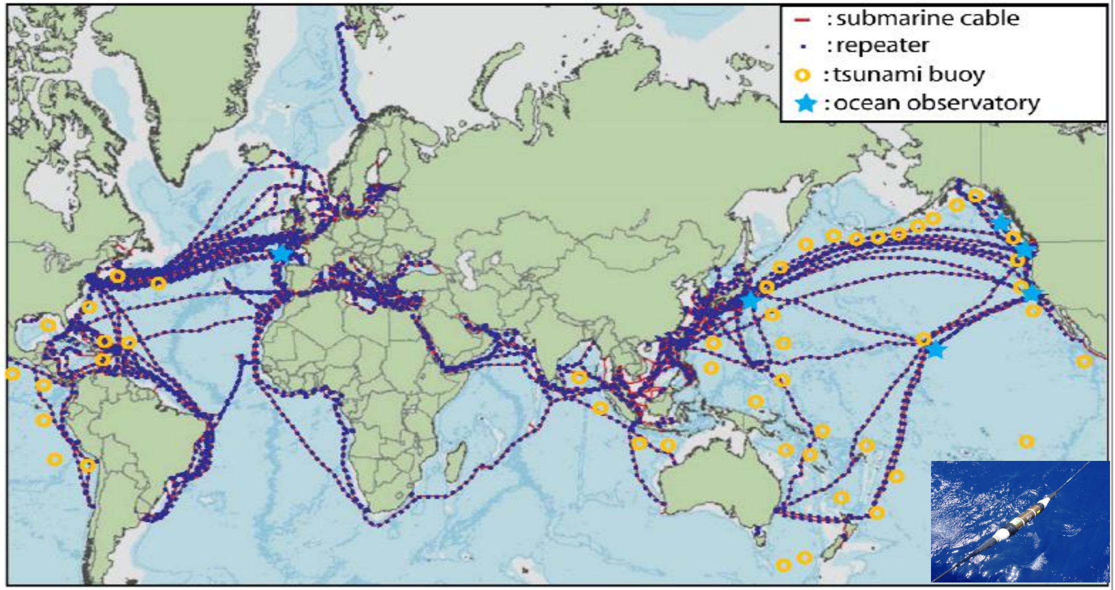
- Motivation
  - Climate
  - Disasters
- **SMART cables**
- R & E Networks
- Sharing infrastructure
- Concluding remarks

SMART Cables - Basic Concepts

Climate, Oceans, Sea Level

Earthquakes, Tsunamis Global array

SMART cables: first order addition to the ocean-earth observing system, with unique contributions that will strengthen and complement satellite and in-situ systems

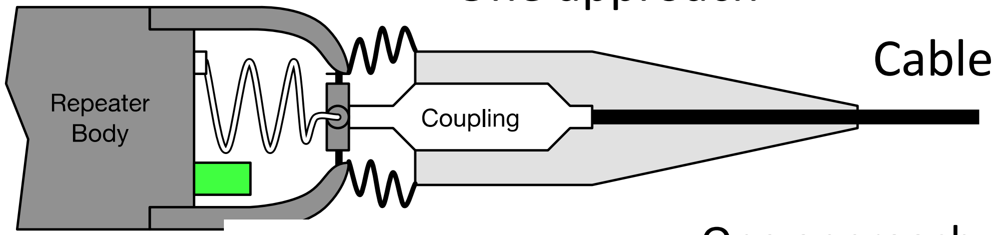


- **Telecom + science, shared infrastructure, $ ↓**
- Cable repeaters host sensors, not to interfere
- Potential: global spanning, trans-ocean, 1+ Gm
  - ~10,000+ repeaters (~100 km)
  - 10-25 year refresh cycle
- Initially: **bottom pressure, temperature and acceleration**; supplement later (fiber sensing…)

Repeater

One approach

Cable



Sensor Module

One approach

Install routinely on new cables

Deploy by cable ship, no maintenance

https://www.itu.int/en/ITU-T/climatechange/task-force-sc/Pages/default.aspx

***John You, Nature, 2010** – Harnessing telecoms cables for science*

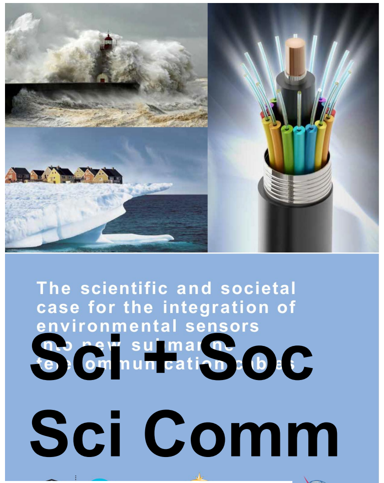
SMART Cable Initiative led by **UN ITU-WMO-IOC**

Joint Task Force (JTF)

150 Members from 90 organizations

- Raise awareness, educate and publicize, workshops
- Search out the **funds** and potential **investors**
- Collaborate for a general solution that can be tailored to specific deployments
- Educate governments to facilitate permits and **funding**, and to utilize new data
- Link to global initiatives, e.g., GOOS, DOOS, JCOMM and other international agencies
- Facilitate implementation

Endorsed by
JCOMM,
DBCP, PTWS,
POGO



https://www.itu.int/en/ITU-T/climatechange/task-force-sc/Pages/default.aspx

The SMART Cable Opportunity

Better observe the ocean

Flywheel of Climate, Source of Hazards

More Sensors

A global network of
ocean floor observation stations

Less Money

Harness 3rd party investment
to save millions in deployment costs

Societal Benefits

Climate change – humanity's greatest existential threat

Adding sensors for climate and disaster monitoring

SDG 13 Climate

SDG 14 Ocean

Sendai

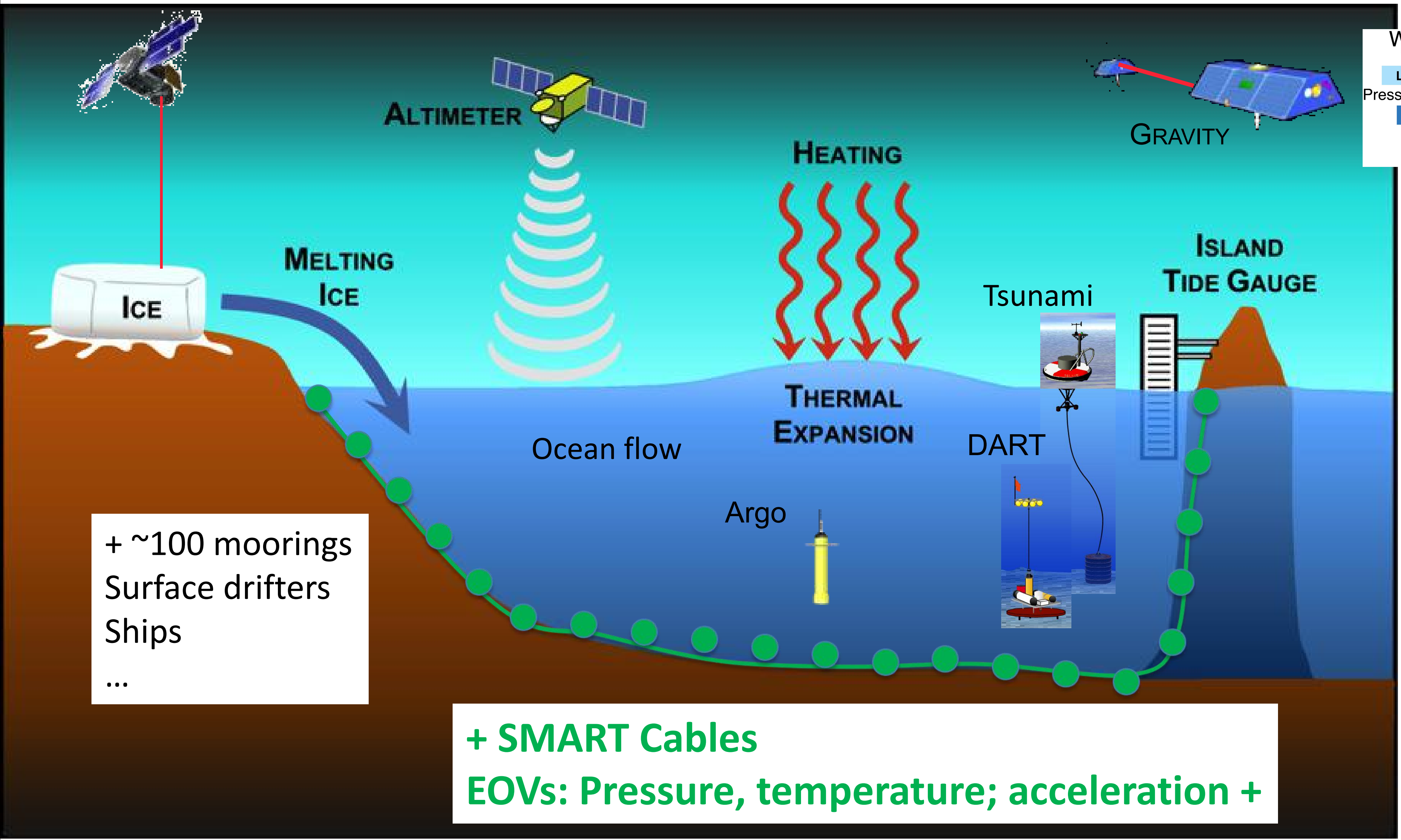
Paris

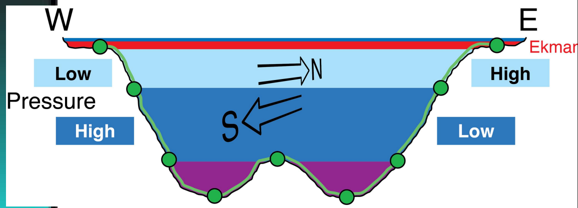
Societal and environmental issues:

