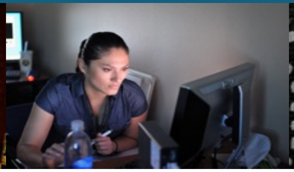
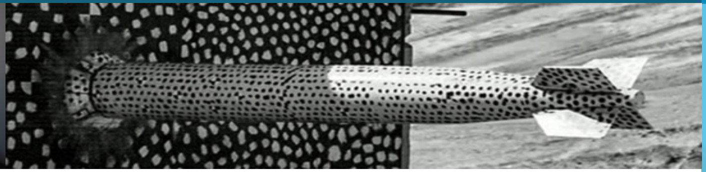
SAND2021-15338C

Exploring Model Resolution for the SALSA3D Global P-Wave Velocity Model – Current Status and Predicted Improvement via SMART Subsea Cable Sensors





Charlotte Rowe, Michael Begnaud, W. Scott Phillips

Los Alamos National Laboratory

Andrea Conley, Patrick Hammond, Sanford Ballard, James Hipp

Sandia National Laboratory

Bruce Howe

University of Hawaii

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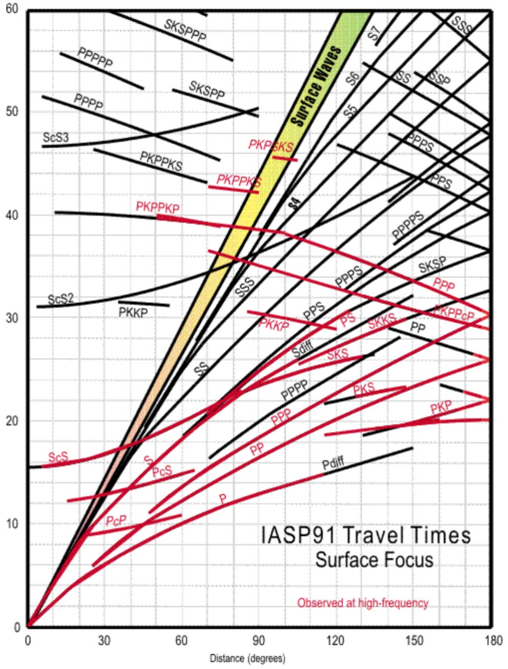
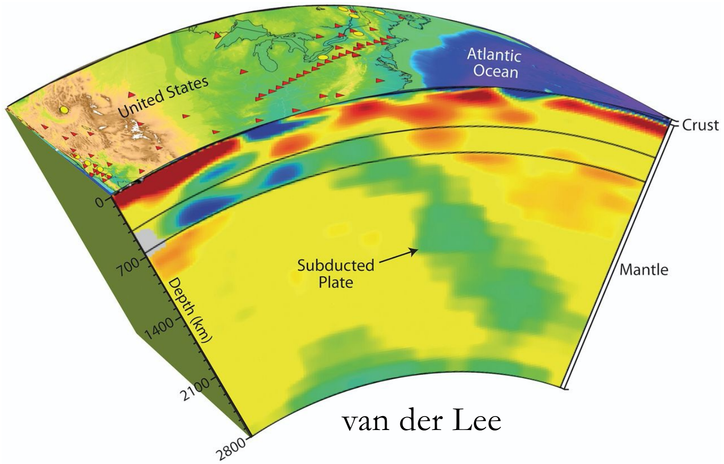
Global tomographic seismic wave speed models can

- Help to illuminate geodynamic / tectonic structures
- Provide improved travel time predictions
- Lead to improved earthquake location
- Reduce location and travel time uncertainties
- Provide insights into needed improvements

