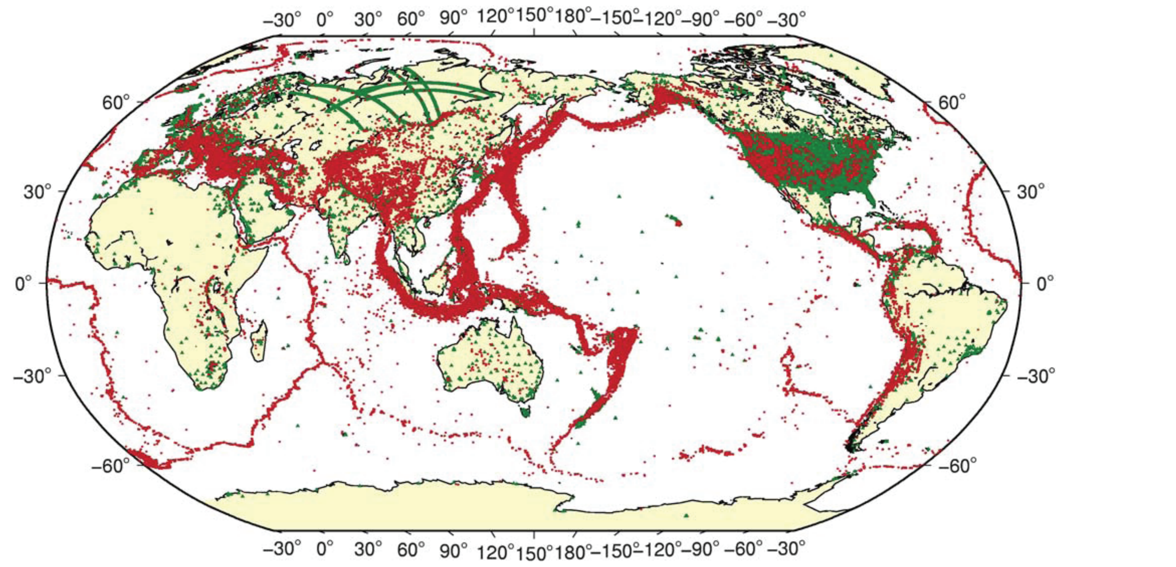
Increased Global Seismic Sampling via Proposed Transoceanic SMART Cable Sensors – Comparing Ray Coverage through the SALSA3D Global Model

Rowe C. A. Begnaud, M.L., Syracuse, E.M. -Los Alamos National Laboratory
Howe B. M. University of Hawaii

ABSTRACT

With the exception of isolated and largely near-shore deployments of ocean-bottom seismometers (OBSs), most seismic instrumentation is located on land, although two-thirds of Earth's surface is covered with oceans. Large earthquakes are generally confined to subduction zones or other plate boundaries, leading to an uneven distribution of seismic sources. This heterogeneity, coupled with the land-based limitations for most for the Earth's interior, leads to significant unsampled parts of the Earth. Our work is motivated by the planning of a Joint Task Force to develop concepts and applications for Science Monitoring and Reliable Telecommunication (SMART) cables. Over a million kilometers of submarine telecommunication cables currently exist, which are un-available to the scientific community for acquisition of geophysical data. If these cables are gradually replaced by SMART cables with oceanographic and seismic sensors at roughly 75 km intervals, one significant benefit to our science will be the near-ubiquitous extent of seismic receivers across the oceans, affording an unprecedented opportunity for both monitoring and modeling.In previous work we presented ray tracing through a 1D reference model to predict improve-ments to ray coverage afforded by sensors on SMART cables, compared to existing land-based seismic network coverage. Here we extend that modeling, tracing P and S rays through the SALSA3D global to-mographic model. We compare results of this exercise to those for the iasp91 model with, and without, the SMART cable sensors.



Earthquakes are unevenly distributed around the globe, as are seismic stations. Above we show the distribution of earthquakes (red) and seismic stations (green) used in the development of the gloal 3D seismic model, "SALSA3D" (Ballard et al., 2016). The oceans in particular lack sensors. Moreover, oceans are also largely aseismic, except at plate margins, leaving large gaps in our seismic sampling of the Earth.