- **Climate change** – ocean temperature and circulation – direct impact on societies, short and long term
- **Sea level rise** – hazard for coasts, island, cities
- **Disaster warning**– tsunami and earthquake monitoring throughout ocean basins and coastal margins

Global ***Regional*** ***Local***

Tools





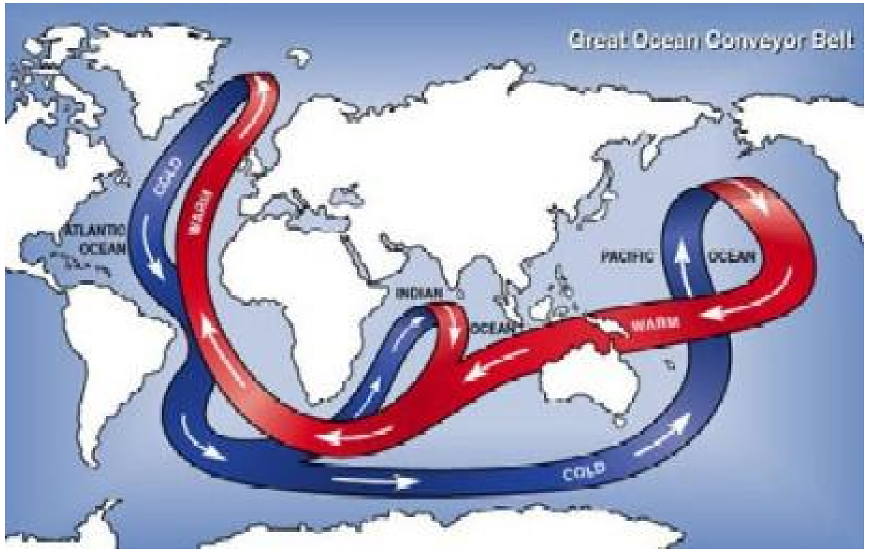
Now, few bottom obs

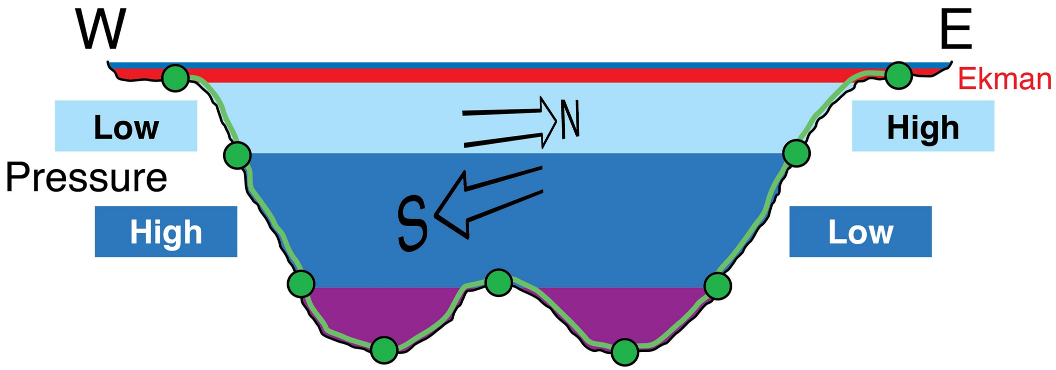
Add SMART Cables:
Unique
Augment
Complement