USGS





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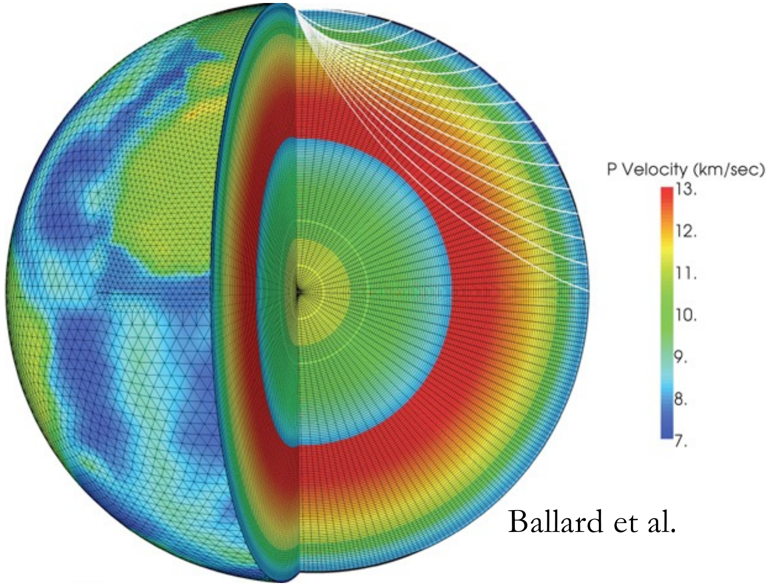
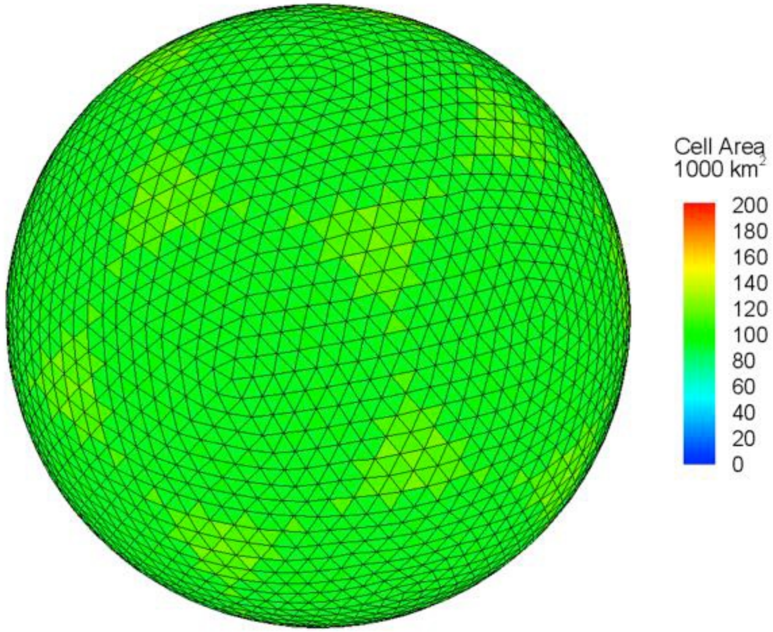
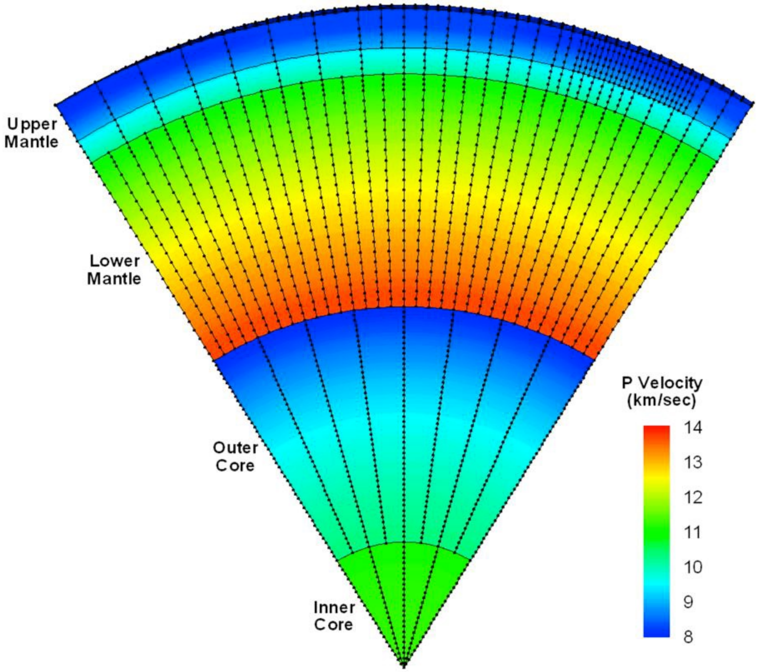


Ballard et al.

