CTBT: SCIENCE AND TECHNOLOGY 2017 CONFERENCE

Bruce Howe, ITU/WMO/IOC Joint Task Force

University of Hawaii at Manoa

Joint Task Force SMART SubSea Cable Systems

SMART Cables Sensing the Pulse of the Planet

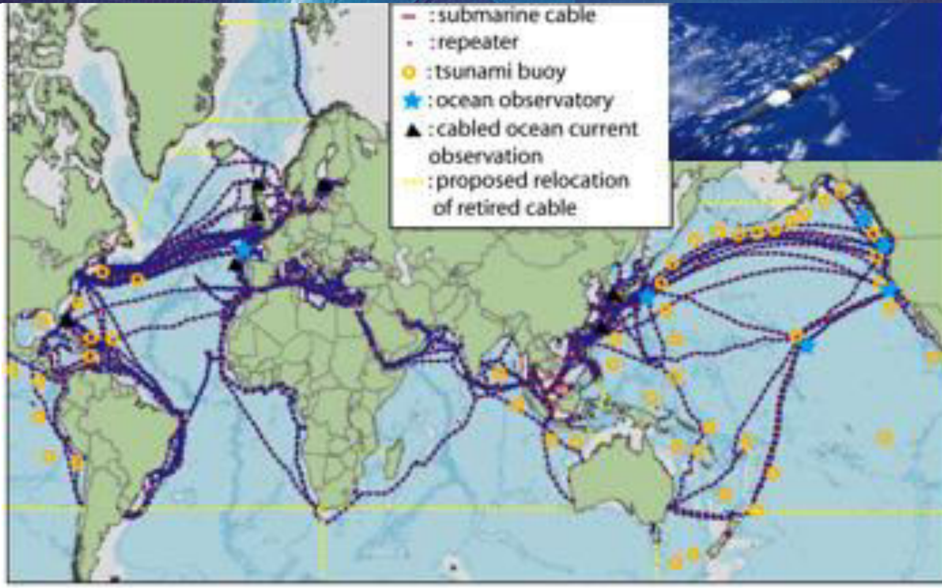
Science Monitoring And Reliable Communication

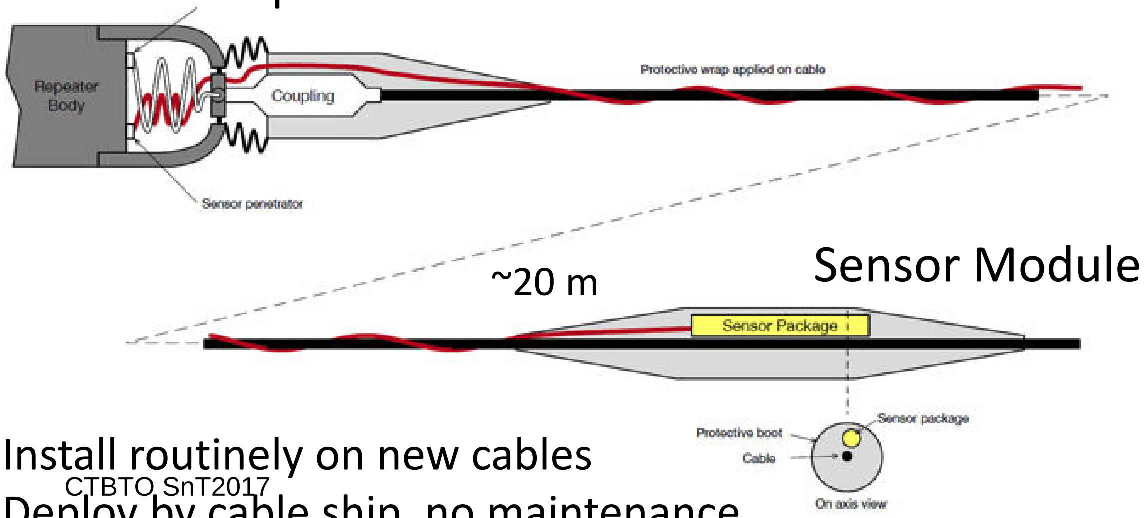
The basic idea

Climate, Oceans

Earthquakes, Tsunamis – Global Array

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





Install routinely on new cables

Deploy by cable ship, no maintenance

- Telecom + science
- Cable repeaters host sensors
- Potential: global spanning, trans-ocean, 1 Gm, ~10,000 repeaters (~100 km) 10-20 year refresh cycle
- Initially: bottom pressure, temperature and acceleration; supplement later

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

Societal benefits

Adding sensors for climate and disaster monitoring

Societal and environmental issues:

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

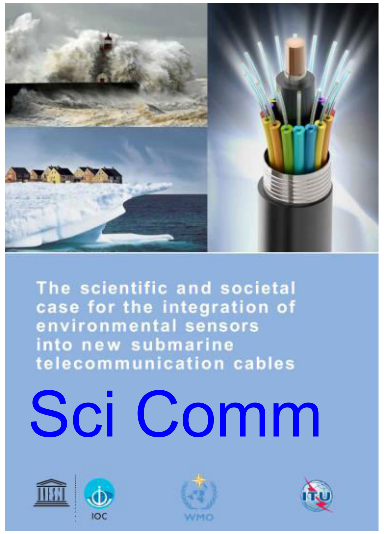
SMART Cable Initiative led by UN ITU-WMO-IOC

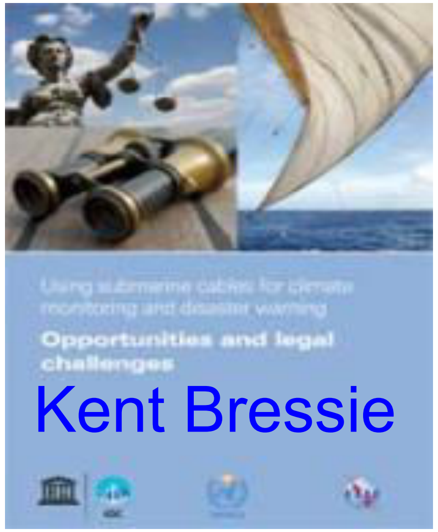
Joint Task Force (JTF)

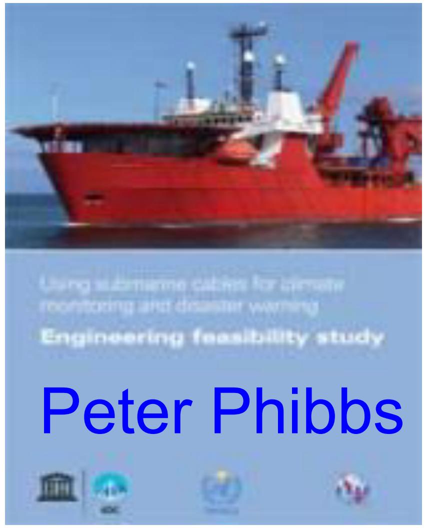
120 Members from 80 organizations

- Raise awareness, educate and publicize
- Search out the **funds** and potential **investors**
- Collaborate for an universal solution, but tailored to specific deployments
- Educate governments to facilitate permits and **funding**, and to utilize new data
- Link to other global initiatives – CTBTO – and international agencies