Adapted from Nerem, 2016

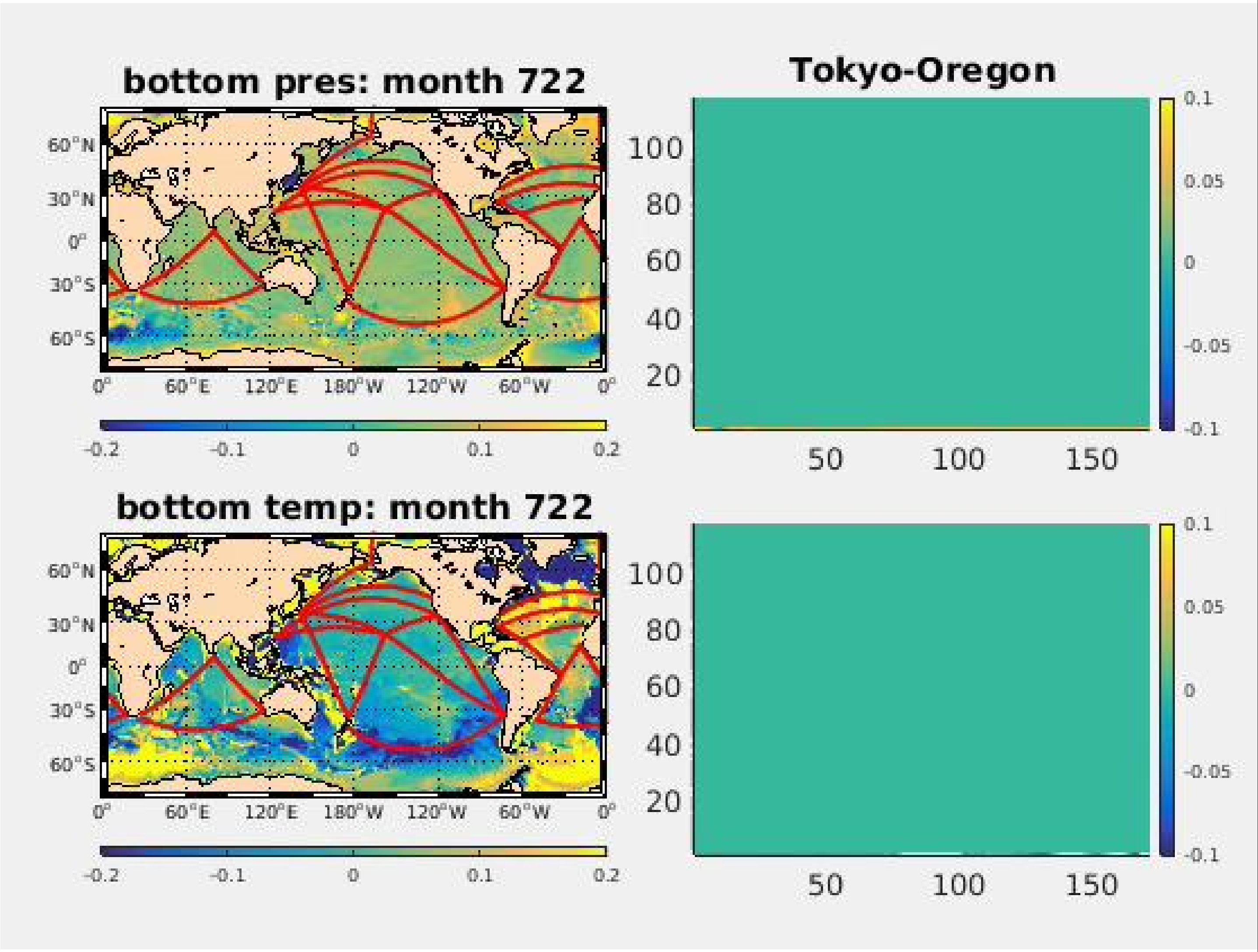
Temp and Pressure (x,y,t) along route

Global meridional overturning circulation – climate



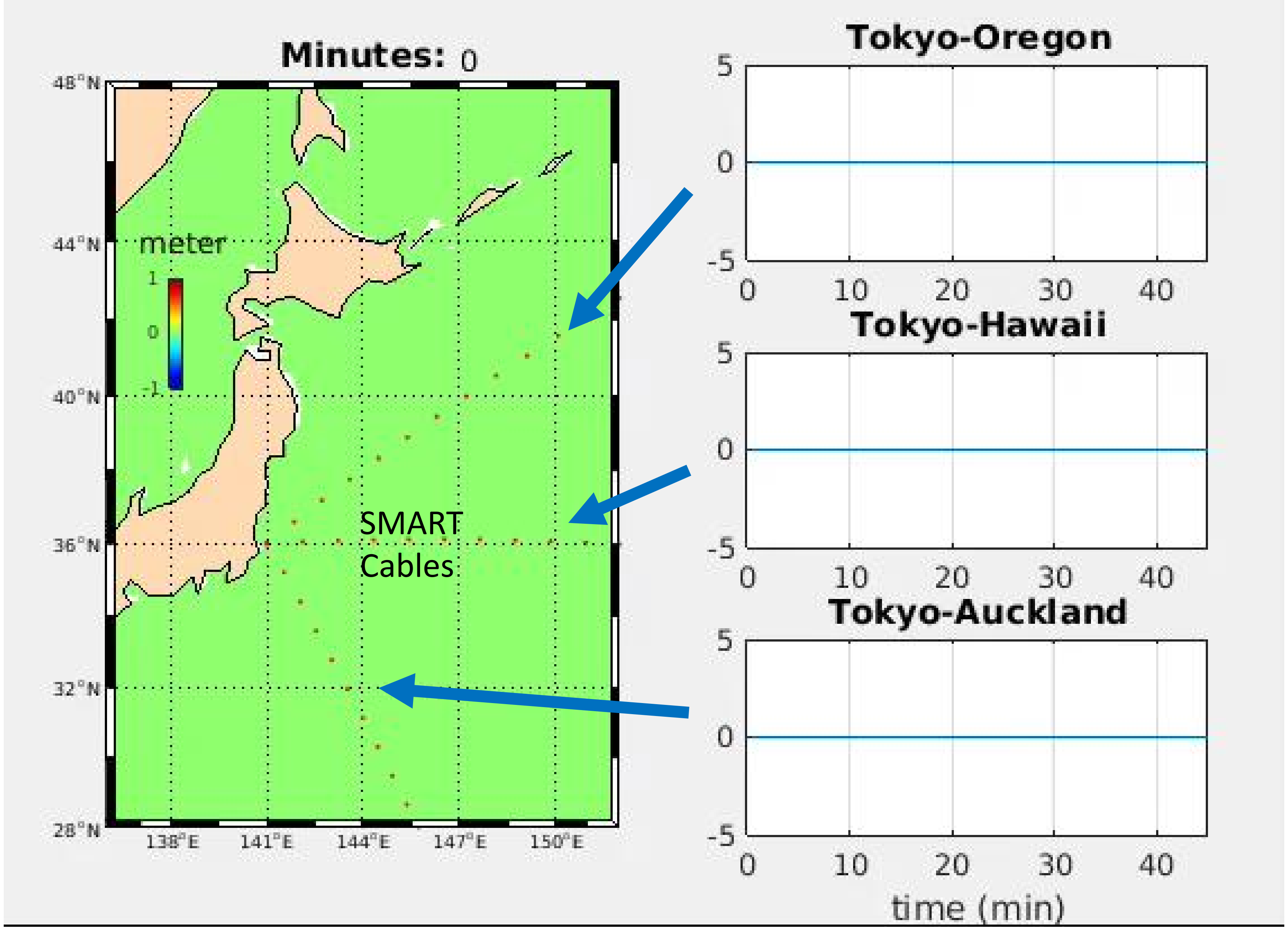


Flow high to low pressure



Tony Song, JPL/CalTech

Tsunami – pressure (x,y,t)

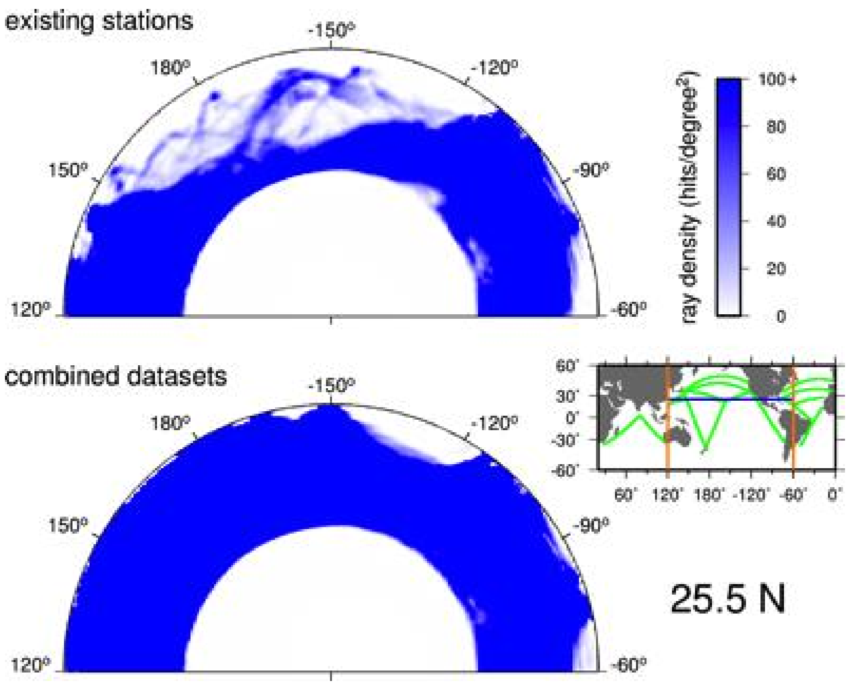


Movie
Color lines
For each sensor
Pressure /
Tsunami wave
vs time

Tony Song,
JPL/CalTech

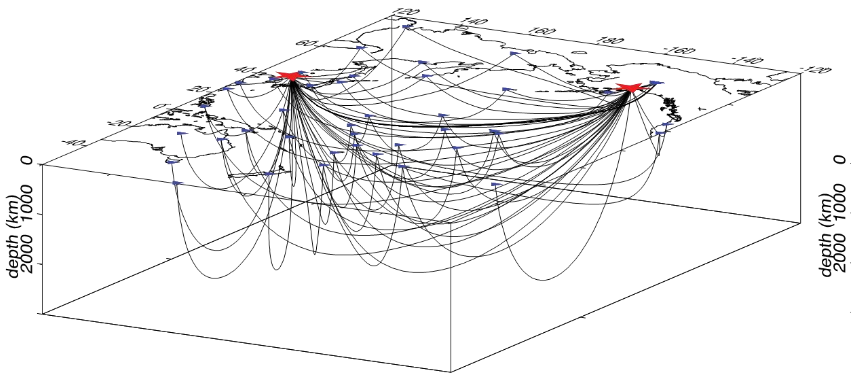
SMART Cables for seismology

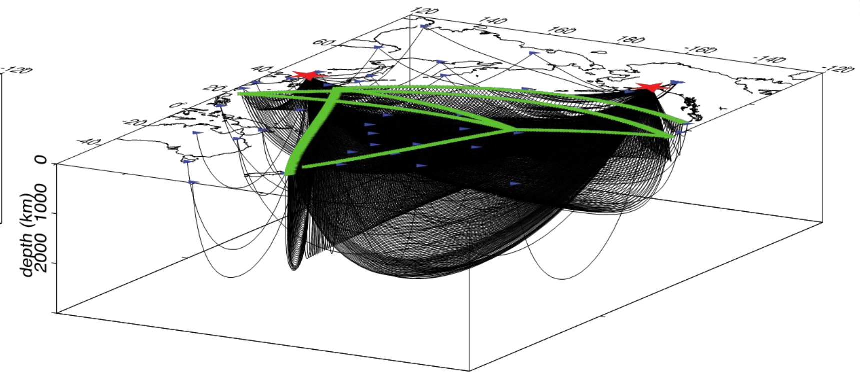
- **Better sampling** with SMART cables
- **Increased – global – coverage** -> **reduced location uncertainties, better magnitude calculations,** may provide reduced detection thresholds.



Current array (with 2 sources) sparsely samples the crust and upper mantle.

Rays to SMART Cable sensors provide improved coverage over large areas.





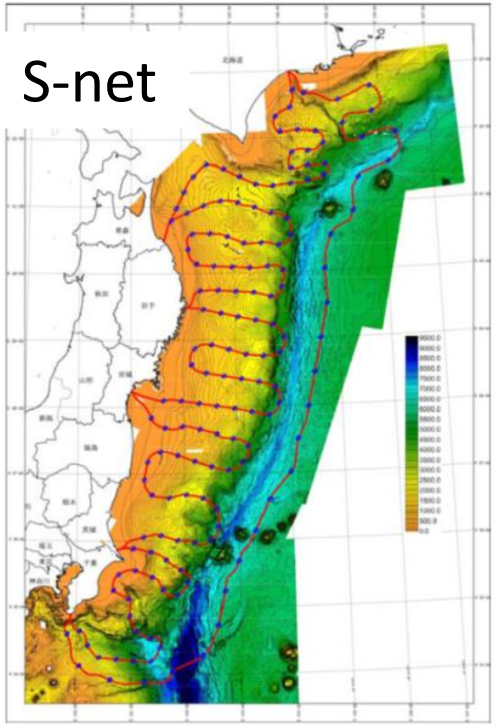
Additional sampling with SMART cables in Pacific, 20 y earthquake sources

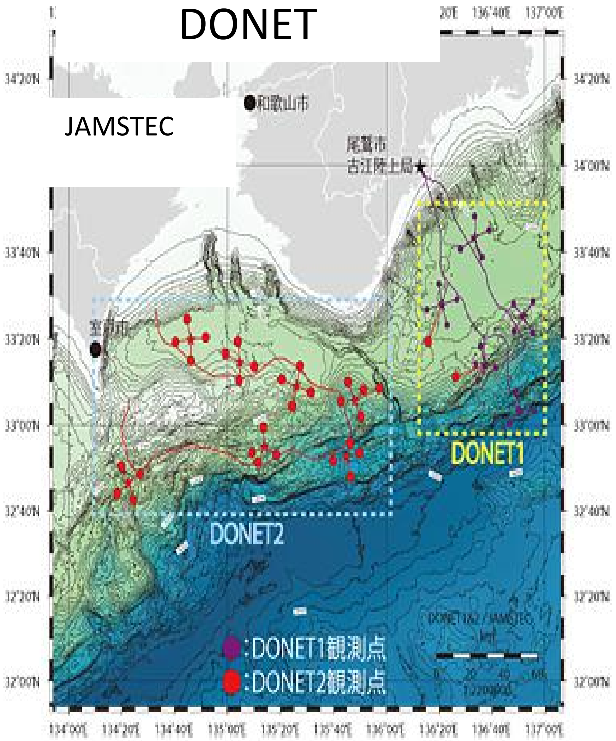
Modeling work continuing – P and S waves, …

N. Ranasinghe, C. Rowe et al., Enhanced global seismic resolution using transoceanic SMART cables, Seismol. Res. Lett., 2017.