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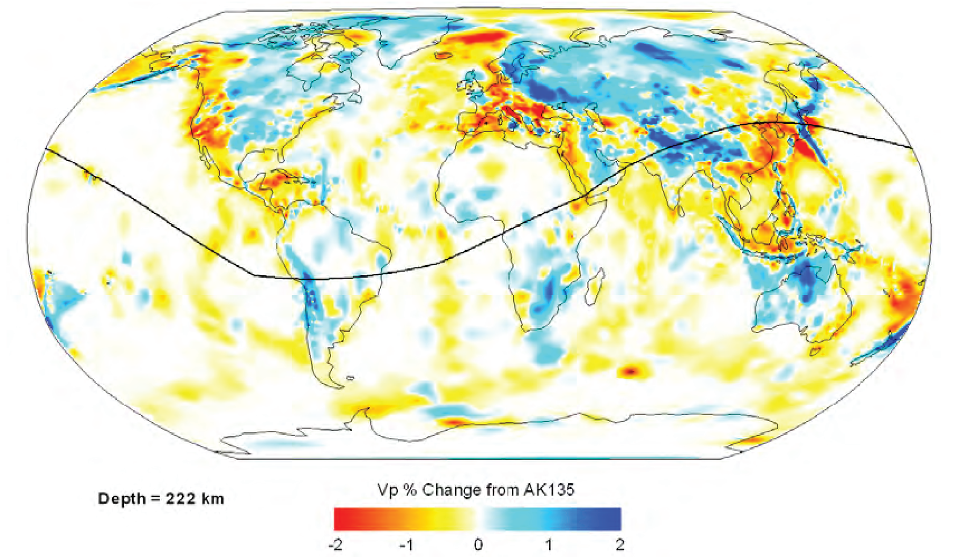
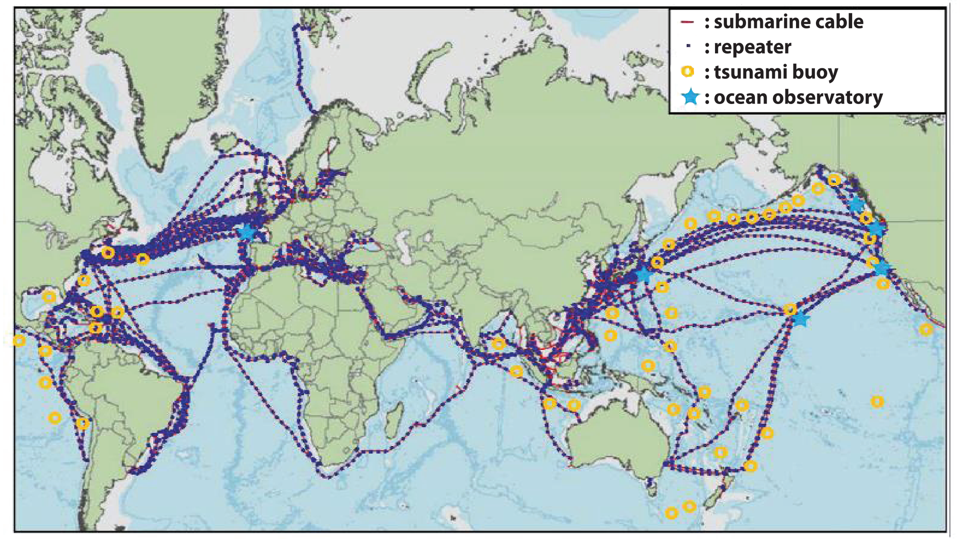
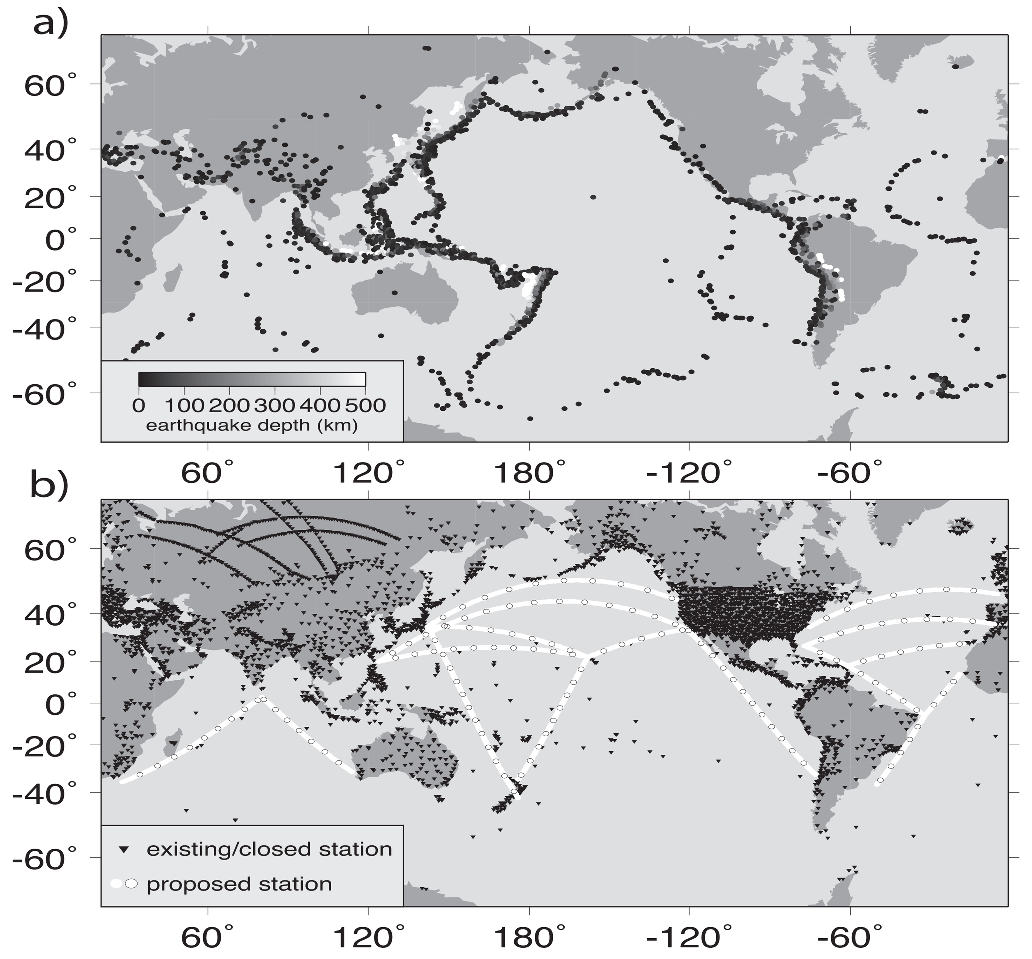


The consequence of heterogeneous sampling of the Earth is that ray coverage is not consistent when we try to invert seismic data for a global travel-time model. Above we see a depth slice within the SALSA3D model, showing velocity pertur-bations from its starting model of ak135 after tomographic inversion. Percent change from ak135 is indicated with colors; the white regions are not areas for which ak135 was fit perfectly, but rather, areas with no data.