- Phased:
  - *Concept*
  - Wet demo
  - **Pilot**
  - Implementation





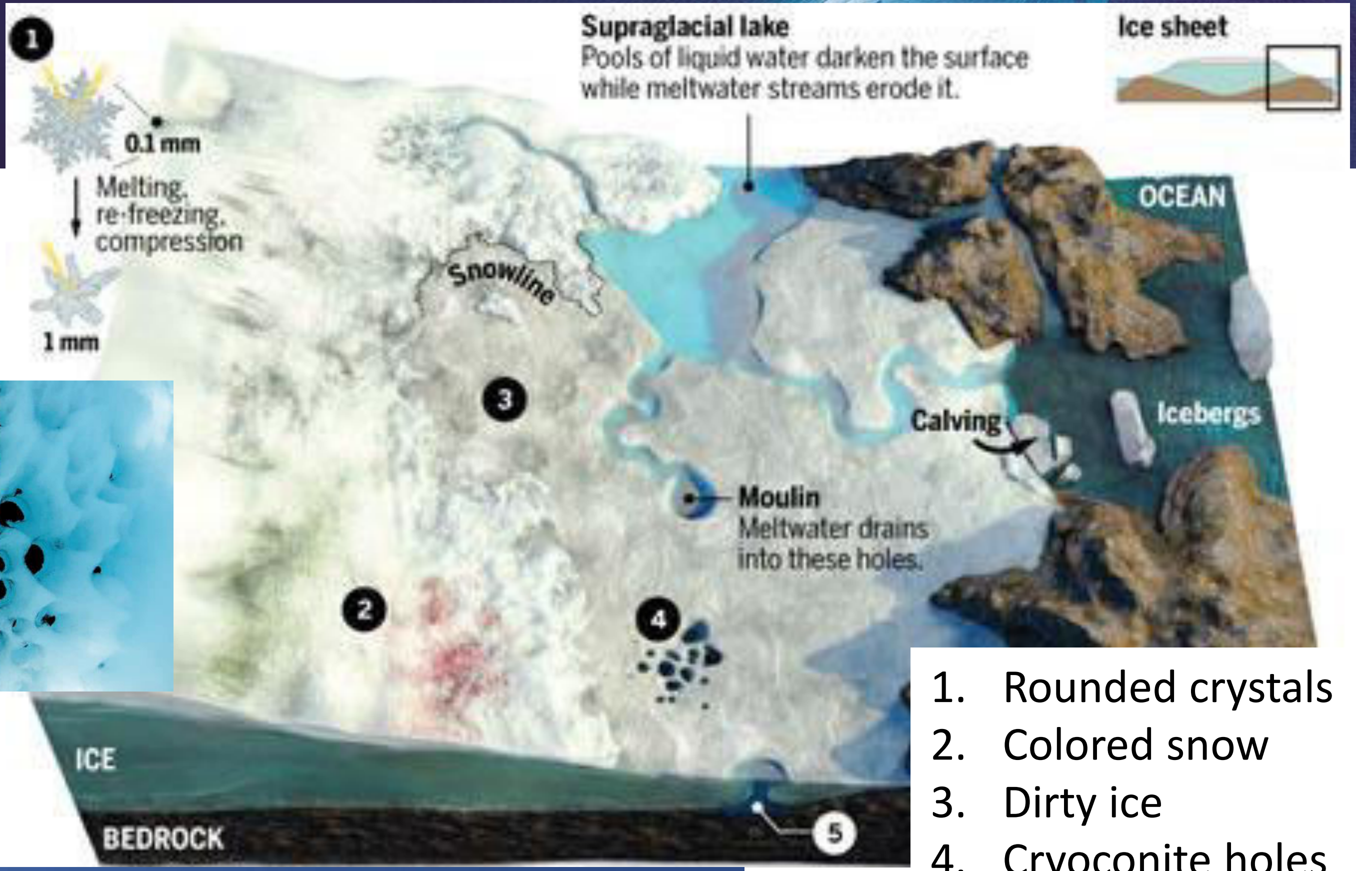


Known Unknowns?

The Great Greenland Meltdown

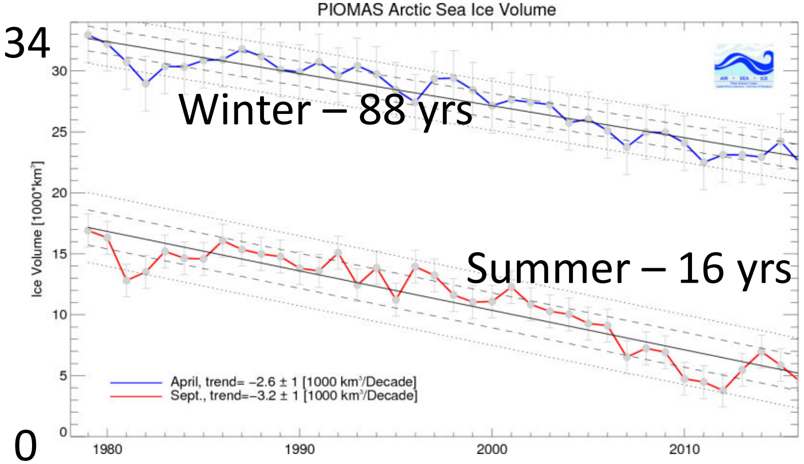
As algae, detritus, and meltwater darken Greenland’s ice, it is shrinking ever faster