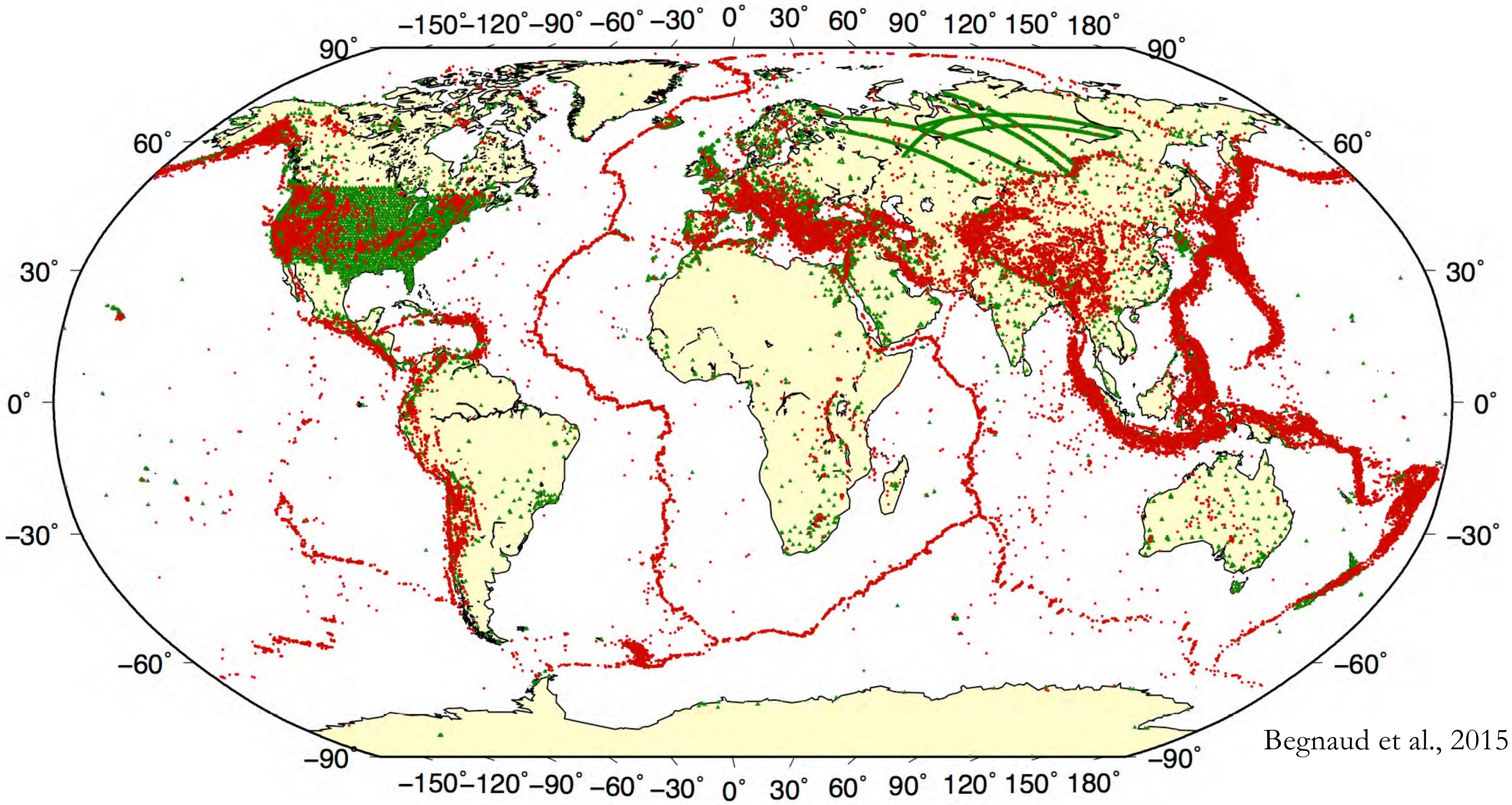
The model that we have developed and will be talking about here is referred to as the **SAndia LoS Alamos 3D** (SALSA3D) model (Ballard et al., 2010, 2016).

This model was developed under a model parameterization called GeoTess (Ballard et al., 2009), which consists of 2D triangular tessellations rather than a latitude/longitude rectangular grid, with radial vectors of nodes associated with each corner. This parameterization provides a globally consistent spacing of starting model nodes without polar singularities, and flexibility to refine tessellation size based on ray density.





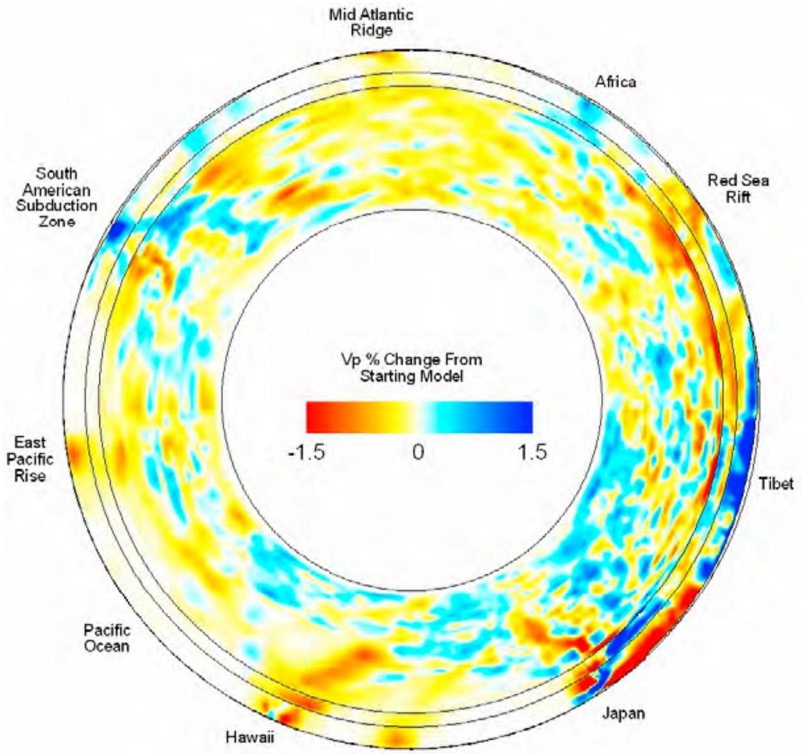
SALSA3D was developed to improve travel-time estimates globally, and was originally derived using ~12 million *P* and *Pn* travel-time picks from 13,000 stations and 122,000 (Ballard *et al.*, 2010, 2016). The seismic sources and receivers are represented by red and green dots, respectively.



