Improving a 3-D Global Propagation Model via SMART Cables and Other Seafloor Data

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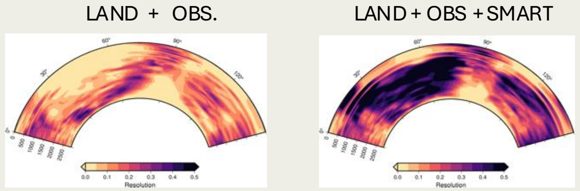
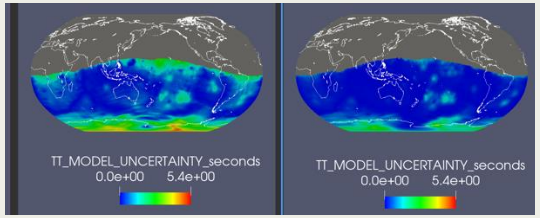
INTRODUCTION AND MAIN RESULTS

Global seismic observations are largely confined to land-based sensors observing arrivals from heterogeneously distributed seismic sources. This results in a paucity of body wave raypaths beneath the oceans, limiting fidelity of travel-time models. We have reviewed ~40 OBS deployments to retrieve waveforms and picks from large teleseisms of interest. OBS data provides modest improvement to model resolution. The inclusion of arrivals from the Science Monitoring And Reliable Telecommunications (SMART) sensors anticipated over the next decade offers dramatic improvement to global model resolution and travel-time uncertainties.



MODEL RESOLUTION



TRAVEL TIME UNCERTAINTY AT STATION SBA

This Ground-based Nuclear Detonation Detection (GNDD) research was funded by the National Nuclear Security Administration, Defense Nuclear Nonproliferation Research and Development (NNSA DNN R&D). This is Los Alamos National Laboratory Publication Number LA-UR-25-27672. The views expressed here do not necessarily reflect the opinion of the United States Government, the United States Department of Energy, or Los Alamos National Laboratory.

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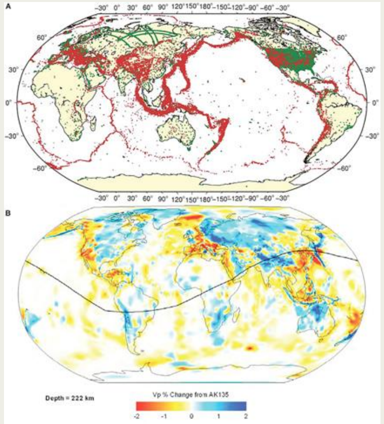
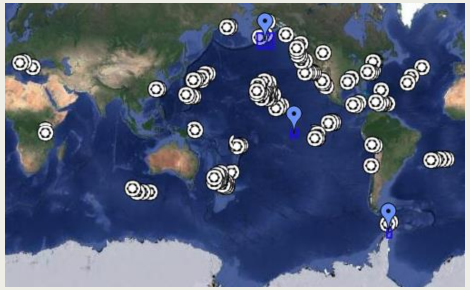
Introduction: Poor Global Seismic Sampling



(a) Global seismic observations are largely confined to land-based sensors (green) observing arrivals from heterogeneously distributed seismic sources (red). This results in a paucity of body wave raypaths, particularly beneath the oceans, limiting fidelity of our travel-time models (b).

Observations from OBS Deployments



Expansion of seismic sensors into the ocean has increased for many years, but deployments generally only remain in place for a year. They are largely for observing local events from tectonic features under study such as transforms and spreading centers. Teleseismic arrivals are not reported to global archives and the 2-3 year latency for data availability contributes to their neglect. We have reviewed ~40 OBS deployments to retrieve waveforms and picks associated with large teleseismic events of interest.