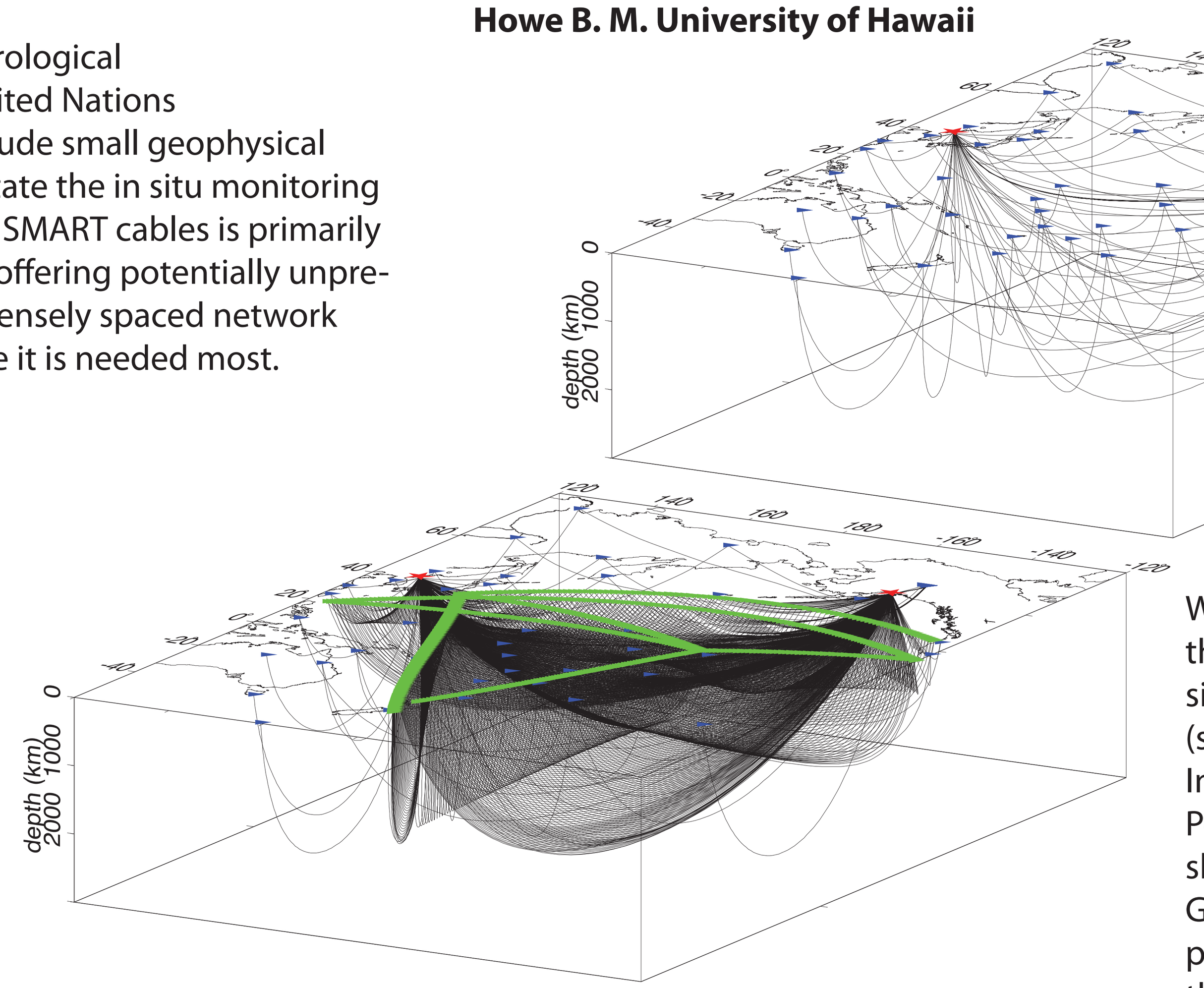
Three agencies -- the International Telecommunication Union, the World Meteorological Organization, and the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organiziation -- have jointly proposed to include small geophysical observatories in the next generation of trans-oceanic submarine cables, to facilitate the in situ monitoring of global oceans (Tilmann et al., 2017). Although the purpose of these proposed SMART cables is primarily for oceanographic monitoring, the instrumentation will include seismic sensors offering potentially unpre-cedented access to real-time seismic data from an extensive,synchronous, and densely spaced network traversing the ocean floors, greatly increasing the Earth's seismic coverage where it is needed most.



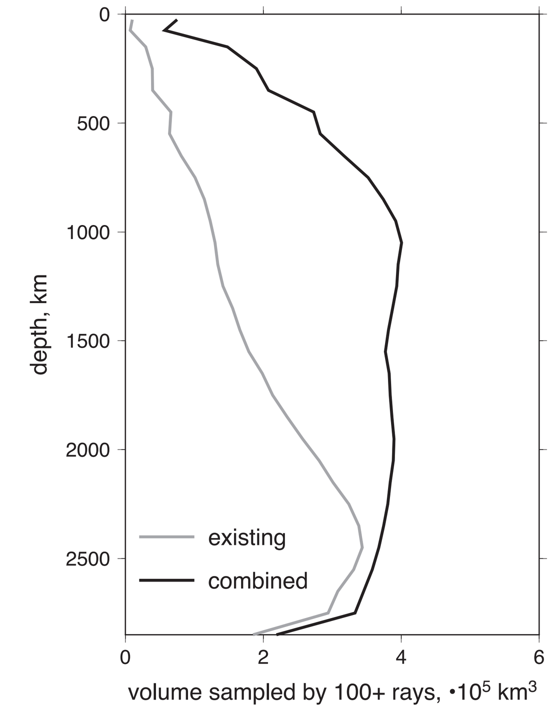
Map of submarine cables. Blue dots indicate repeaters along the cables, which would govern the locations of instrument packages as cables are replaced in the future with SMART cables.