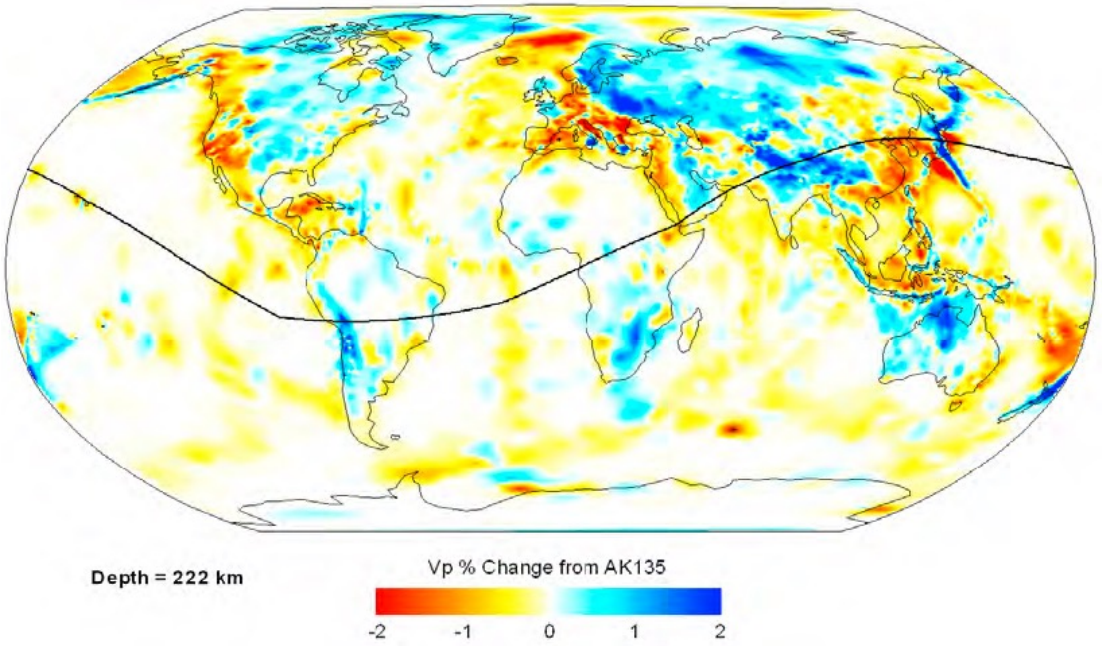
Begnaud et al., 2015

Heterogeneous distribution of both sources and receivers is obvious, and is a problem for all global models.

SALSA3D addresses heterogeneities in the mantle. The crust and core, which are not solved for, are derived from Crust1.0 and ak135, respectively.