E. Kintisch, Science, 23 February 2017



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

Arctic Sea Ice Volume – 1000*km3



CTBTO SnT2017

PIOMAS APL-UW

Antarctica too – on all edges and interior

Nansen Ice Shelf

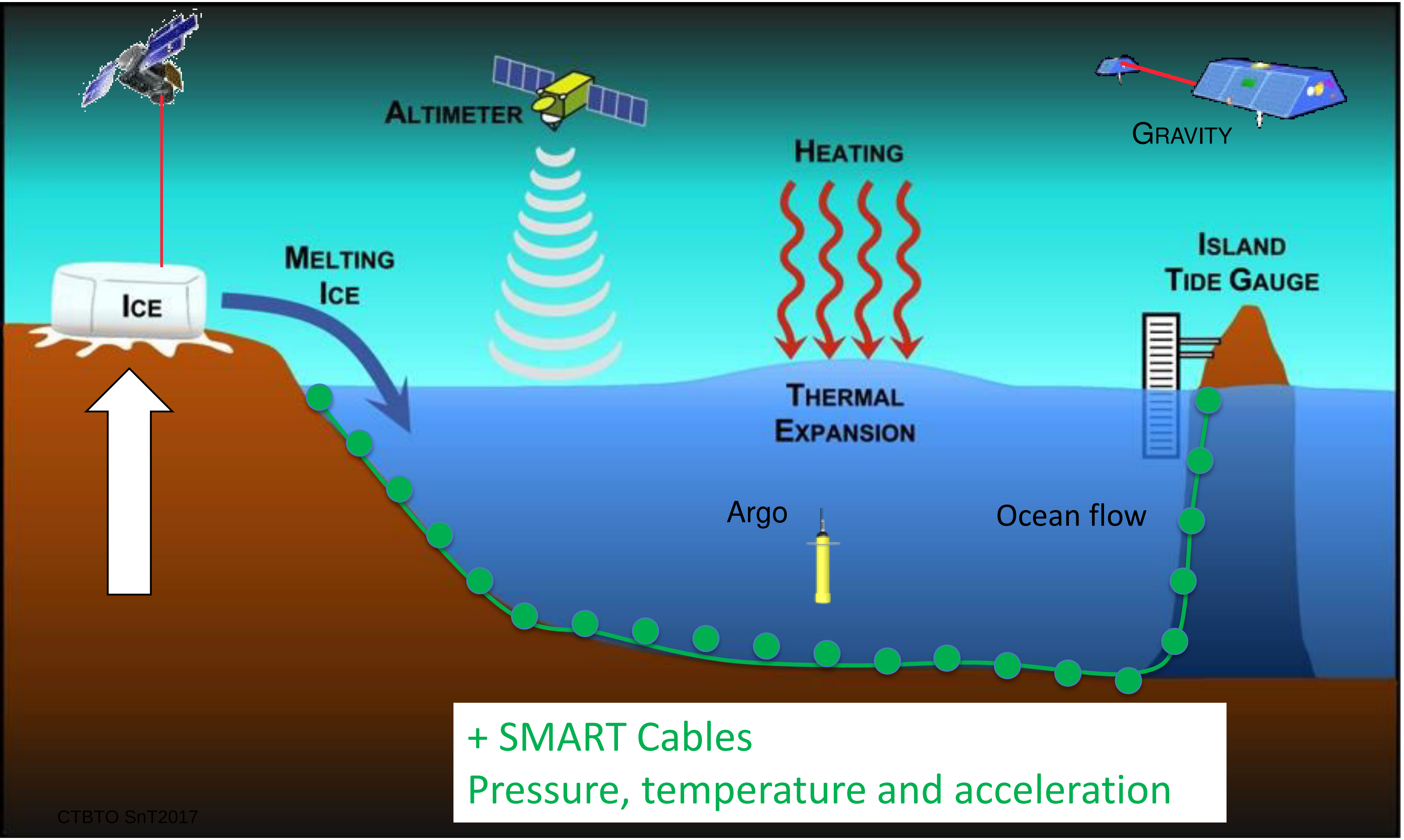
Kingslake, Nature, 2017

Wong Sang Lee/Korea Polar Research Institute

Recent science steps

- Workshops
  - NASA – climate and ocean circulation
    - CalTech, October 2014, Univ Hawaii, May 2015
  - GFZ – tsunami and earthquake
    - Geosciences Research Center, Potsdam, Germany, November 2016
- Modeling – in progress
  - Ocean – Song, JPL/CalTech; Weber and Thomas, GFZ-Potsdam
  - Seismic – Rowe et al., Los Alamos National Lab (Poster T1.2-P21)
  - Tsunami – Weinstein et al., Pacific Tsunami Warning Center

Tools for Measuring Sea Level and Ocean Circulation



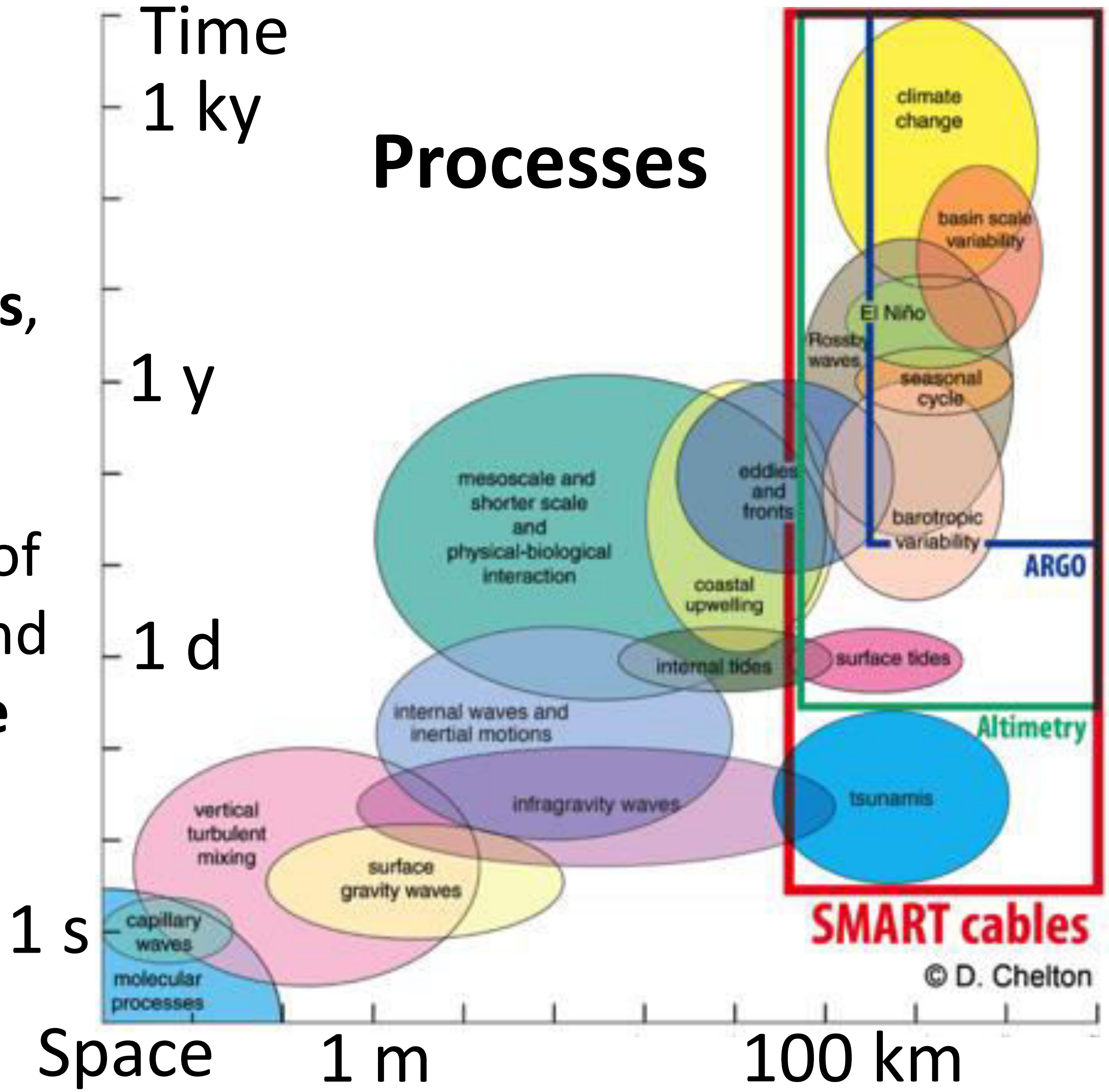
Now, few bottom Obs

Add SMART cables

Adapted from Nerem, 2016

SMART cables in the ocean observing system

- **Initial sensors:**
- **Temperature: spatial and temporal variability of deep-ocean temperatures**, track heat through ocean, along boundaries
- **Bottom Pressure:** Temporal variability of **waves, tides and currents** (<10 day), and **sea level**, **constrain tsunami amplitude**
- **Acceleration:** improve **earthquake parameters,** solid earth



[Report on two NASA workshops]

CTBTO SnT2017

Toward a SMART Cable "mission simulator"