For this exercise, we have selected 1681 M > 6 earthquakes (above, top panel) and 4421 existing or former seismic stations unique to 1x1 degree bins (black circles, lower panel). We choose a threshold of M > 6 so that in our forward modeling of P-waves we can assume that most stations will see arrivals for our selected earthquakes. The one-degree bin size was chosen to reduce raypath redundancy in this exercise. We use a ray tracer based on the equations of Um and Thurber (1987). In earlier work (Ranasinghe et al., 2017) we used the ak135 reference global model to obtain global ray coverage for direct P for event-station offsets within 90 degrees. Here we present results using the 3D global seismic model, SALSA3D (Ballard et al., 2016) for both P and S waves to compare the global ray coverage without, and with, sensors spaced at 75 km along notional SMART cables, which are shown as white lines in the lower panel. Every tenth SMART cable sensor is indicated as an open gray circle along the cable path.



We illustrate, above and left, the improvement in ray den-sity for two seismic sources (shown by red stars) in Cook Inlet, Alaska, and on the Korean Peninsula. The upper image shows ray coverage for existing GSN stations and the lower panel shows ray coverage with the addition of SMART cables (sensors shown as green circles)



Ray density plots (right) illustrate location and depth variations in sampling before, and after, the addition of SMART cable sensors. We sum-marize in the figure at left, the improved sample volume for the North Pacific, where several cables reside. Seismic sampling without (gray line) and with (black line) SMART cable sensors for our test data set. We show Earth volume sampled by 100 P-wave rays for the test data set, as a function of depth.

ACKNOWLEDGMENTS

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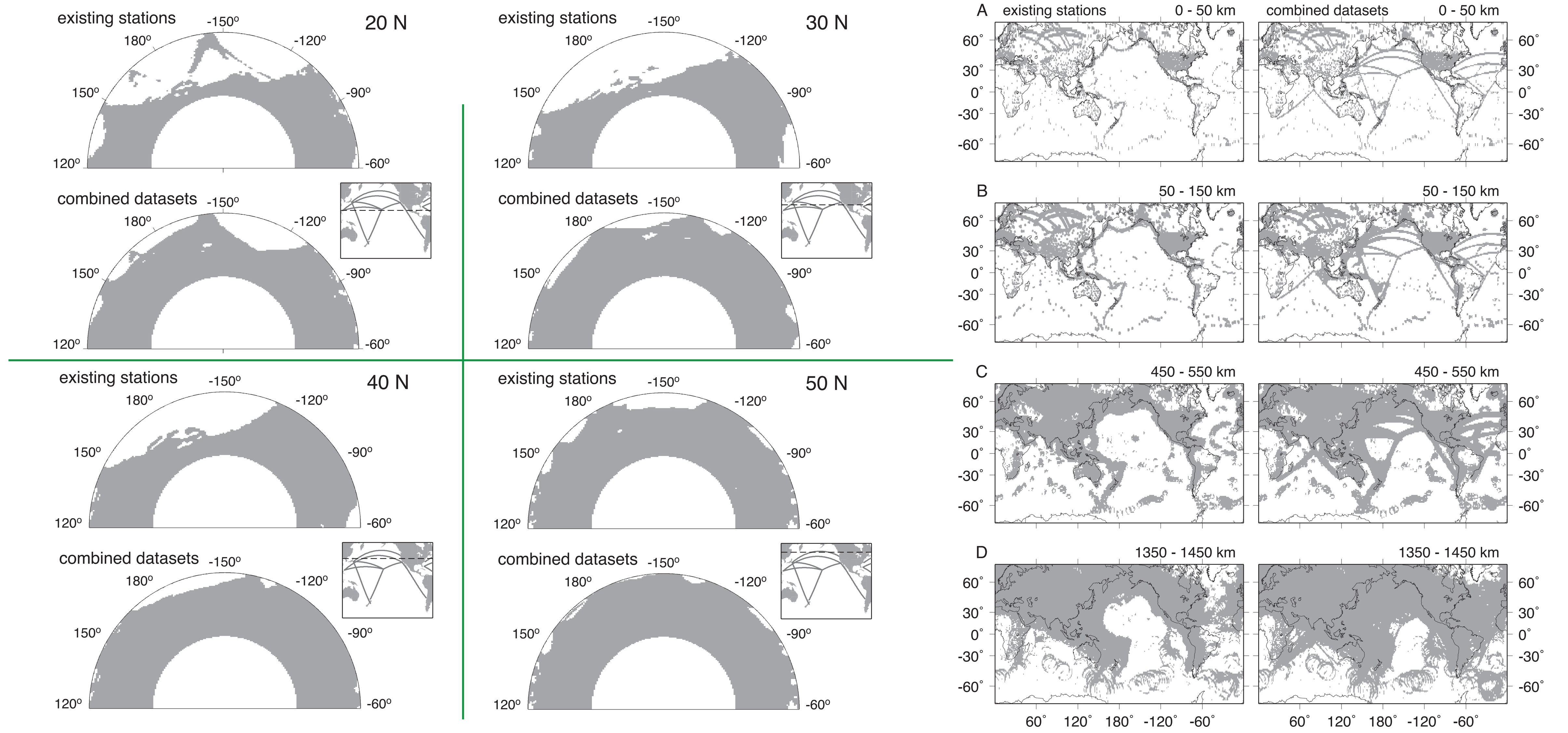