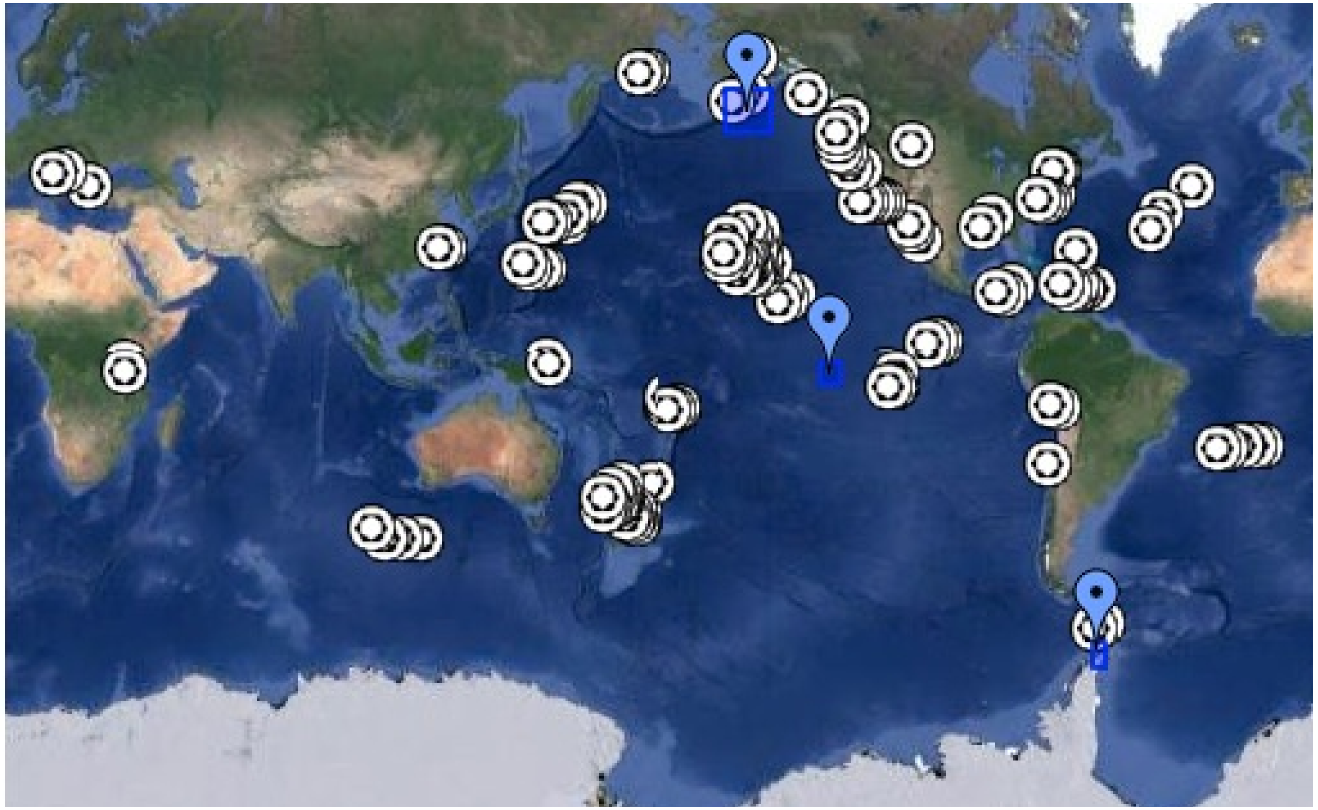


Ballard et al., 2010



The model exhibits compressional wave velocity features consistent with what we know about tectonics and geodynamics of the Earth. Due to the previously noted source and receiver distribution, however, large regions are unsampled.

Filling in the gaps



- In recent years, numerous seafloor deployments have added to global seismic observation, through temporary installation of targeted experiments.