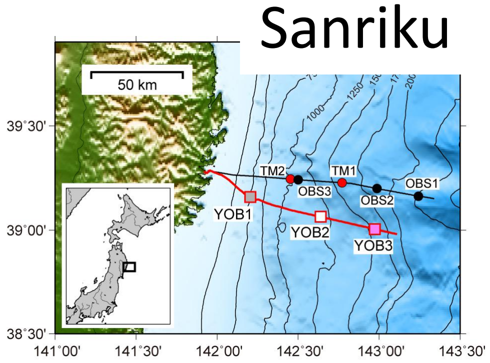
Existing tech components

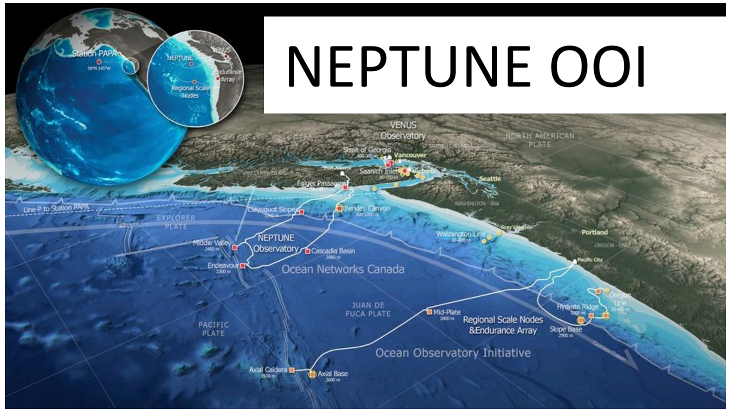
- Dedicated cable systems
  - Existing and proven:
    - S-Net, Sanriku
    - DONET, perhaps NEPTUNE, OOI-RCA (high power, ROV)
    - ***N-Net – new***
  - Sanriku lower cost, close to SMART





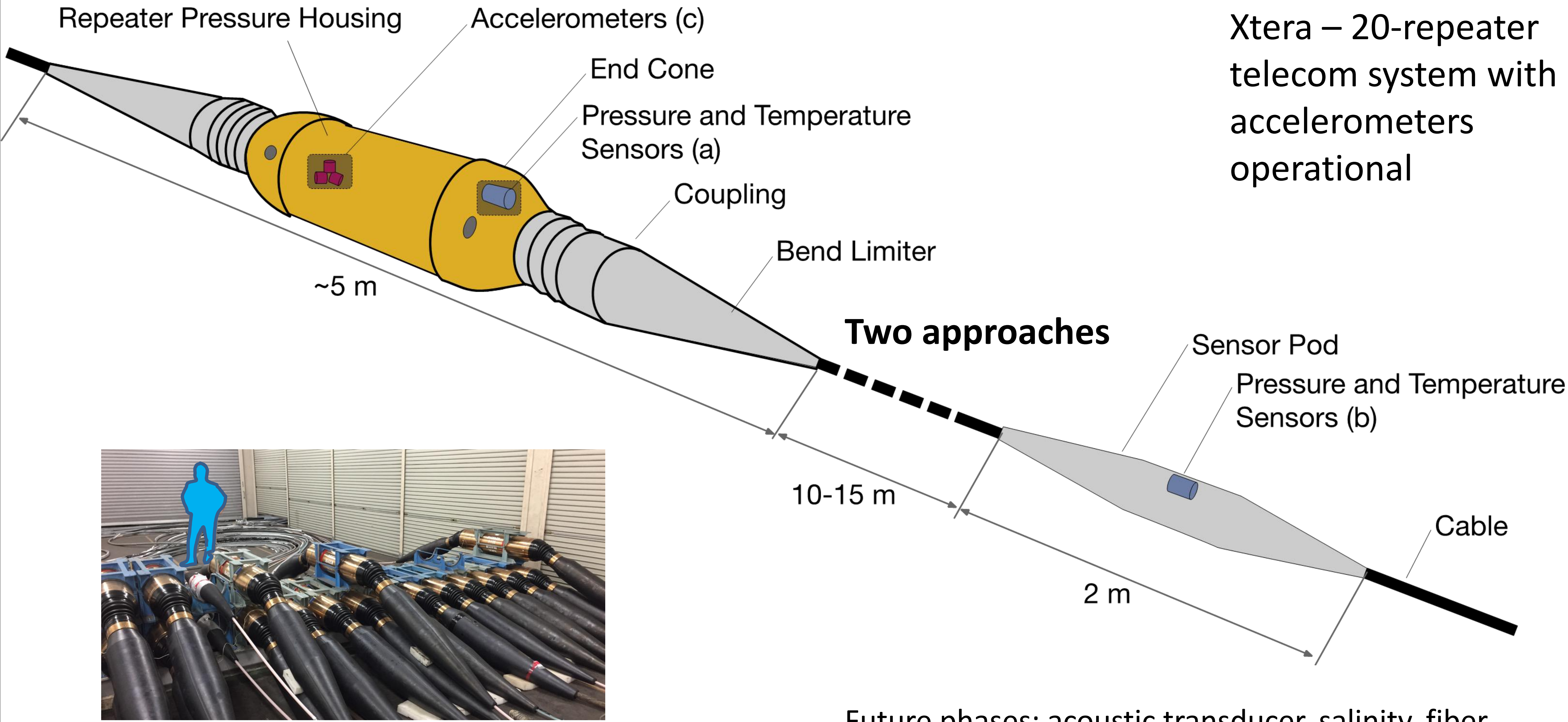
©JAMSTEC





SMART Repeaters

Xtera – 20-repeater telecom system with accelerometers operational

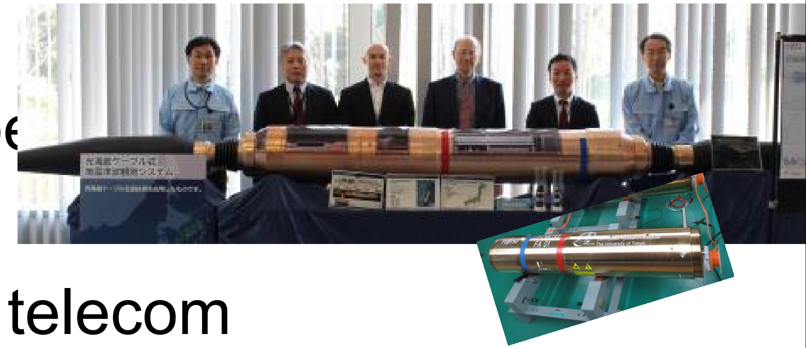


Two approaches

Future phases: acoustic transducer, salinity, fiber, ...

Costs

- Plug and play science systems like NEPTUNE-Canada, US OOI-RCA, DONET very expensive, based on ROV use
- Dedicated single purpose EW systems like Snet, Nnet expe
- SMART
  - *Expect **lower cost*** - Share/incremental costs only, with telecom
  - Assume no wet maintenance for SMART part
  - Pick and choose which systems
  - Build up coverage over time



Global Scenario

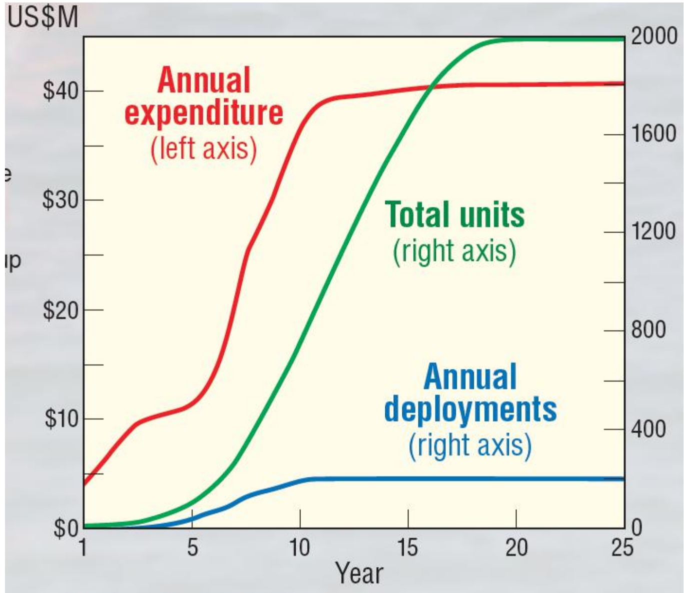


Figure 3. SMART deployment over time.