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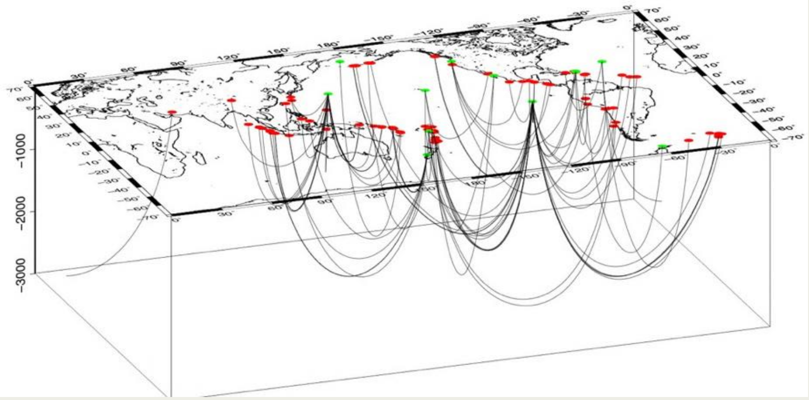
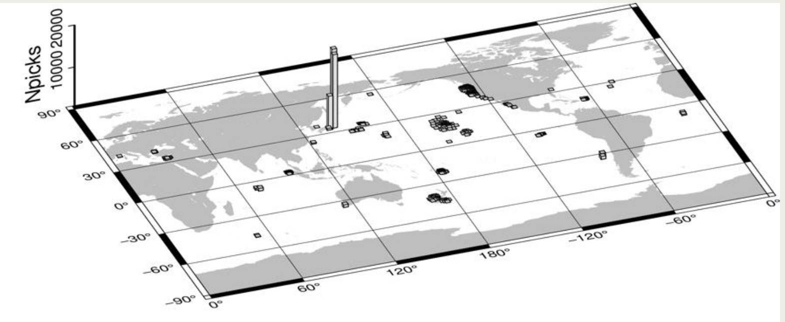
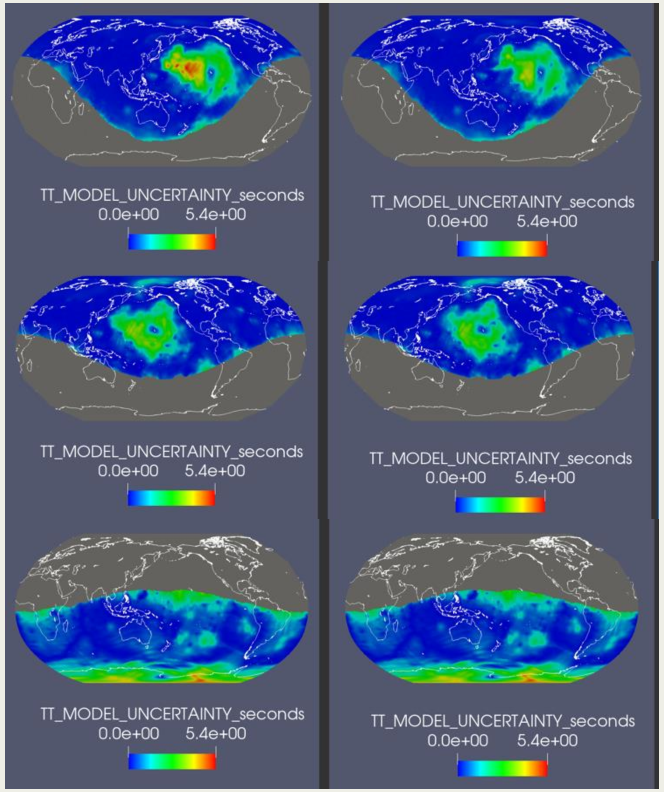
Results from OBS Deployments



Above: unique rays that our OBS analysis has yielded. This is roughly 4,000 arrivals out of the roughly 60,000 arrivals in the database attributed to OBS, determined based upon station elevation below sea level. The histogram below shows the full database OBS phase counts. The spike just east of Japan is attributed to the near-shore cabled arrays (S-NET, DONET), which comprise ~40,000 of the total count. These arrivals are generally redundant, reflect largely local and regional phases, and hence offer moderate, limited impact on the global model.