- These sensors are typically deployed for a year or two at most, after which they are retrieved and the data downloaded for evaluation.
- Because of the often noisy seafloor environment, it is lucky when a large teleseism is recorded.
- Most such experiments are targeting a local feature such as axial ridge, transform system, triple junction, or an active source experiment.

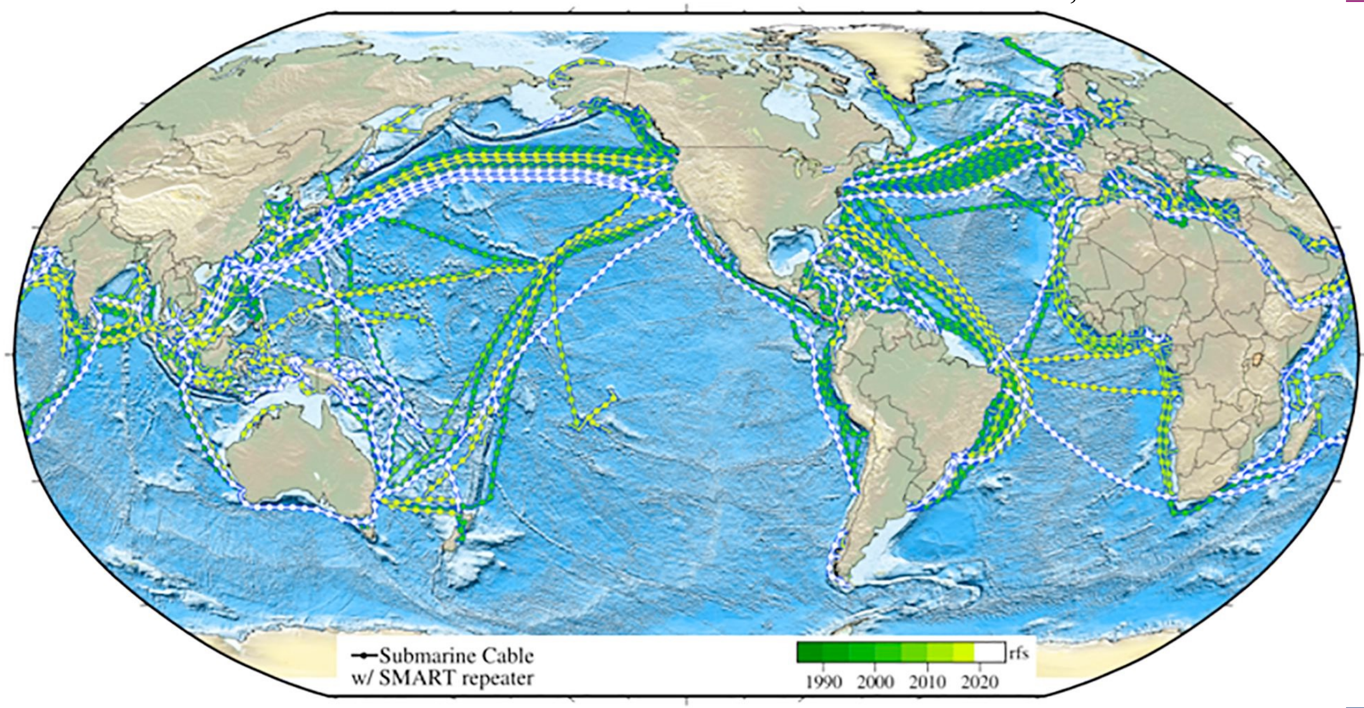
Science Monitoring And Reliable Telecommunication (SMART) Cables