Telecom \$40k/km; SMART \$4k/km incremental above

Steady state: 10 year cycle, 3 systems/y, \$175k/repeater

\$20k/y/repeater, 0.16 Gm, 4x around world

Laid out in OceanObs19 community white paper)

Howe et al., SMART Cables for Observing the Global Ocean: Science and Implementation, *Front. Mar. Sci.,* doi: 10.3389/fmars.2019.00424, 2019

Comments

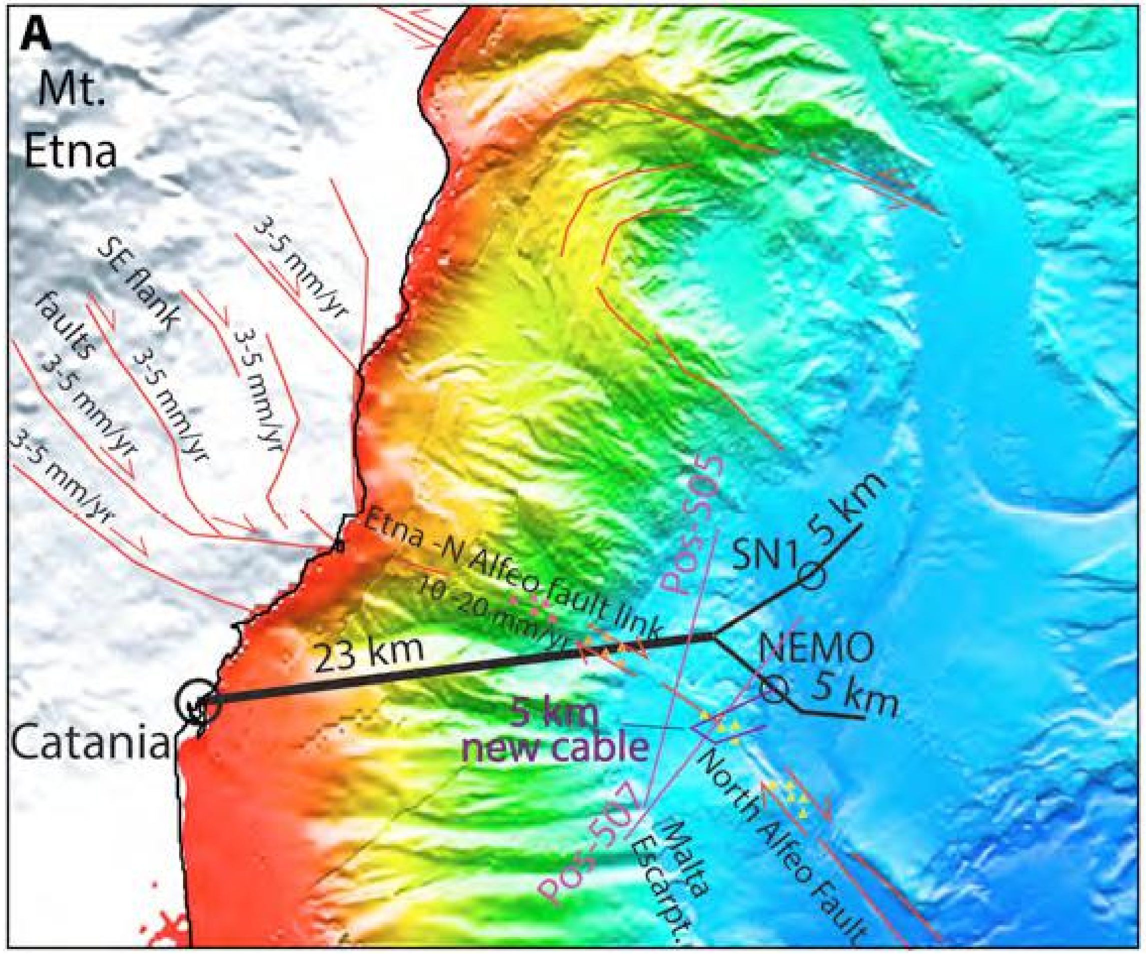
- Be clear – funding is largest challenge – governments, MLDBs – others?
- First modest projects just starting (next slides)
- Commercial challenges
- All suppliers say they can do it technically, just time and funds
- Need development of submarine qualified SMART repeater – need “off-the-shelf” – start small/modest – wet demos and pilots
- Legal/permitting/security
- **Approach – start with countries that need SMART capability – tsunami, earthquake, sea level, etc. Engaged governments. Access to Development Bank funds.**

Next steps

Systems under consideration

INGV – Italy – Sicily

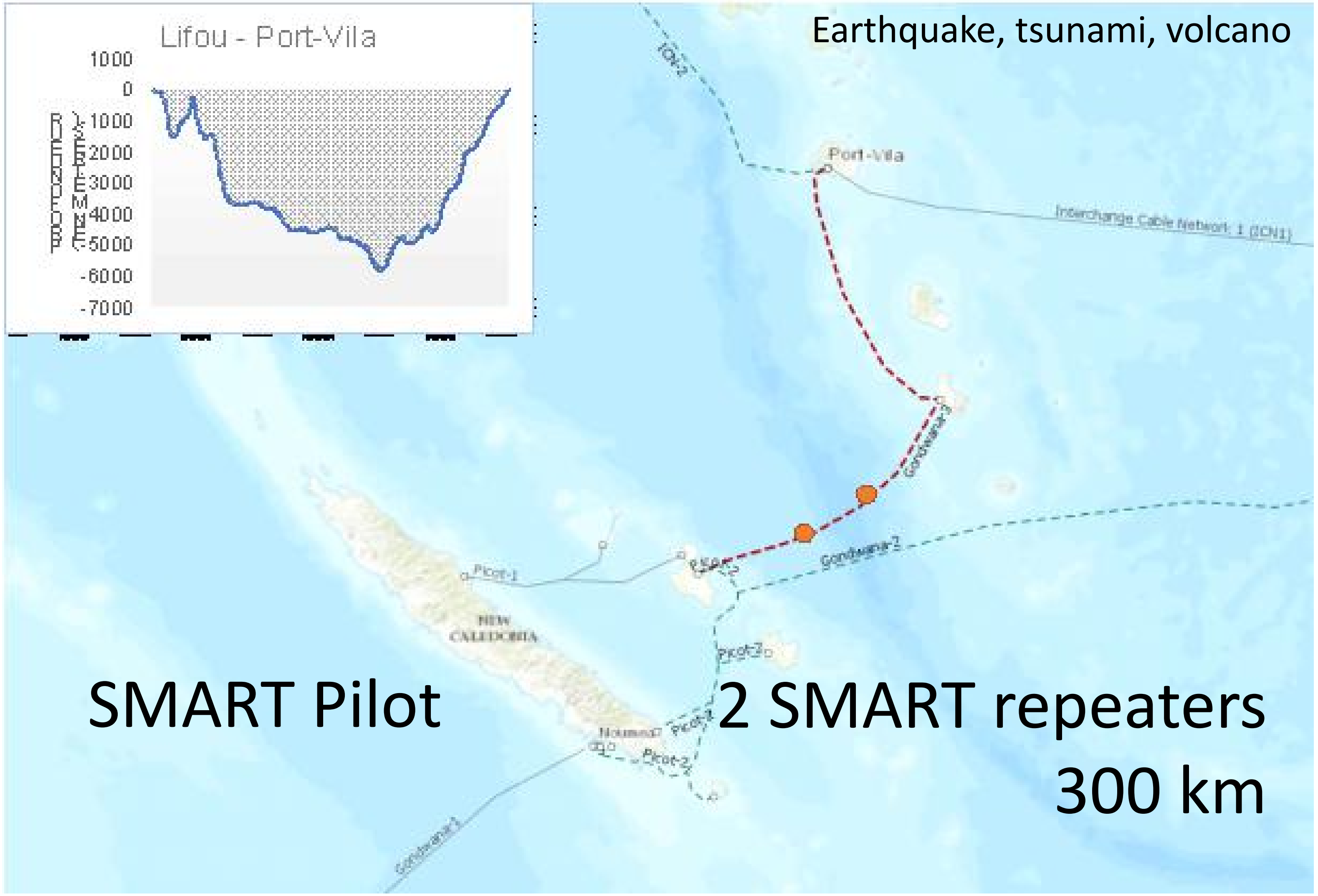
- InSea Project
- **Just funded 6/2019!**
- **Wet demo**
  - Demo mechanical, science
  - Test system on spur
  - Attached to observatory
  - Possibly use recovered repeater housings/cable, SMART prototype



Gondwana-3, New Caledonia–Vanuatu

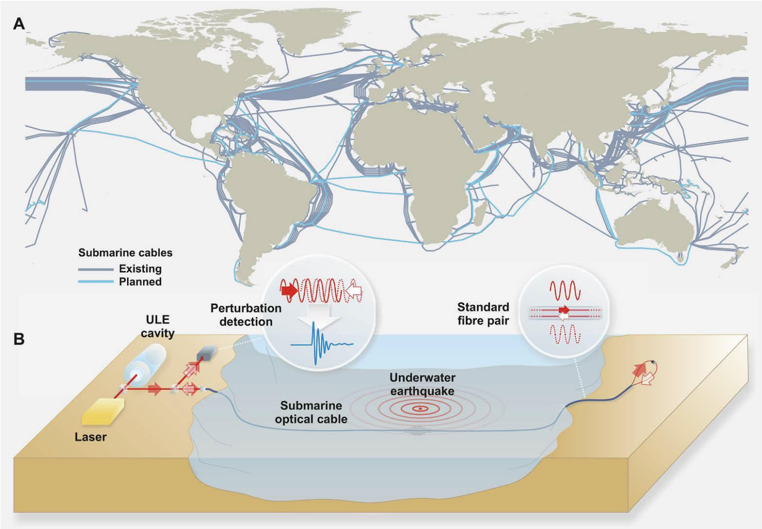
- Project SMART Cable Gondwana-3
- **Backup cable: more flexible on risk and schedule**
- Funding:
  - OPT Proposal to French government mid-2019 includes development
  - Additional funds to be requested by Vanuatu from ADB High-Level Technology Fund