Extract data along cable routes - Provide to users

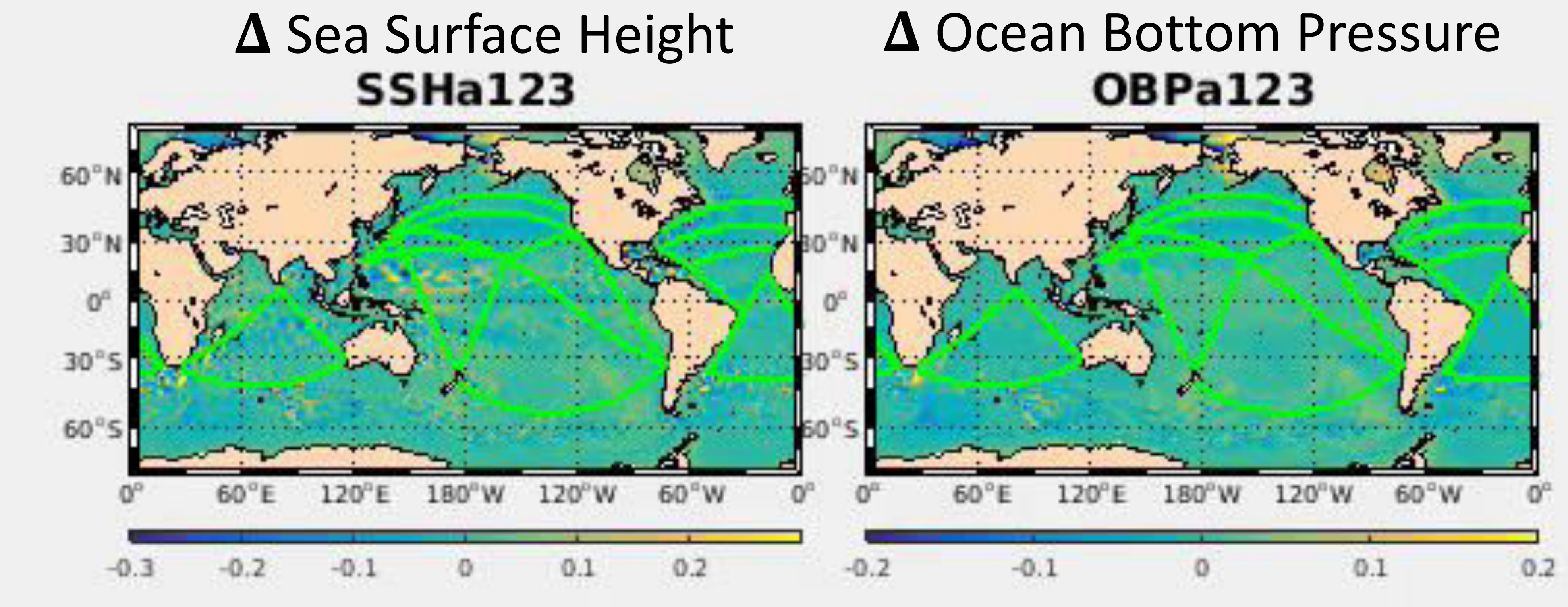
Tony Song, JPL/CalTech

1958 – 2016
30 layers vertical

Terrain following
¼ degree (~25 km) x,y

In progress!

2014-2016
daily (shown)