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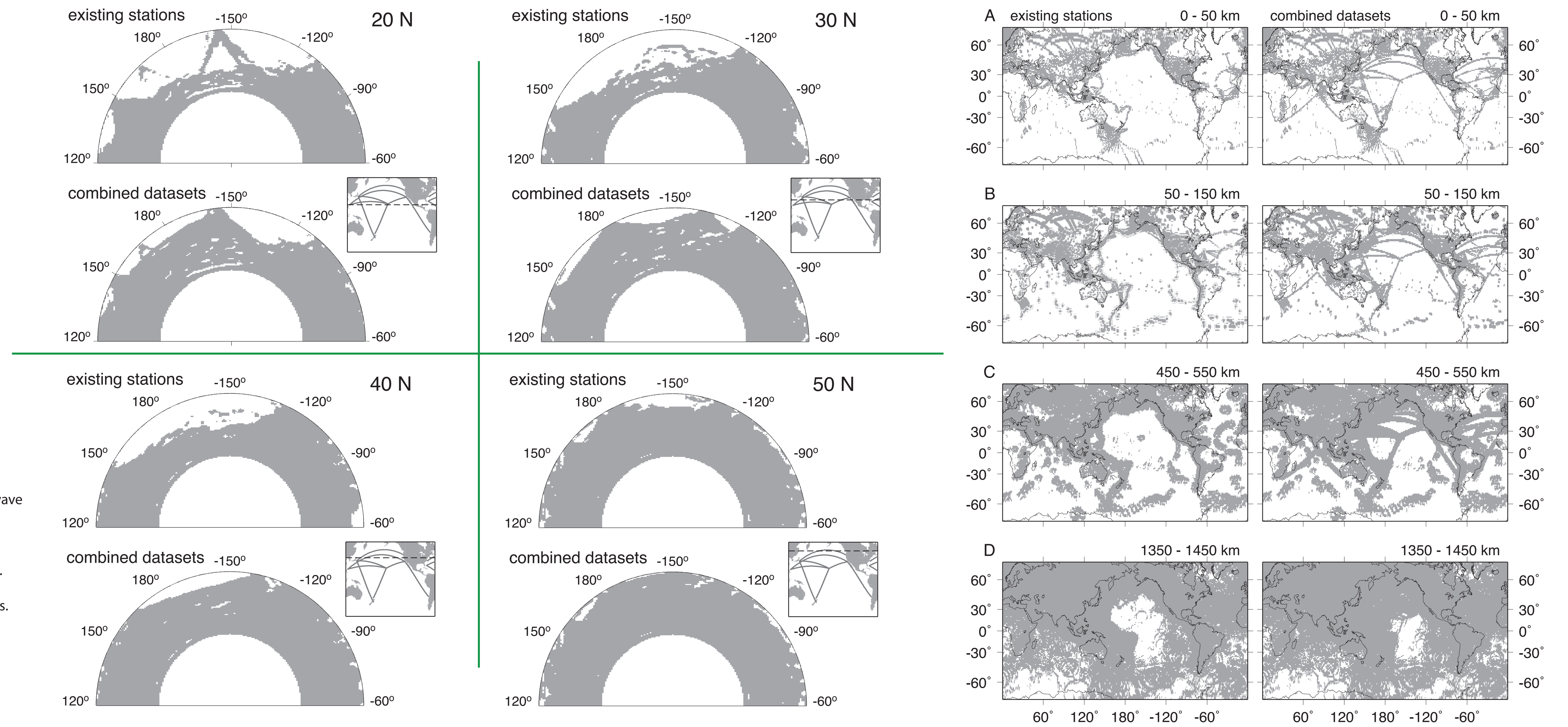

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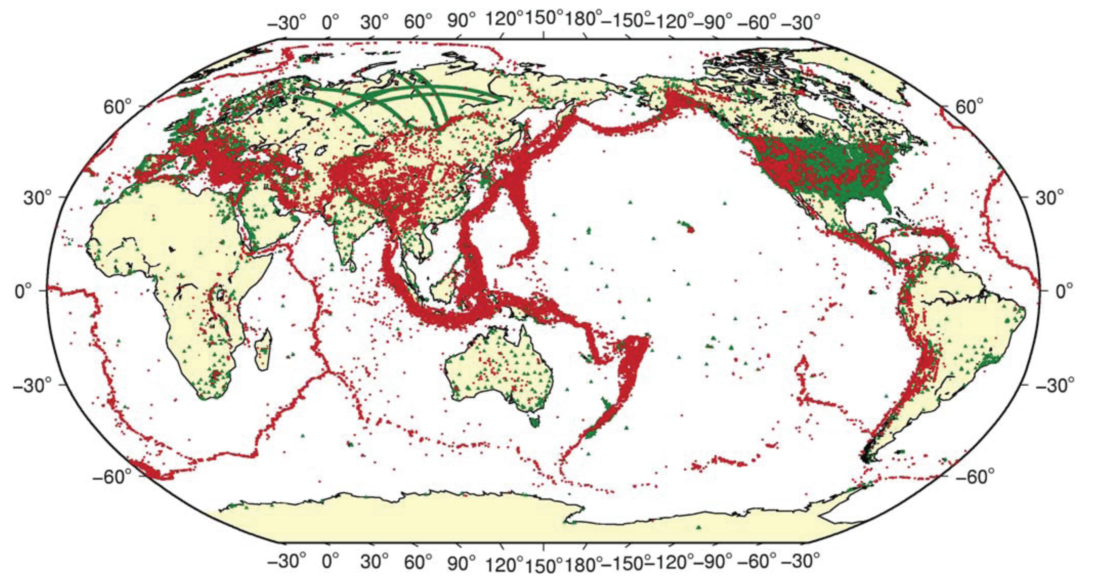