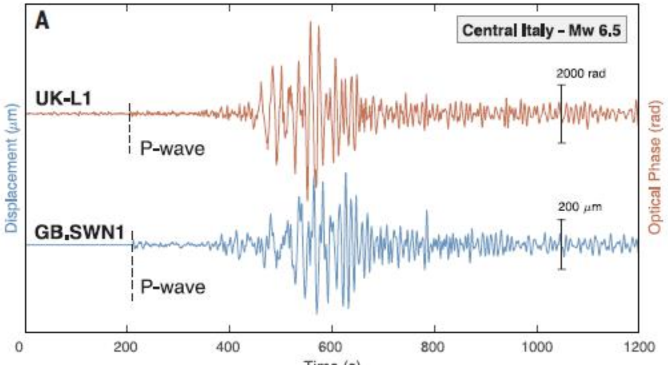
Need sea level, disaster warning

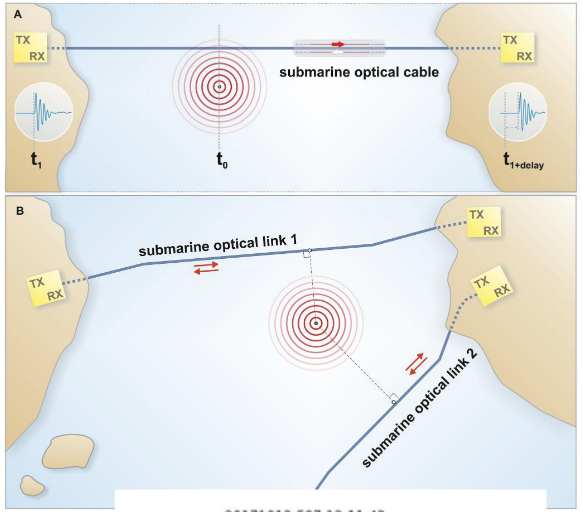


New Tech: Optical fiber sensing

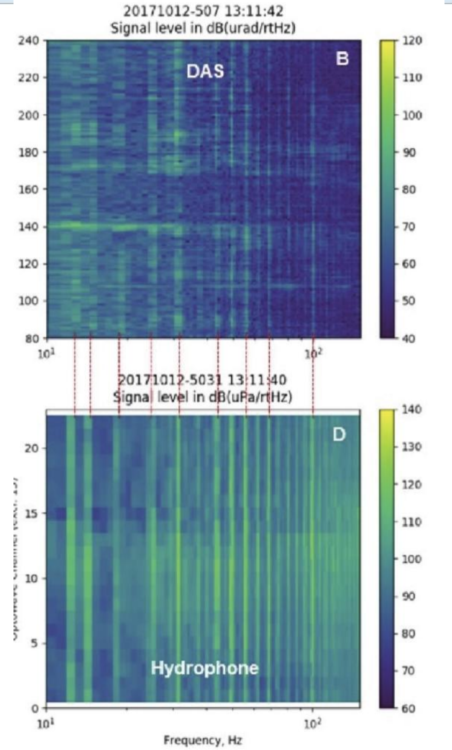
Interferometry







Challenge – calibration – point sensors
Integral measurement – enough cables -> tomography?



- **Measure strain across the oceans** – track phase(t)
- Depends on ultra stable lasers
- Connect clocks together via all optical links
- A global nervous system!
- Non-invasive – uses a wavelength like any other

Marra et al. Science, June 2018

Distributed acoustic sensing (DAS)

- **Measure strain, to ~140 km**
- Backscattered light, like sonar
- Dedicated fiber
- 500 Hz, 5 m resolution – **Big data!**

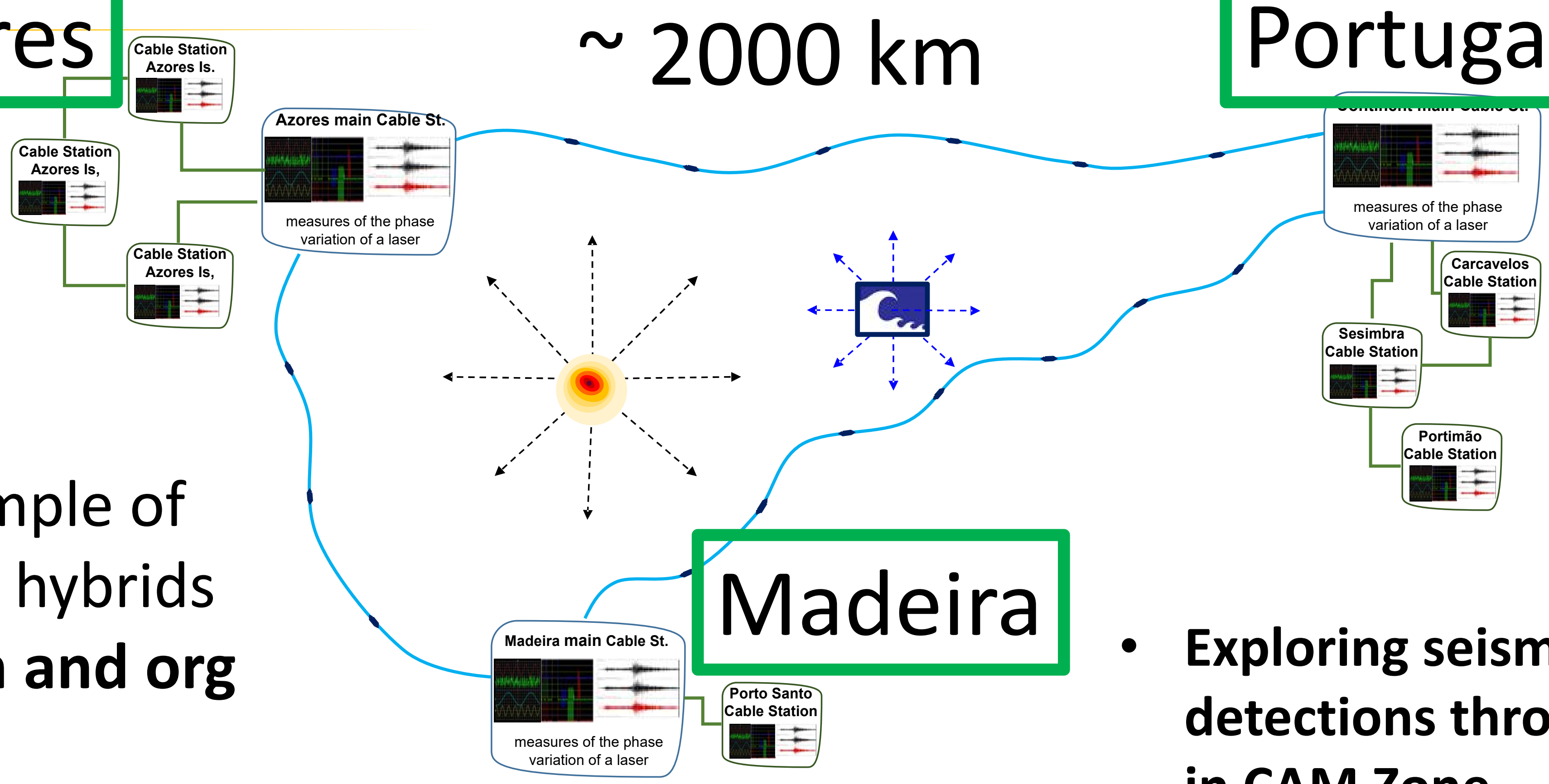
DAS compared with nearby hydrophone

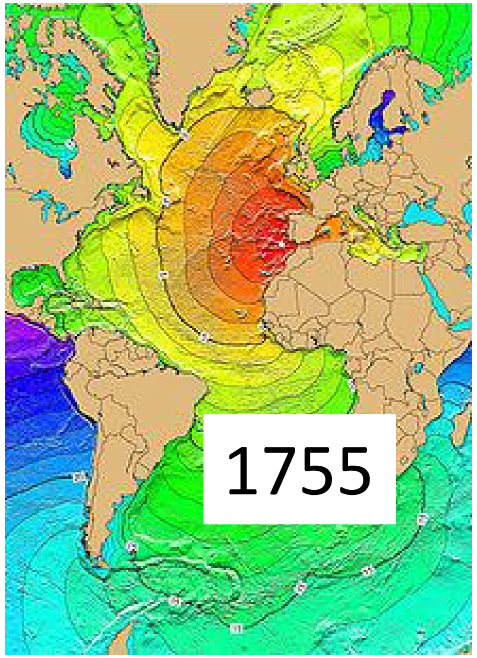
Land or water – seismic/acoustic sensing