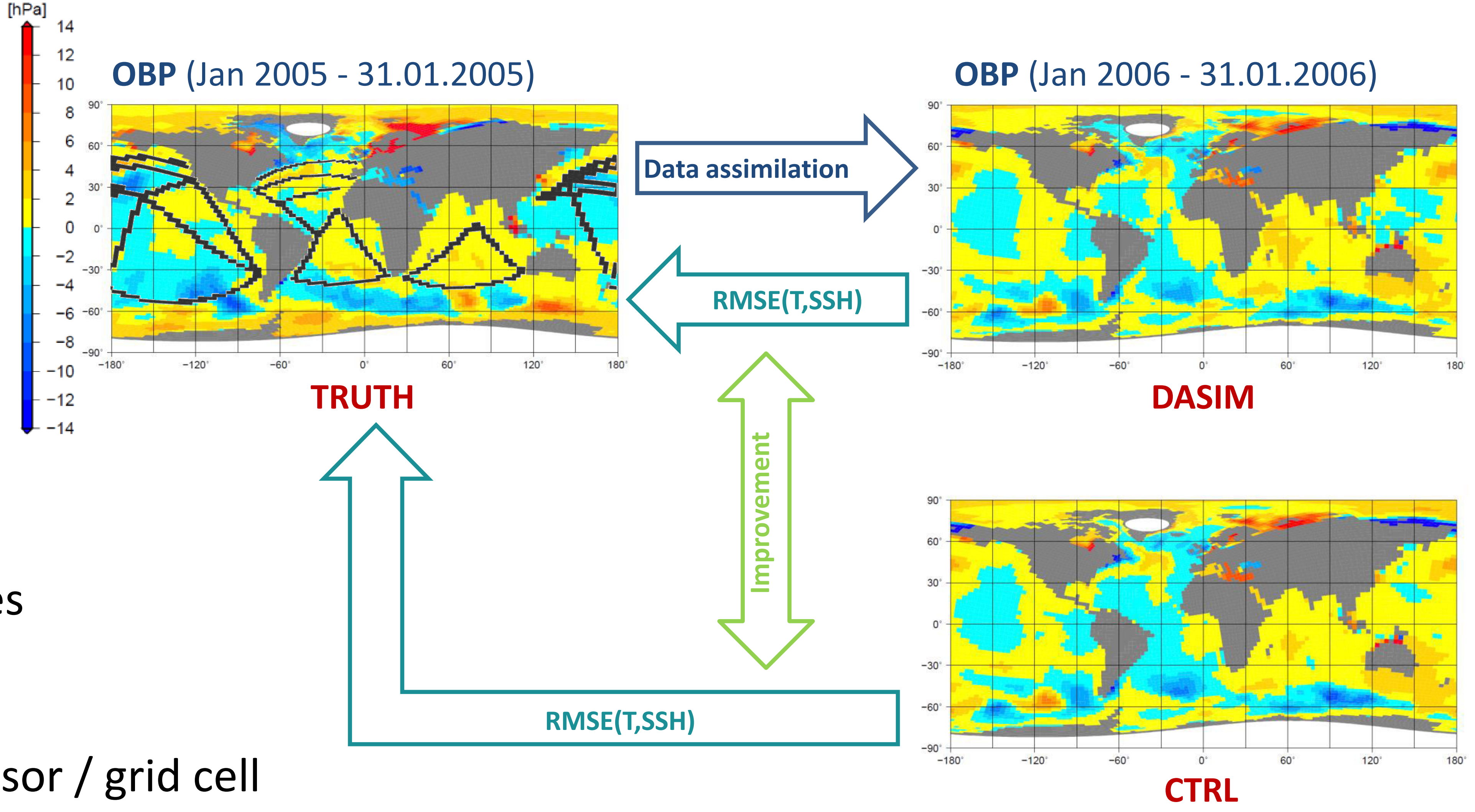


Observing System Simulation Experiments

Data Assimilation study: setup

Tobias Weber
Maik Thomas
GFZ Potsdam

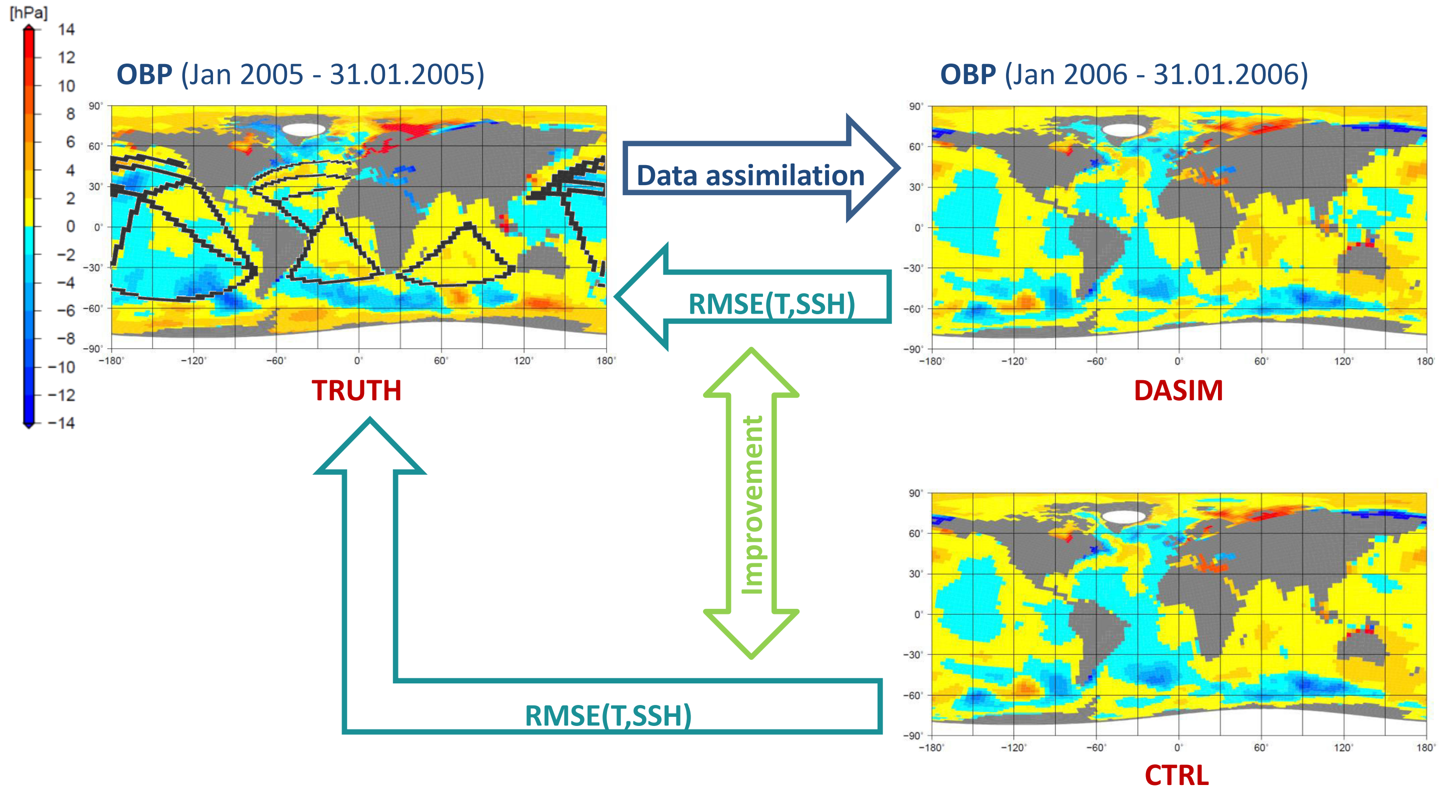
In progress!

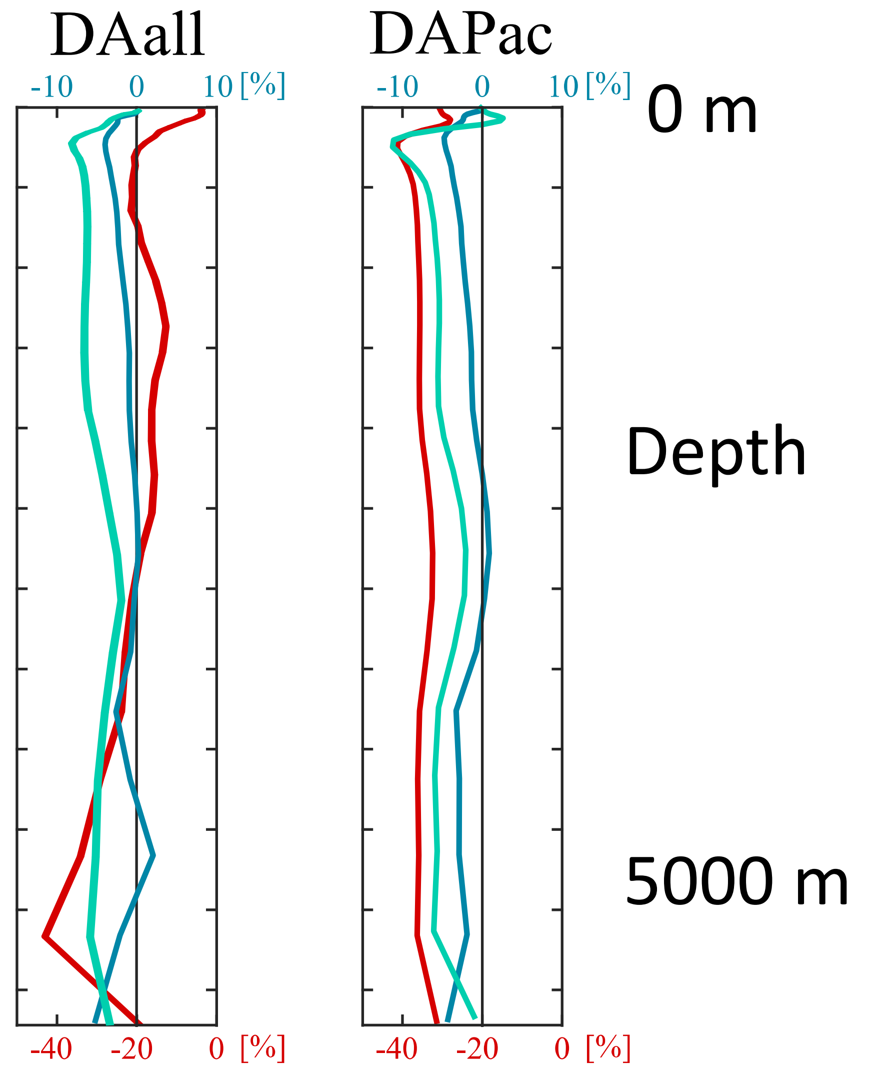


2005-2006
Time step 144 minutes
3 deg – 300/40 km
40 layers vertical
Along cables, one sensor / grid cell

Observing System Simulation Experiments

Prelimenary results





RMS improvement (NB caveats):

~40% temperature, ~10% velocity

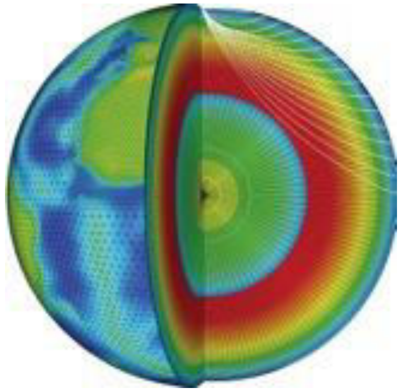
Next: fraternal twin, coupled atmos-ocean

Weber and Thomas, GFZ Potsdam

SMART Cables for seismology

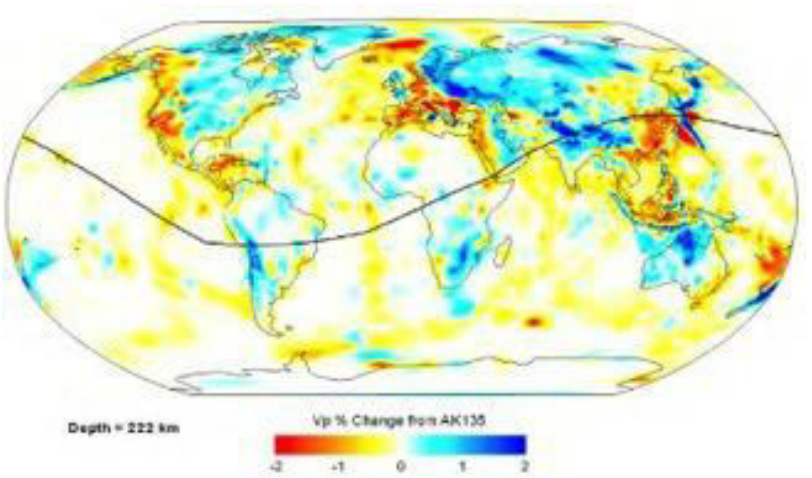
Two fundamental linked problems:

1. Estimation of location, size and site characterization of a seismic source
2. Determining properties within the Earth using seismic waves – whole earth tomography



Lead to inferences about tectonics, rheology, mineralogy, fluids, economic potential, planetary history and seismic and tsunami risk.