Model TT Uncertainty



ABJ

COLA

SBA

LAND LAND+OBS

Changes to model resolution maps directly into changes in travel-time uncertainties for network stations. Here we see in the northern Pacific a notable reduction in travel-time uncertainty for selected station ABJ (top) for events in the north Pacific, while COLA (middle) and SBA (bottom) do not benefit appreciably from the limited OBS picks we have been able to add to the data set.

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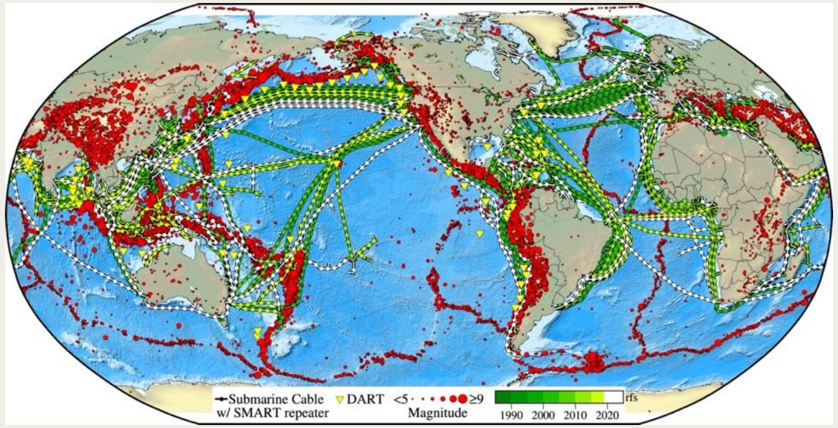
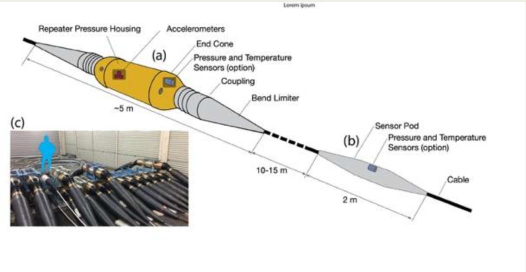
Transoceanic Telecommunications Cables



Above: Global seismicity (red) and current transoceanic cable deployments (shades of green). Cables currently cover for over 1.5 million km across the seafloors. The International Joint Task Force (JTF) for Science Monitoring And Reliable Telecommunications (SMART) Cables, a United-Nations backed initative, seeks to provide new cables and cables that replace ageing current routes, with oceanographic and geophysical sensing capability.

Right: proposed sensor additions to standard cable optical amplifiers, which are positioned every 75 km along standard cable deployments..



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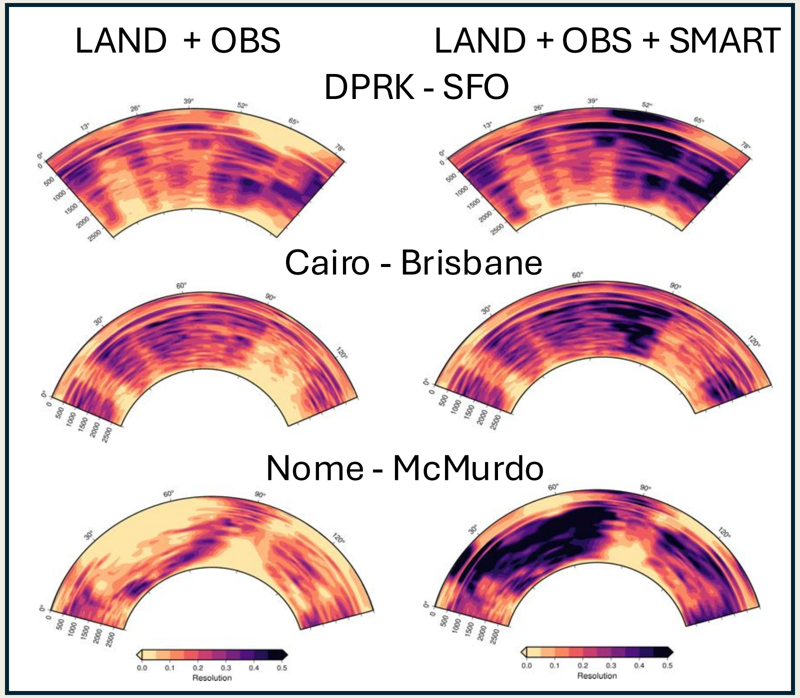
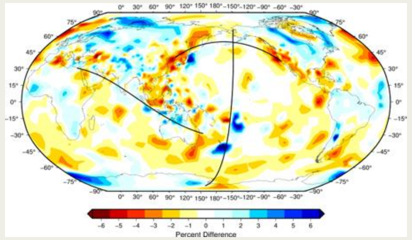
Resolution Improvements via SMART Sensors