Example - CAM: Portugal – Azores – Madeira

Fiber strain (backscatter, interferometer), sensors in repeaters, other wet sensors

Azores



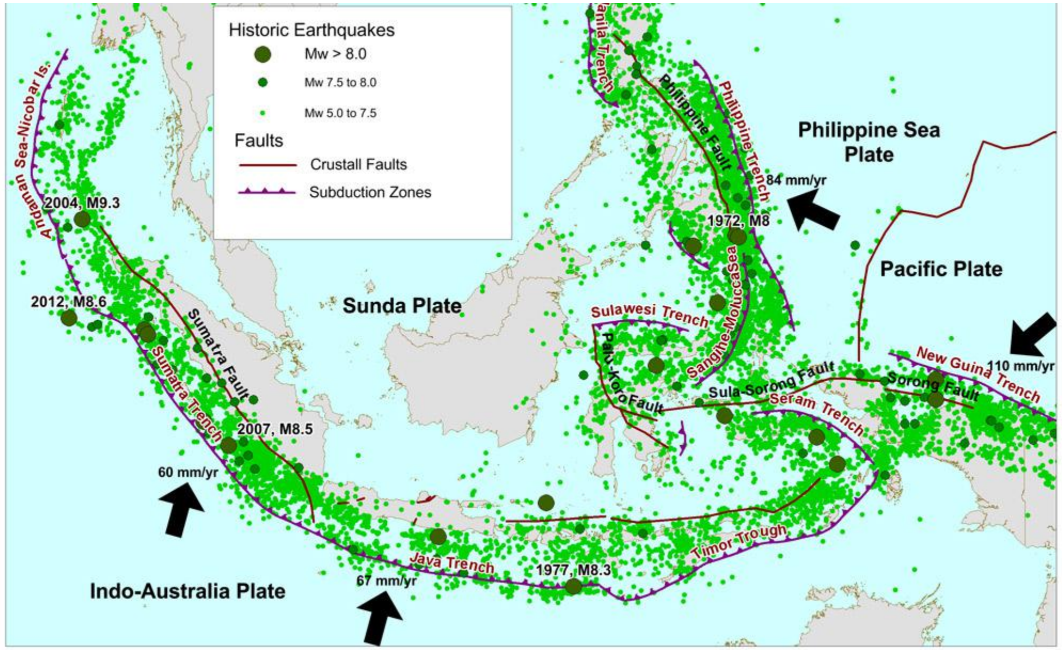


Example of new hybrids
Tech and org

ANACOM - Government telecom regulatory

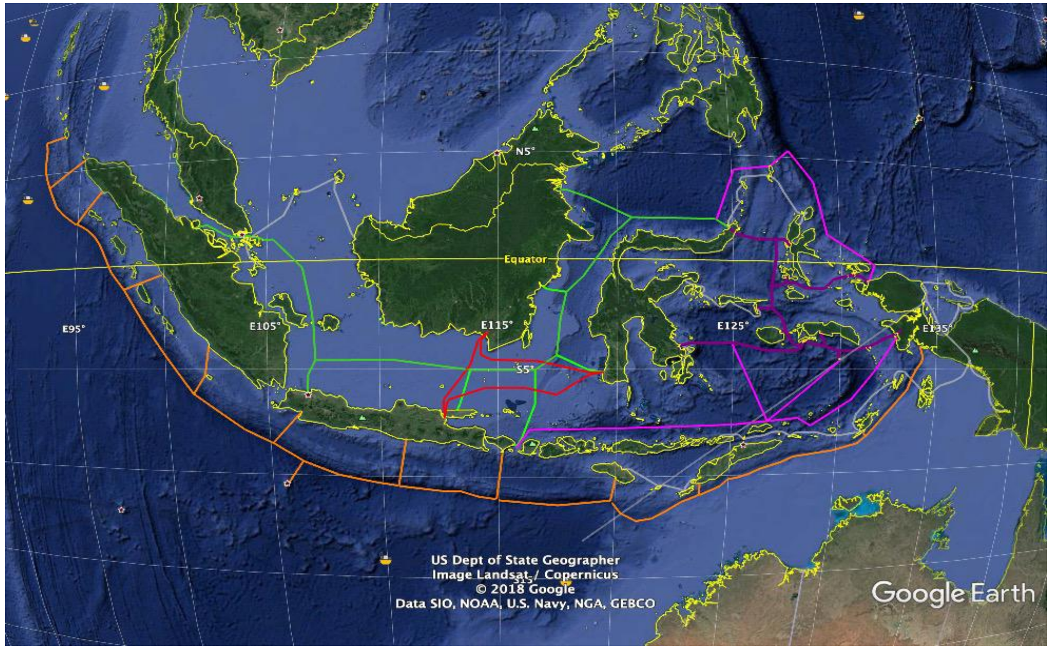
- **Exploring seismic and other kind of detections through submarine cables in CAM Zone**
- **Smart, Green & Blue CAM Ring**
- **ANACOM, CIVISA, FCT, IPMA, IT, IVAR**

Indonesia, ASEAN



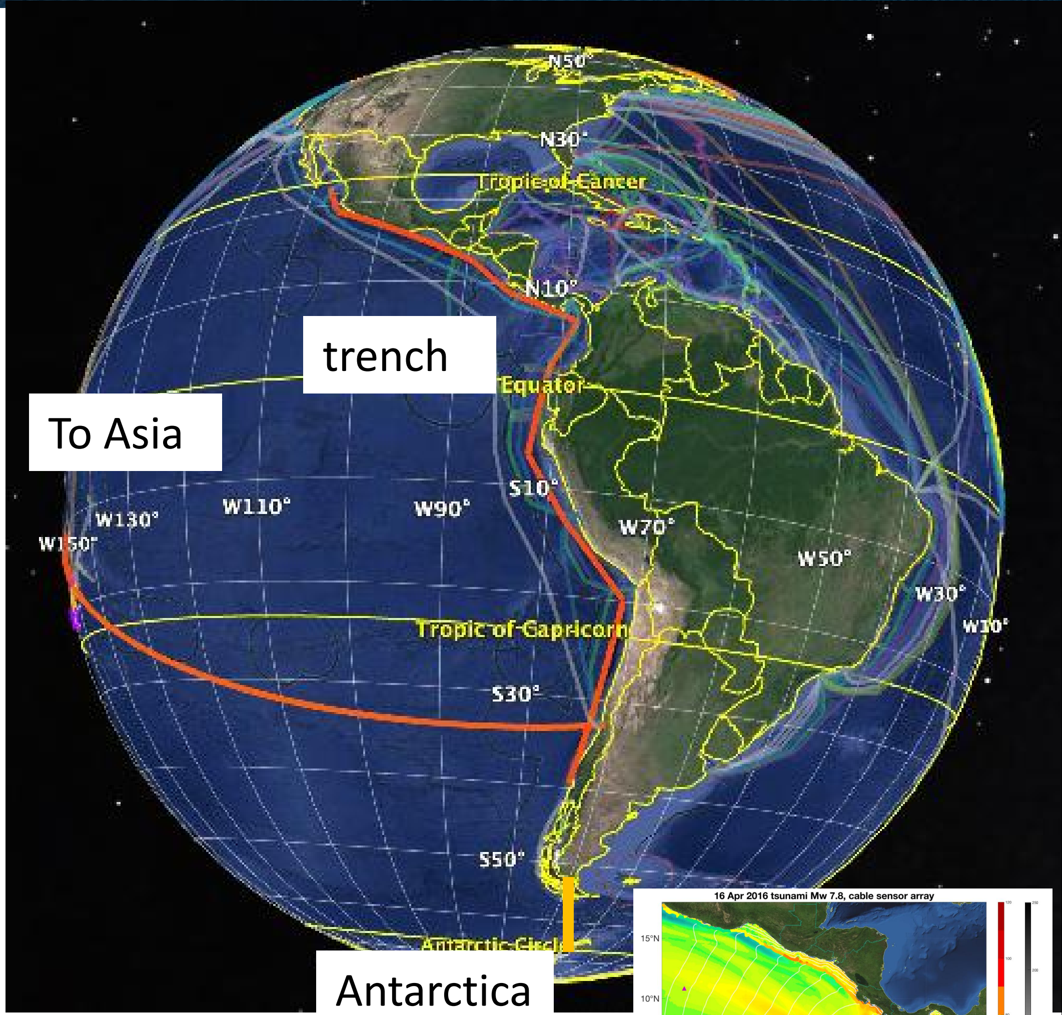
- Cost – SMART essential to leverage telecom
- Reliable, achieve good coverage
- Encouraging telecoms
- Governments mandate SMART
- Include neighbors and international
- **Cable based tsunami warning + ocean**

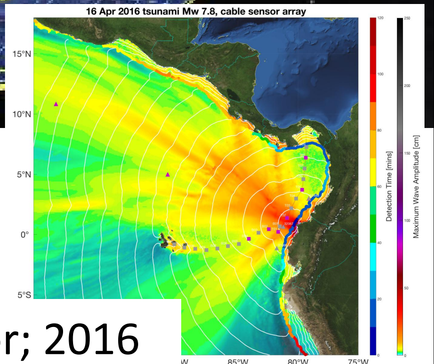
- Need tsunami warning
- Also ocean/climate, ITF
- **Need 20 year plan**
- Phase next 10 - 20 years
- Pick and choose which



Possibilities in Latin America and Caribbean

- Early Warning Tsunami and Earthquake
  - IOC PTWS reports
- Ocean, climate, El Niño, sea level
- InterAmerican Development Bank (IADB)
  - SMART ”Two for the price of one”
  - Critical, Shared Infrastructure
  - Encouraging telecoms, permitting
  - Study group/Publication to support IADB funding for SMART cable systems
  - Latin Am Region considering connection to Asia (from Chile, …Subtel Feasibility Study)
  - Improve inter-country connections
  - Also Antarctica – oceanography In Drake amazing!