But, beneath the oceans, large areas of the crust and upper mantle are un-instrumented and poorly sampled

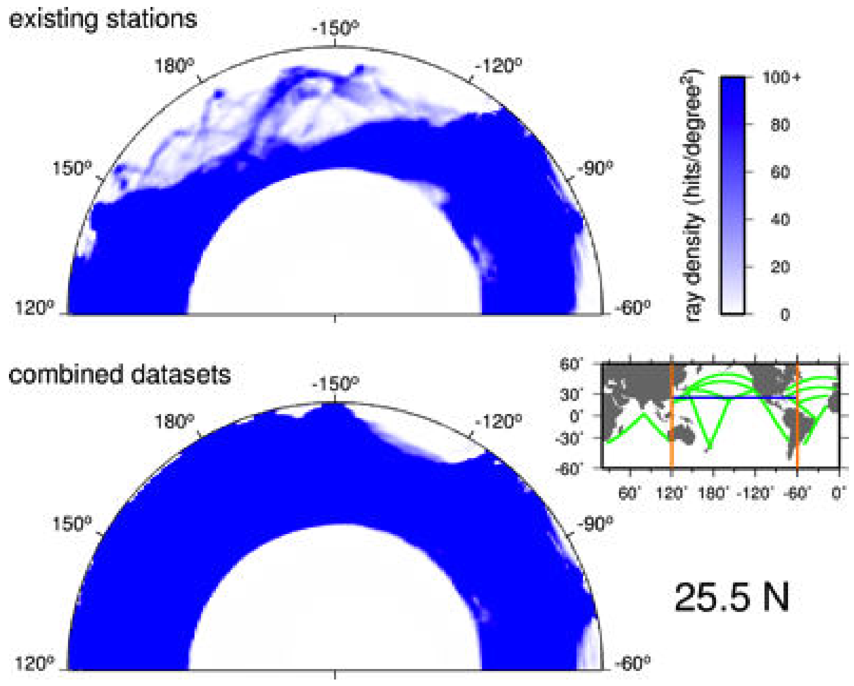


Global seismic inversions suffer from little or no data in places, resulting in no model resolution (white).

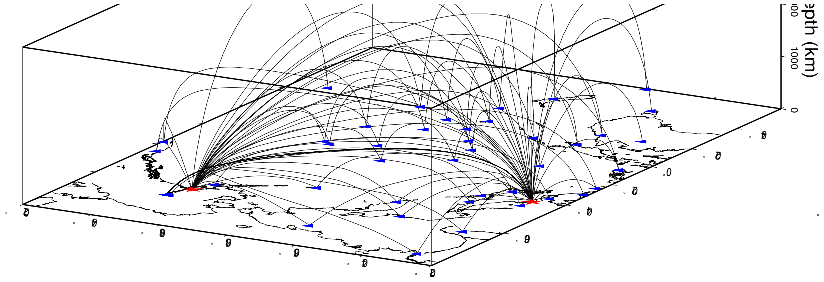
From Charlotte Rowe

SMART Cables for seismology

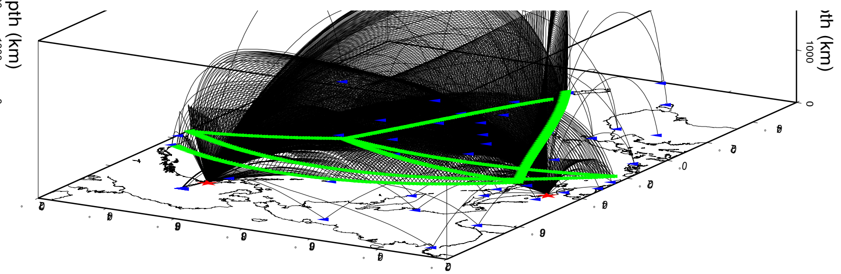
- Better sampling with SMART cables
- Forward ray modeling - significant improvement in crust and upper mantle sampling beneath the oceans with SMART cable sensors.
- **Increased – global – coverage** -> reduced location uncertainties, better magnitude calculations, may provide reduced detection thresholds.



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



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

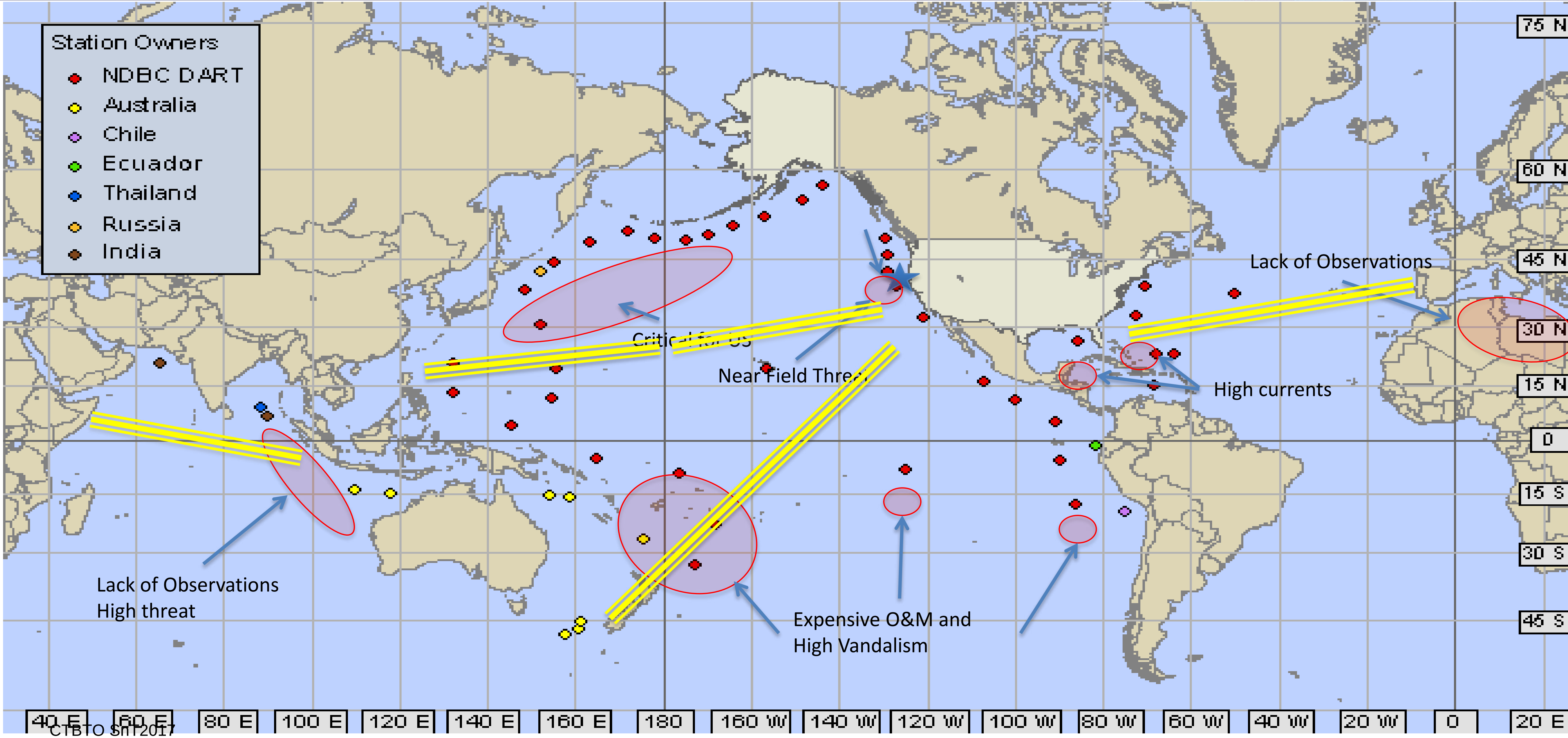


Rays to SMART Cable sensors provide improved coverage over large areas.