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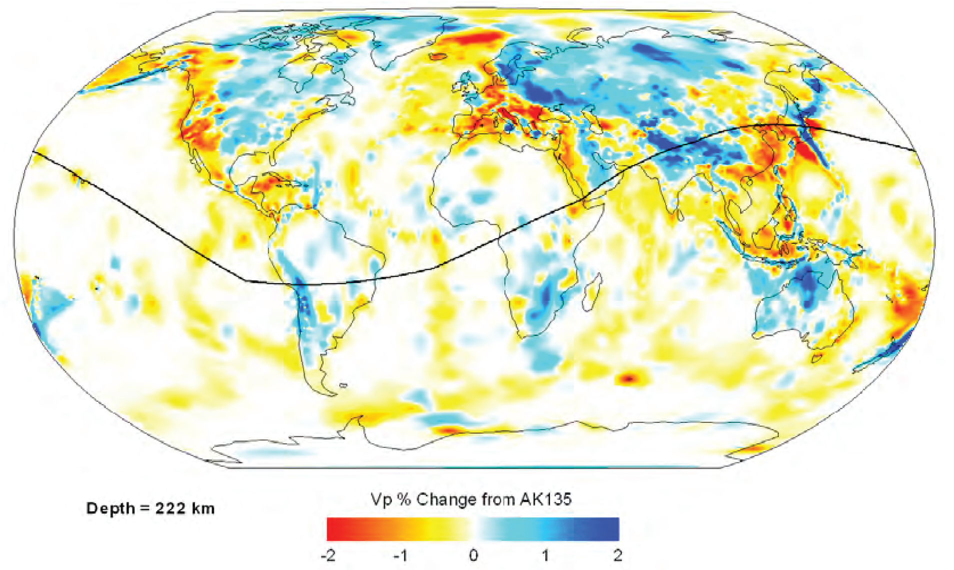

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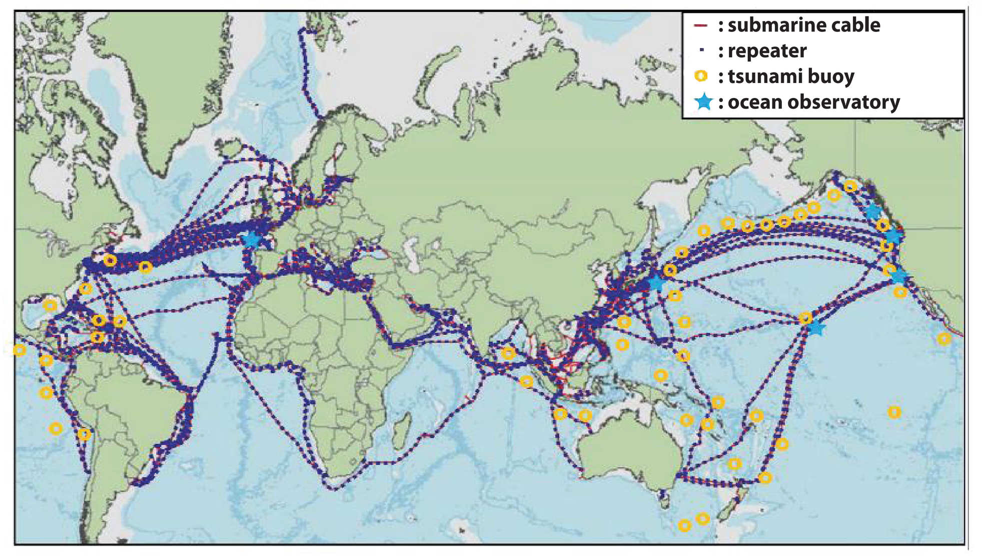