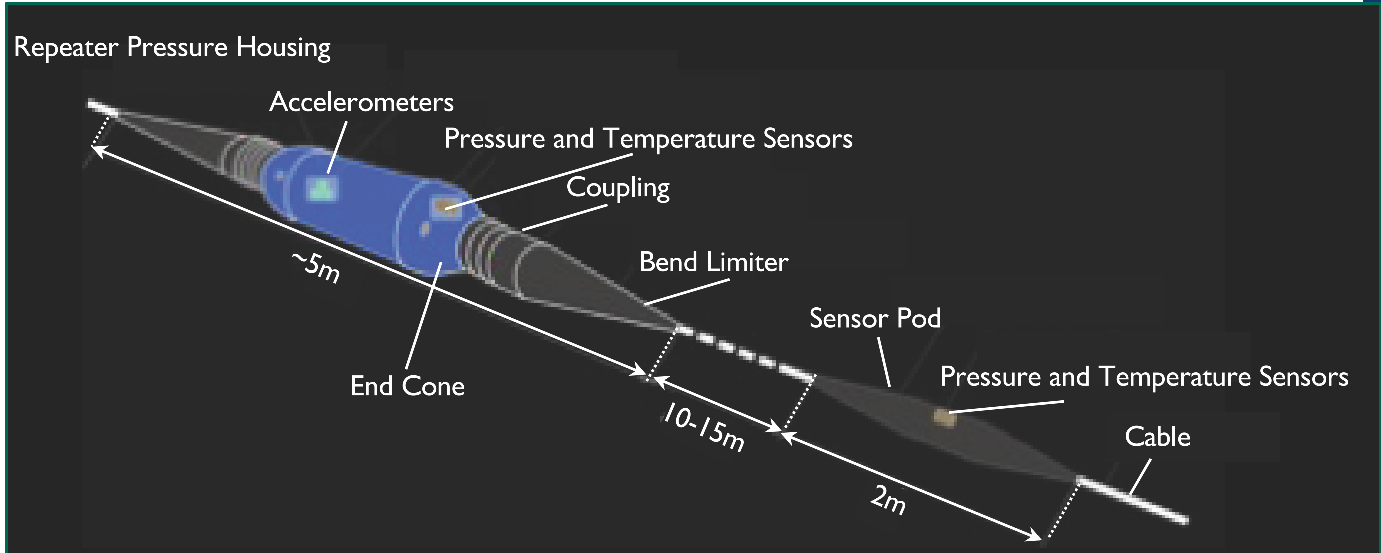
Howe et al., 2021

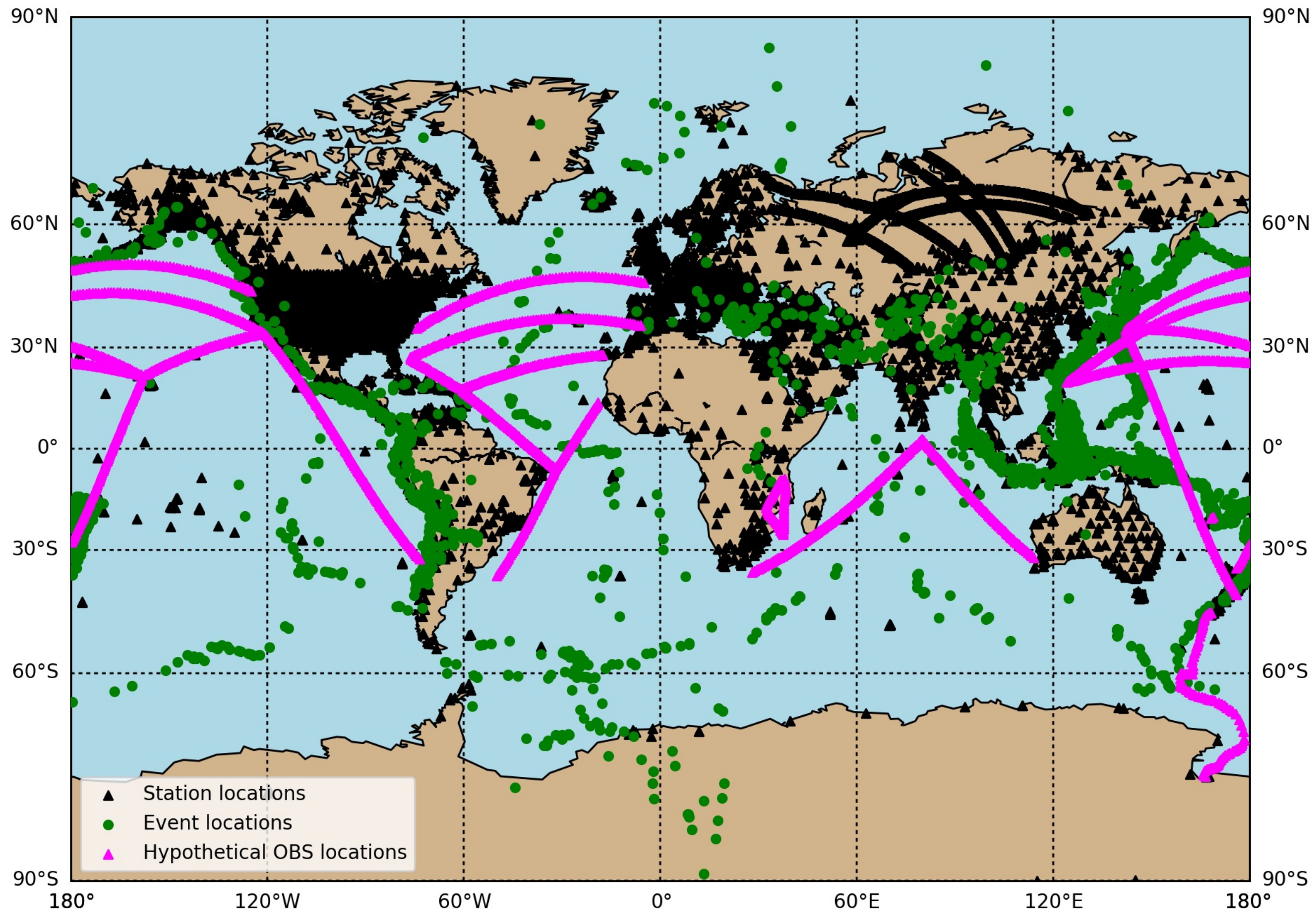
- The global infrastructure of submarine telecommunication cables is the backbone of the world's connectedness for business, finance, social media, entertainment, political expression, and science.

- We look to a future where these cables serve both as communications infrastructure and a scientific backbone for monitoring tsunamis, earthquakes, and the world's ocean climate and circulation.

- Technological advances have made it possible to integrate basic sensors with repeaters on submarine telecommunication cables at intervals of about 50-70 km.