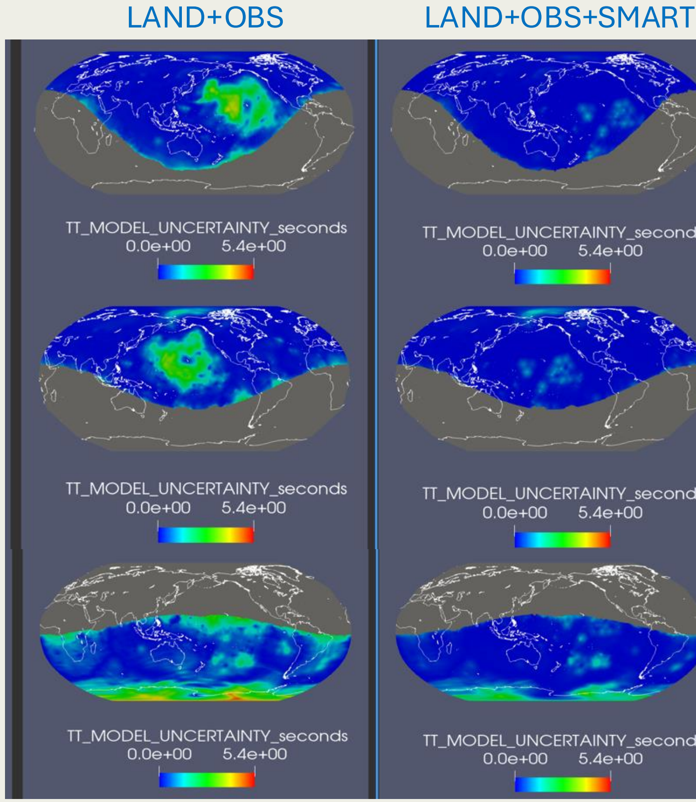
Above: model resolution gains based on addition of SMART sensors, shown for three random great circle paths through the Sandia Los Alamos 3D (SALSA3D) model (right).



Conclusion

Adding seafloor sensors on transoceanic cable routes will significantly improve our global models and hence detection and location abilities. Please see following slide for SMART deployment information.

TT Uncertainty Reduction via SMART



Above: Travel-time uncertainty reduction computed for land+OBS situation (left) vs. land+OBS+SMART, based on model resolution obtained for SALSA3D. Shown are TT uncertainty values for three stationis: ABJ, COLA and SBA. Note the addition of SMART sensors significantly improves TT uncertainty for all three test stations, which will directly lead to improved event location confidence.