Galapagos-Ecuador; 2016

(Arctic Borealis, NORDUnet; Australia AARNet; CANARIE)

Outline

- Motivation
  - Climate
  - Disasters
- SMART cables
- **R & E Networks**
- **Sharing infrastructure**
- Concluding remarks

NRENs and RedCLARA

National Research and Education Networks (NRENs)

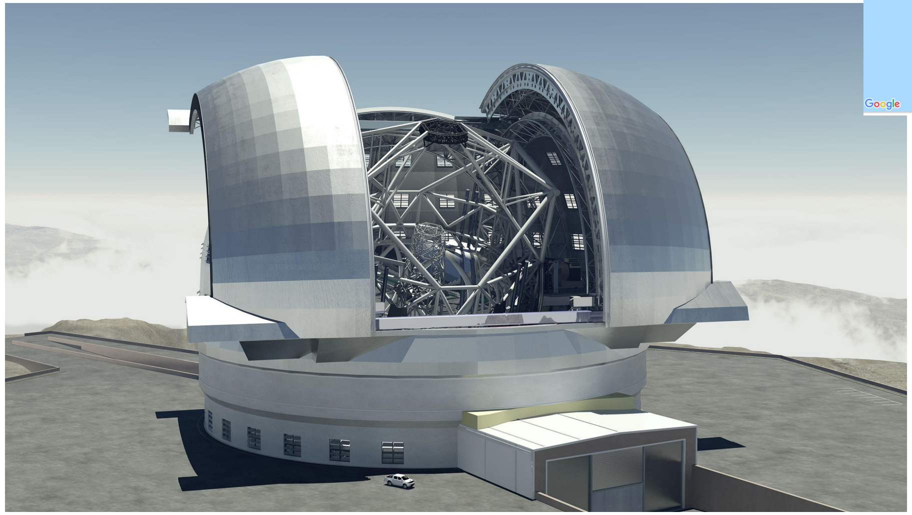
RedCLARA main services

- Provide advanced academic backbone connectivity for LAC NRENs
- Affiliated networks communicate with universities, research centers and the scientific community worldwide and partner institutions.
- Dedicated network, no congestion, non-commercial/independent, high QoS, low latency and secure transit
- Submarine cables (wavelengths) part of system

Summary: connectivity and communication

Examples
Extremely Large Telescope under construction, 2025
~40 m mirror

Large Synoptic Survey Telescope



EllaLink – RedCLARA and GEANT

RENs have bandwidth on such cables

Indefeasible Right of Use (IRU)

Sharing infrastructure

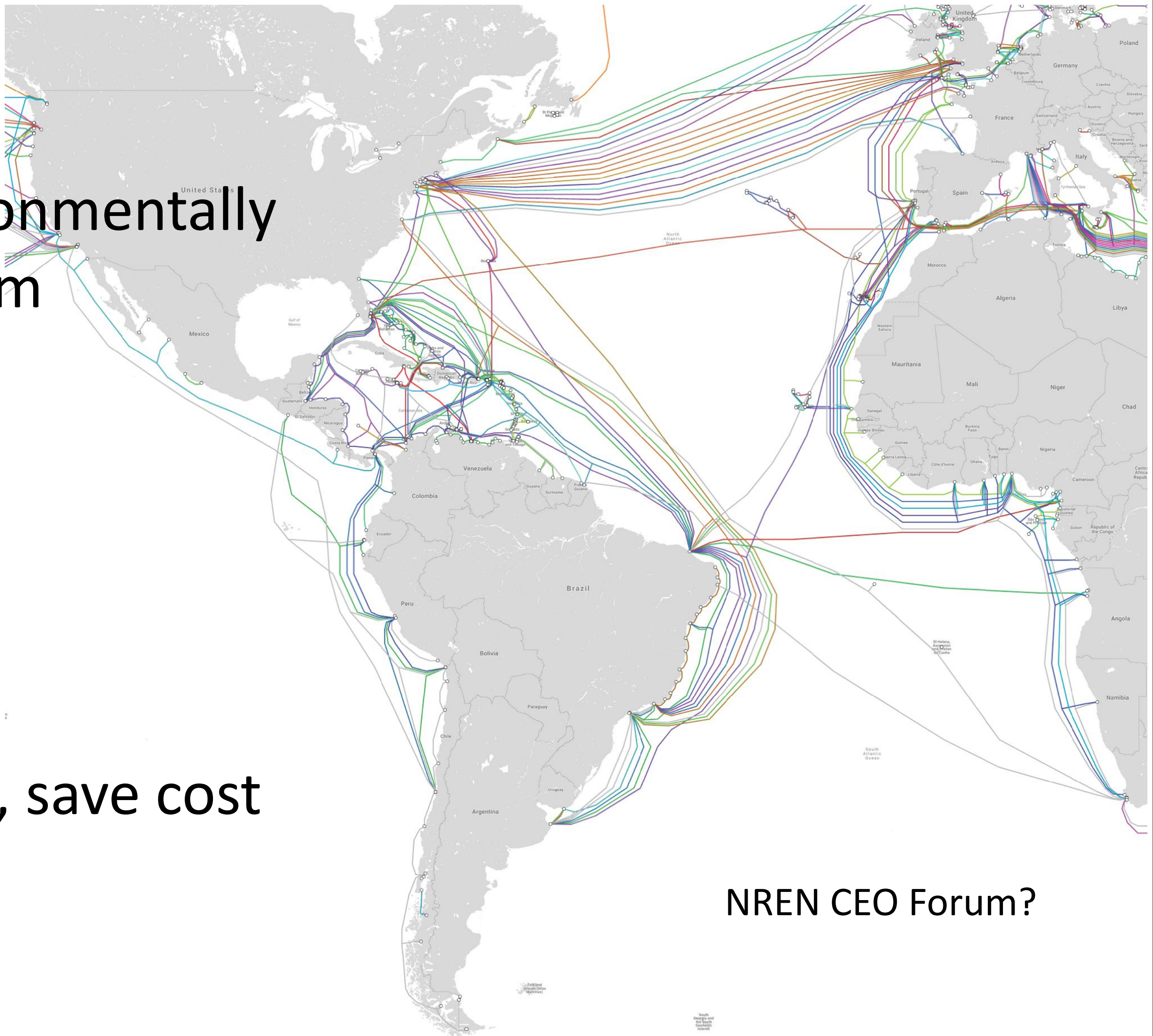
An opportunity for RENs?

Extend NRENS, RedCLARA to be a environmentally self-aware network a la a nervous system

- Help protect the network
- Scientific and societal benefits

Shared infrastructure

- multi-purpose
- dig once
- two for the price of one, save cost
- Fiber sensing
- Point sensors



NREN CEO Forum?

In 1998, Bill St Arnaut, CANARIE, proposed combining academic internet, science, and native community connectivity in the Arctic

IADB – Miami – Recommendations to Regulators

- Recommend Governments and other possible sponsors/banks should
  - Recognize telecom and SMART systems as critical infrastructure
  - Require disaster risk reduction elements in all critical infrastructure
  - **Recognize that submarine cable systems are shared infrastructure and shall combine telecom and ocean observing/early warning capabilities**
  - Implement procedures to streamline the consortium process in this context
- Latin America and Caribbean countries + banks can lead the adoption of SMART capability: utilize shared infrastructure, provide societal benefits – better regional climate forecasts and tsunami and earthquake early warning capability.

Concluding Remarks - SMART

- Initiative in transition: concept ➜ wet demo ✔ , pilots ✔
- UN organizations supporting SMART cables ✔
- Indonesia – toward SMART tsunami warning ✔
- Development Banks (ADB, IADB) positive ✔
- Need to encourage more Corporate Social Responsibility
- Need very early access to proposed systems – smaller, government, development banks, need
- Common issue – ***FUNDING***

Thanks to NASA for planning funding!

Concluding Remarks - RENs

- Climate monitoring and disaster mitigation are worthy topics for RedCLARA and NREN attention
- Research and Education Networks should play an active role
- And, they can player a larger role
- Consider their networks as infrastructure to be shared, for science and societal benefit
- Use their influence as infrastructure stakeholders to take advantage of the possibilities

SMART Cables

Gracias!
Questions

JTF SMART Cable web page: https://www.itu.int/en/ITU-T/climatechange/task-force-sc/Pages/default.aspx

SMART Cables for Observing the Global Ocean: Science and Implementation
https://www.frontiersin.org/articles/10.3389/fmars.2019.00424/full

TICAL2019
Cancun, Mexico
2-4 September 2019

TICAL
Comunidad y tecnología

e·ciencia
Encuentro Latinoamericano
2 0 1 9

Red CLARA
Cooperación Latino Americana de Redes Avanzadas