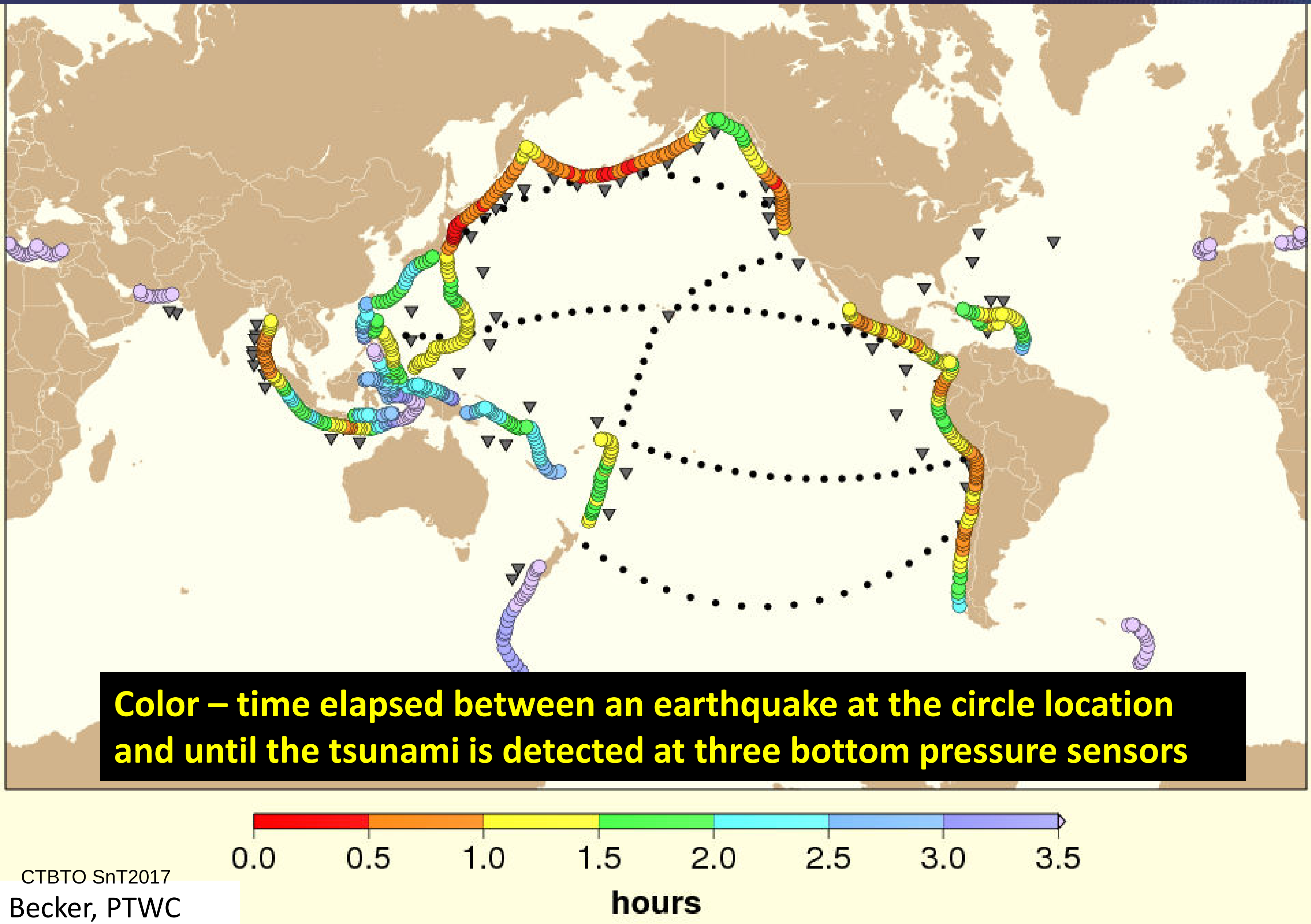
Poster T1.2-P21

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

Tsunamis - Where do we need to measure?



Tsunami Detection Time at three bottom pressure recorders (2016)

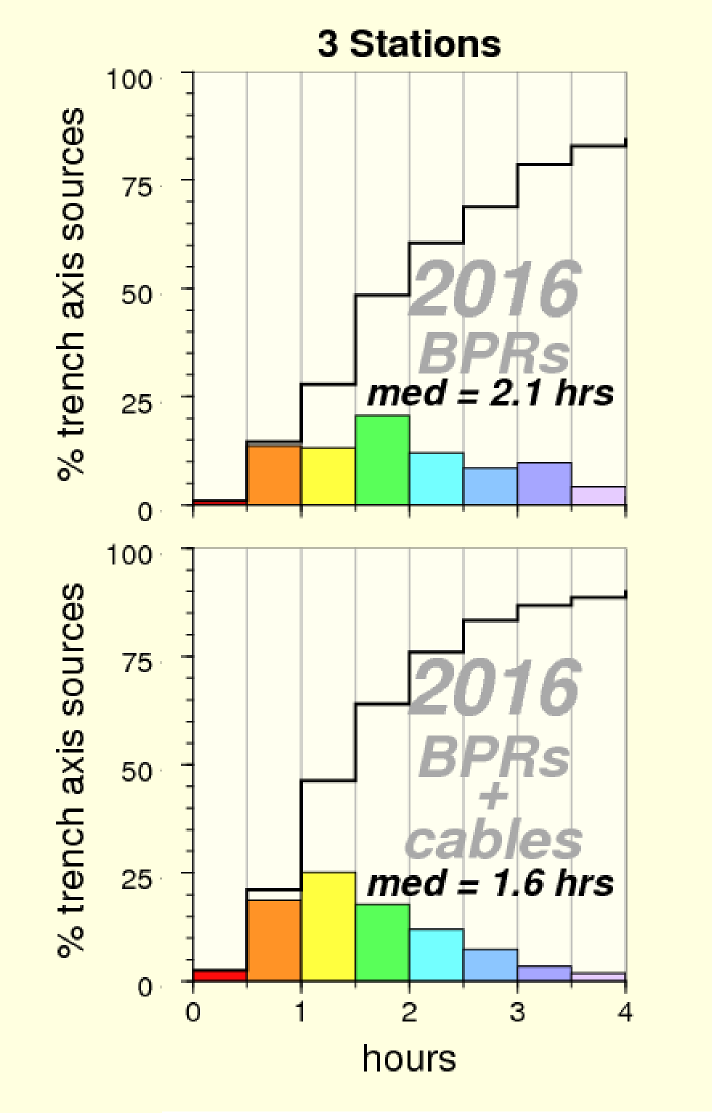


Add SMART
500 km spacing

Circles:
Potential Epicenters of Tsunami Generating Earthquakes
120 km spacing
(For this modeling)