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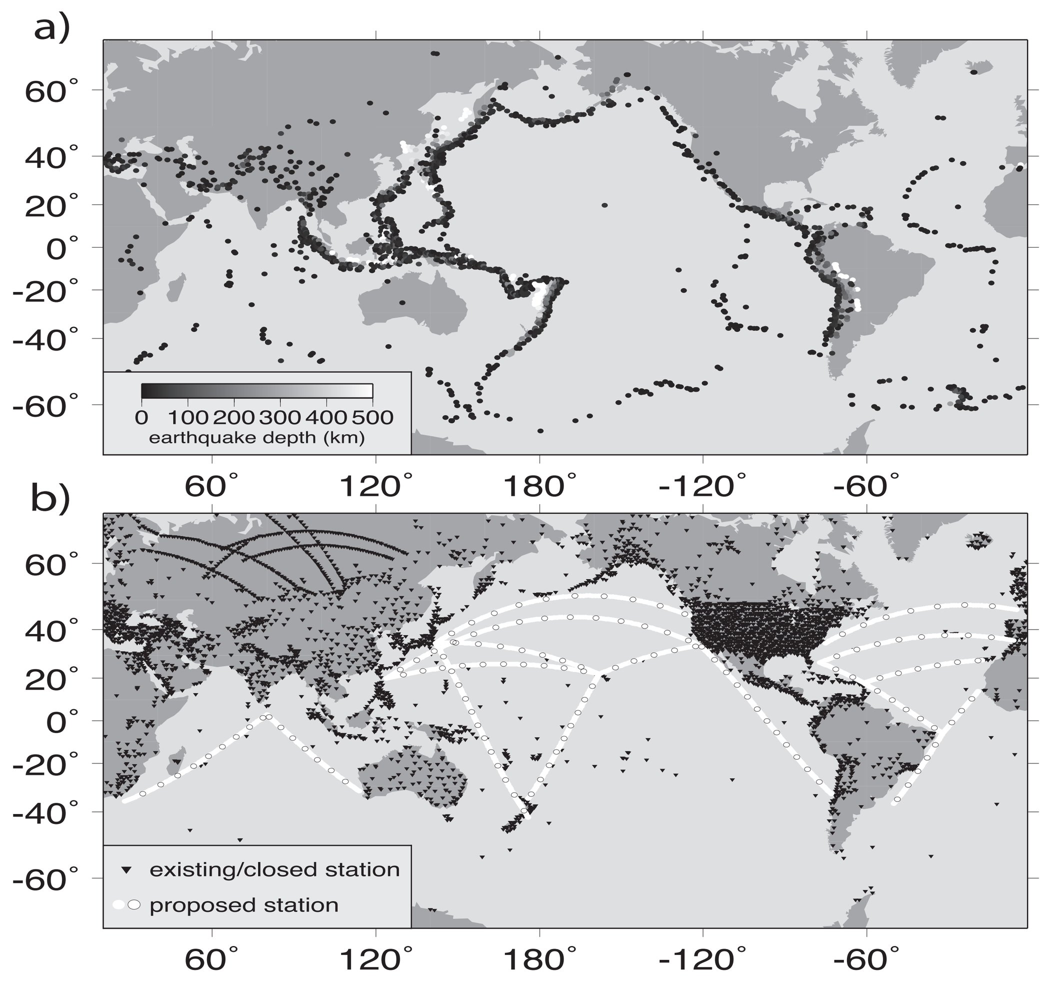

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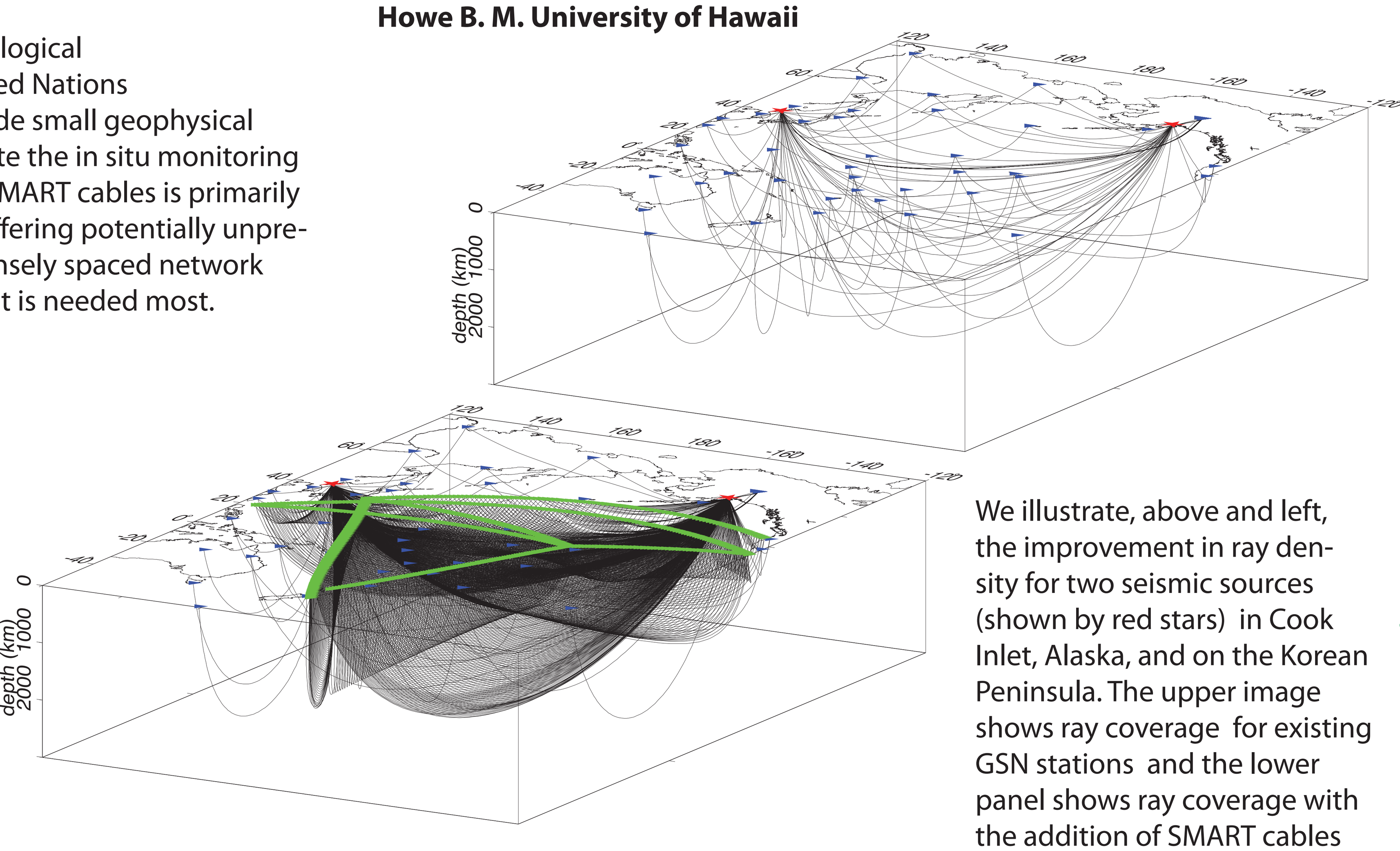