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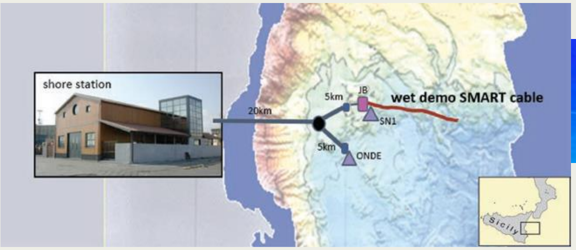
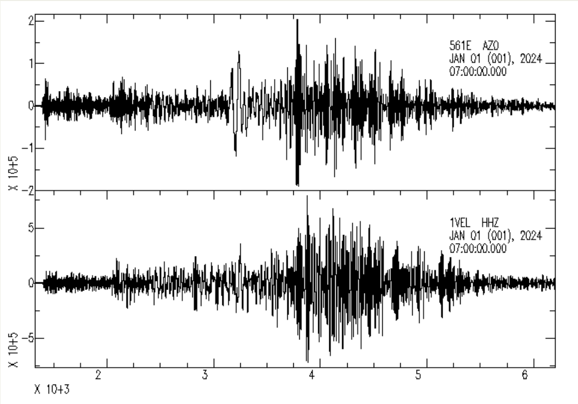
SMART Wet Demo – online since 12/23



Above: An underwater electro-optical-mechanical cable runs on the seafloor from Catania harbor and splits into two branches hosting non-SMART-system geophysical, environmental, oceanographic and physics/neutrino seafloor platforms, managed by Istituto Nazionale di Geofisica e Vulcanologia and Istituto Nazionale di Fisica Nucleare, respectively. A test deployment of a SMART system with three sensors has been added to the northern branch, and began operating in December 2023.



Left: standard 3C Guralp broadband OBS (top) and SMART 3C seismic sensor (bottom) adjacent to one another, recorded the 1 January 2024 Japan earthquake with good fidelity.

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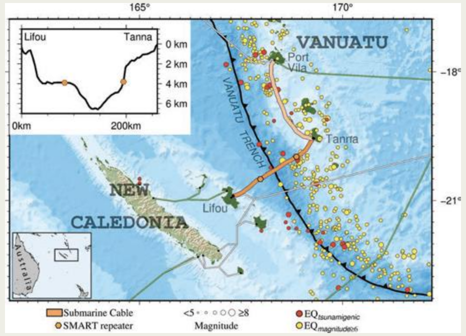
Two SMART Deployments for 2027

Portugal
Right: This SMART project will link Continental Portugal to the Azores and Madeira (CAM) in a 3,700-km ring in an explicitly SMART system.



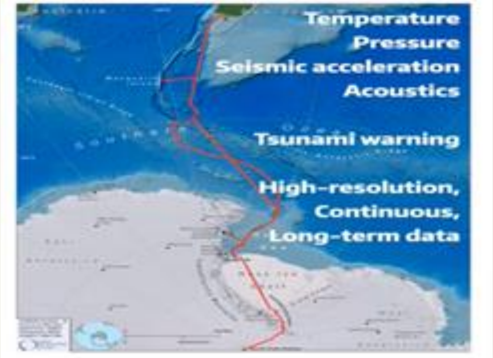
The Tam-Tam cable crossing the trench/subduction zone between Vanuatu and New Caledonia (left) to improve their telecommunications will provide valuable early warning tsunami capabilities and earthquake early warning.

Antarctica—Planning Underway The U.S. National Science Foundation is interested in a submarine fiber optic telecom cable from New Zealand to McMurdo Station (right). This would serve as a scientific platform using SMART sensors to monitor ocean conditions and seismic activity. Observations of temperature and pressure will provide important metrics in the Southern Ocean, including Antarctic Bottom Water temperature and volume, Antarctic Circumpolar Current transport, and regional sea-level rise. These simple measurements are invaluable for understanding the progression of polar region changes and predicting both marine and atmospheric conditions into the future. The presence of the seismic sensors will provide unprecedented observational capacity.

Polar SMART – Arctic and Antarctic

Polar Connect, Far North Fiber, Tussas, PISCES, IRIS, IOMEA: Arctic Plans

These mixed deployments are once again meant primarily to enhance international telecommunications but plans are being considered for SMART capability. The Polar Connect and Far North Fibers, which will run from Europe to Japan via the Arctic Ocean through the Bering Strait, are on hold while additional icebreaker capacity is developed.



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