N. Becker, PTWC

Tsunami warning – Summary



From S. Weinstein, PTWC

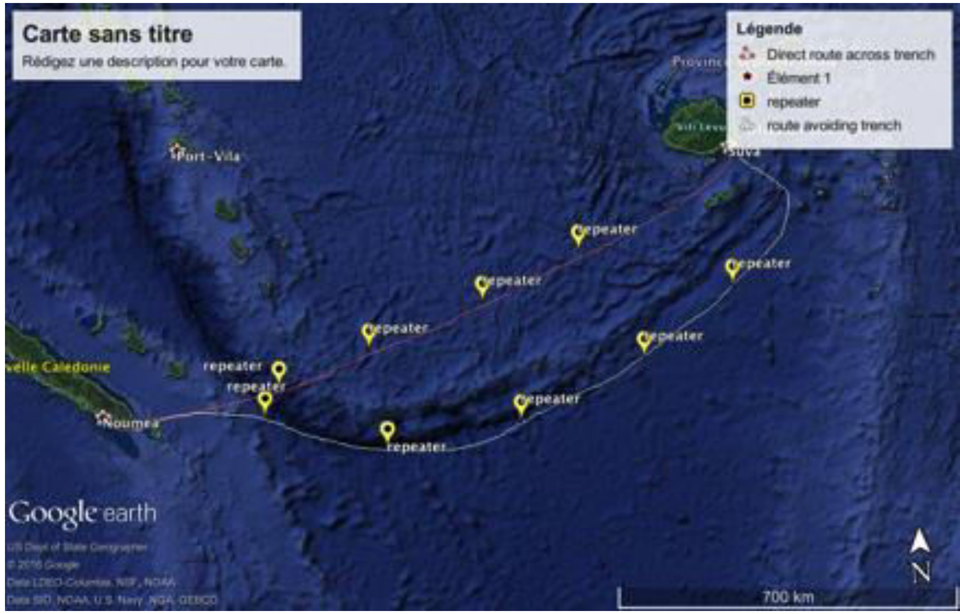
- Tremendous progress in the development and sharing of seismic and sea-level networks since the Great Sumatra Earthquake and Tsunami
- Just a few SMART Cables can speed up:
  - Determining tsunamigenic epicenters by 20%.
  - Characterization of Ocean-crossing tsunamis by ~25%, and allow for more rapid assessment of Tsunami Forecasts.
- => Imagine effect many SMART Cables with 1/10 the sensor interval could have! => more modeling

Recent Progress

- ITU issued RFI for mechanical Wet Demo, Dec 2016 – good response
- RFP for New Caledonia to Fiji cable issued by OPT
- Tsunami Warning, Education and Research Act of 2017
- Other projects with possible synergies:
  - Deep Ocean Observing Strategy
  - International Seabed Authority

OPT-New Caledonia system to Fiji

- RFP issued December 2016 with SMART option
- Nearly ideal for pilot:
  - High earthquake/tsunami threat, oceanography
  - Project wants SMART for societal benefit
  - Modest scale (~20 repeaters)
  - Between friendly countries
  - Fewer permitting and legal issues
  - Telecom system single government funded
  - Plausible can raise incremental funding required
  - DART buoys here extremely expensive to maintain
  - Time frame reasonable
  - Demonstrate complete capability - integration into repeater power+comms, interface, external sensor package



Possible option – to Hawaiki

US Tsunami Warning, Education and Research Act 2017

- 18 April 2017 became Public Law No: 115-25
- Authorized activities … "Development of practical applications … including the integration of tsunami sensors into Federal and commercial submarine telecommunication cables if practicable."
- Responsibilities … "consider appropriate and cost effective solutions to mitigate the impact of tsunami, including … integration of tsunami sensors into commercial and Federal telecommunications cables, … "

... Will positively influence other agencies:

FCC, USGS, NSF, BOEM, DoD,

Technical Challenges

- Mechanical is “easy” to solve, connectivity harder
- Bringing data back to shore with no loss of in-band capacity is key
- Out-of-band could be ‘something for nothing’
- Low impact will enhance chances of acceptance
- Need wet demo and pilots – various hybrids
- NB Pacific Fibre 2012 – project deemed doable

Summary

- Science and Society needs are clear, continual
- Science consensus (white papers, workshops, pubs starting)
- Modeling in progress – essential to quantifying cost/benefit
- Technical solutions tractable
- Legal issues
- Need interaction with sponsors, governments, UN. …
- Continue science/warning community/users buy-in
- Design, development and deployment

- all have a common issue ➜ ***Funding*** the first pilot(s)

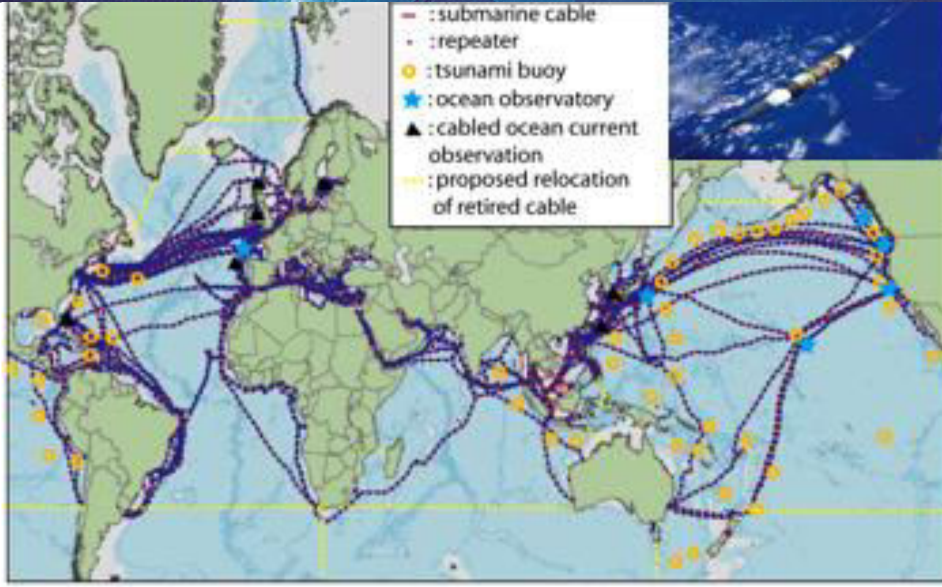
SMART Cables and CTBT SnT

- Toward a much denser global array coverage – ocean and climate, earthquakes and tsunamis
- Planned and future sensors can contribute to CTBT mission

Complementary with

- Third UN World Conference on Disaster Risk Reduction: Sendai Framework 2015 – 2030, March 2015
- UN 2030 Agenda for Sustainable Development – January 2016
  - Goal 13. Take urgent action to combat climate change and its impacts
  - Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development
- Paris Climate Agreement, November 2016

The basic idea



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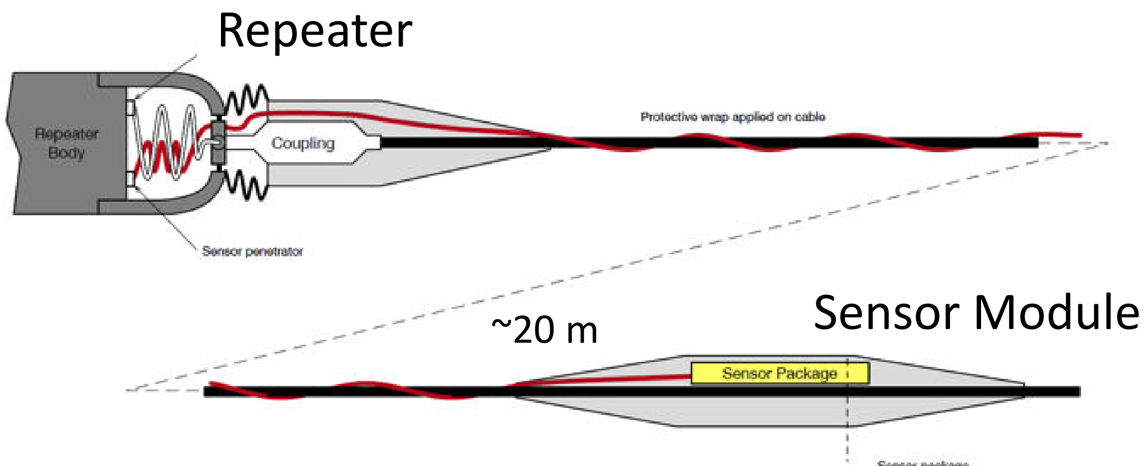

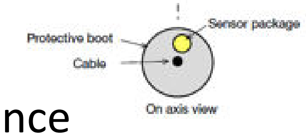

Install routinely on new cables

Deploy by cable ship, no maintenance

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