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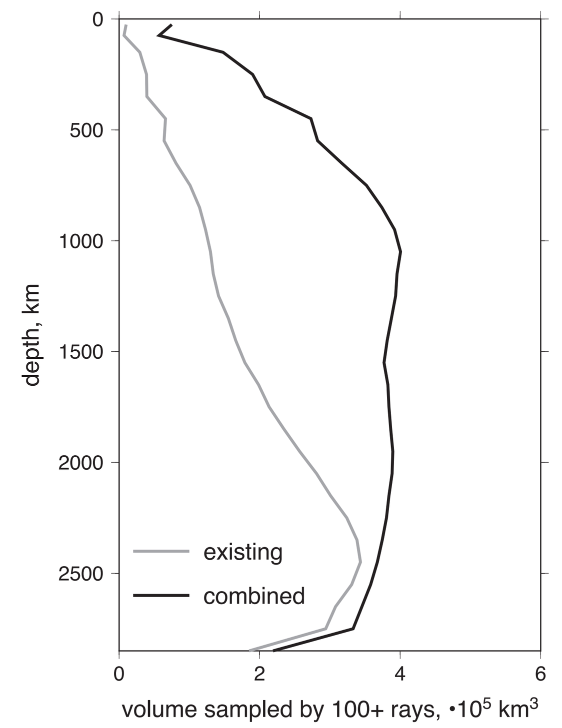

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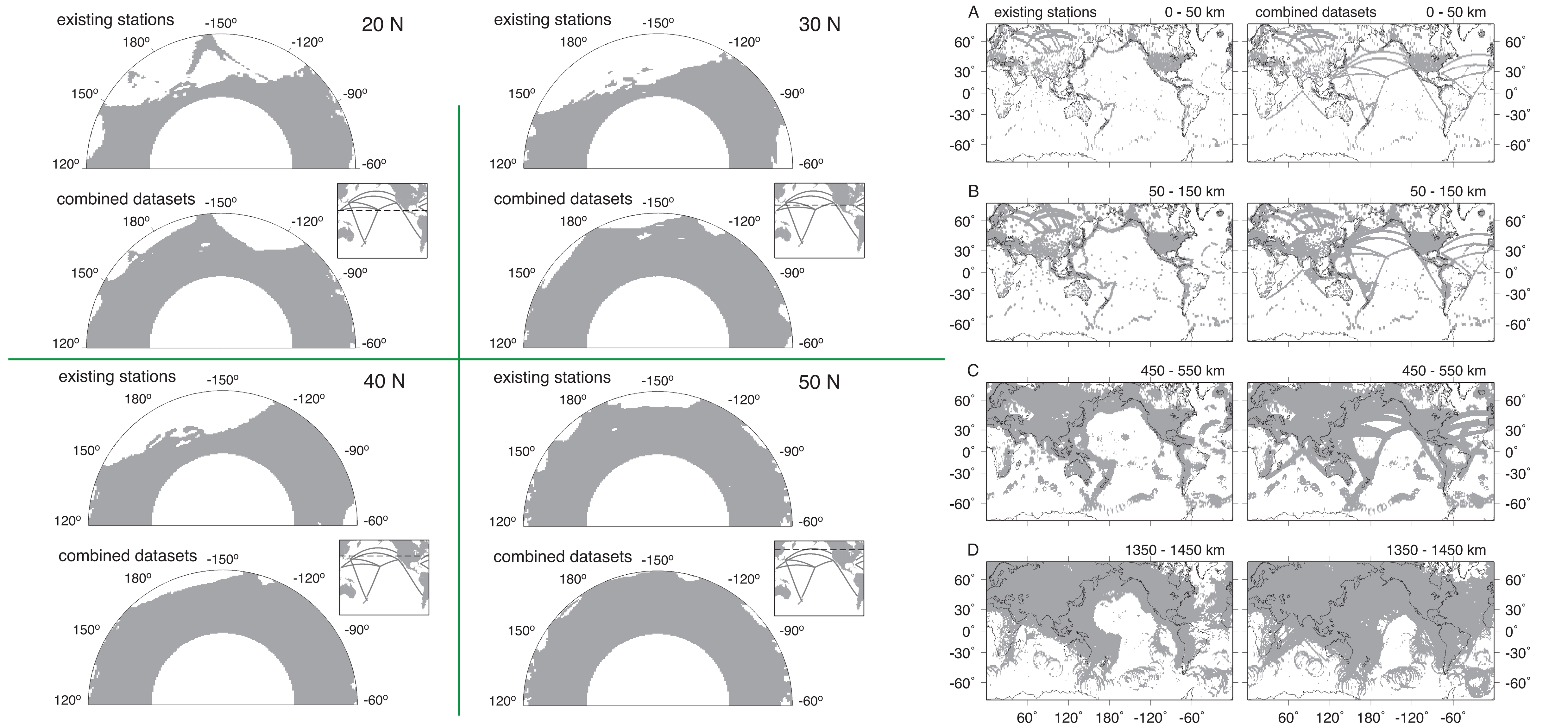

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