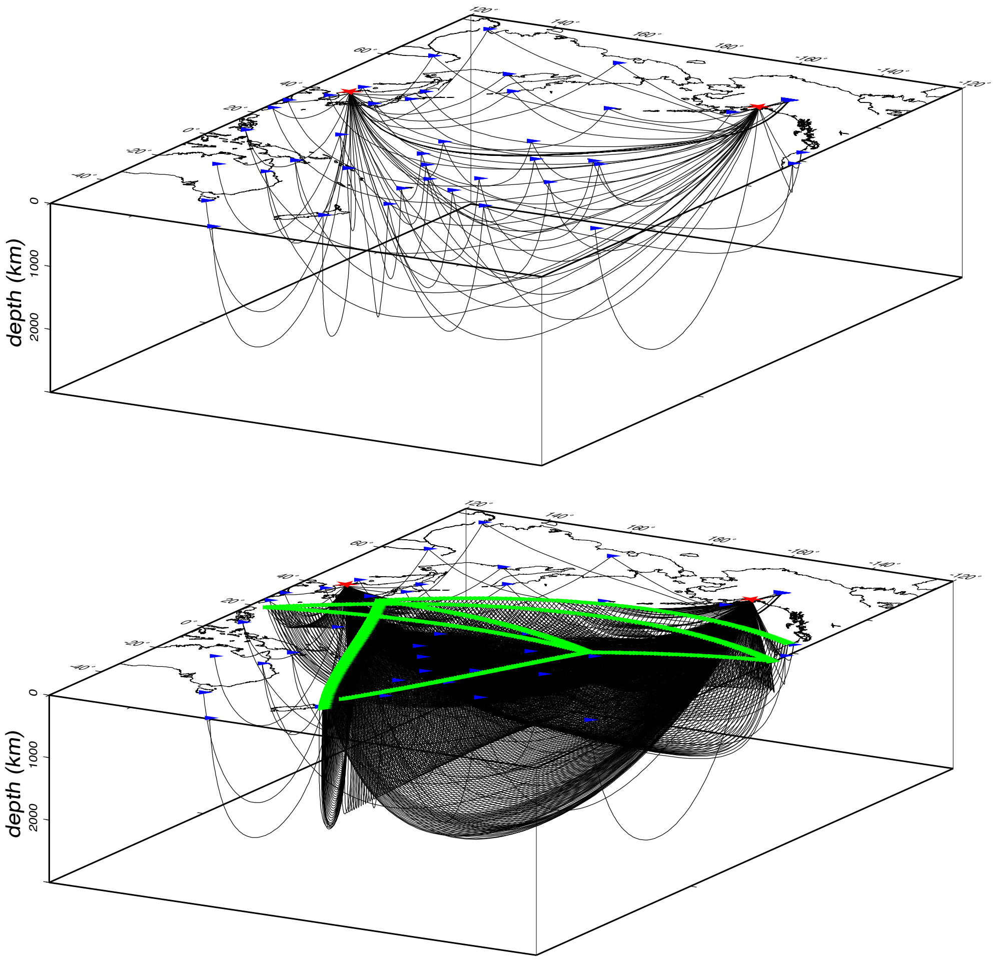


It is intuitively obvious that the addition of the SMART cables will, over time, provide for significantly improved seismic ray coverage for global velocity models.

We have sought to quantify this. In Ranasinghe et al. (2017) we explored ray coverage improvement through an ak135 global model for a first glance at the potential of these cables to enhance our global models.

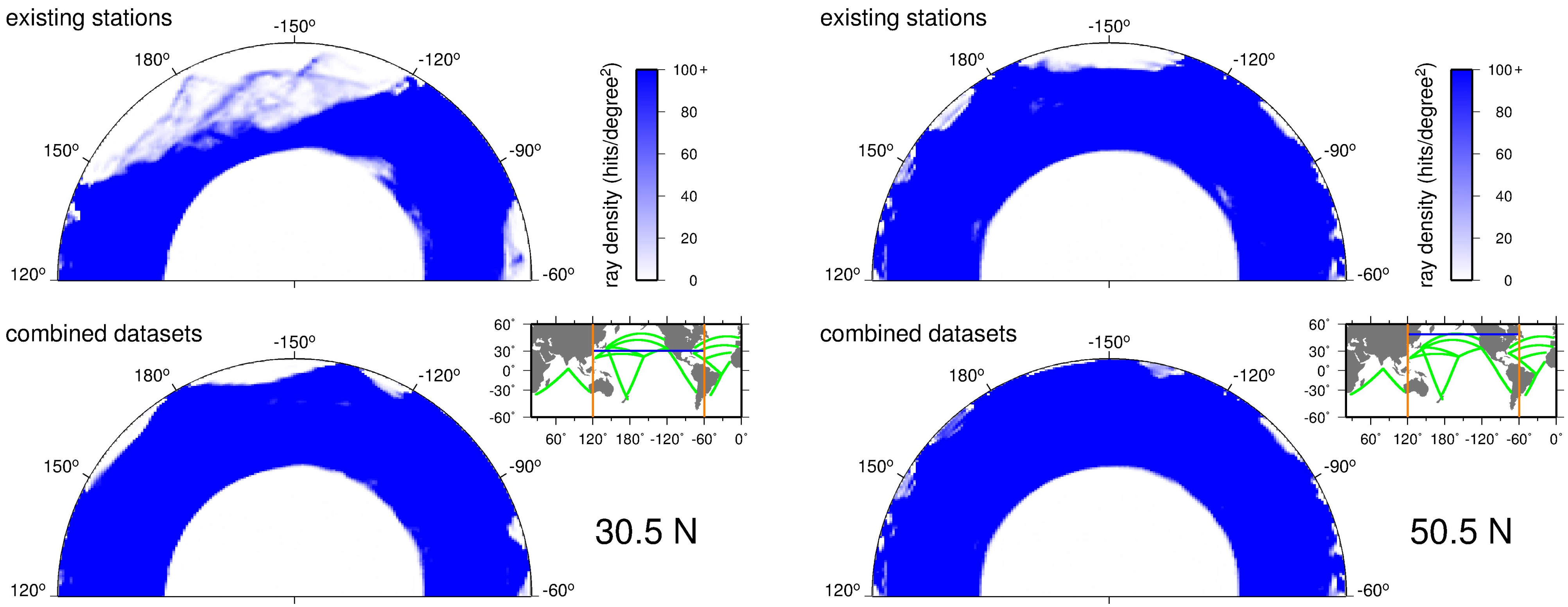
In that study we selected earthquakes of M > 6.0 in a 20 year period (green symbols), and predicted raypaths to actual seismic stations (black symbols) as well as to notional sensors along SMART Cable routes (pink symbols).

Comparison of Seismic Sampling With and Without SMART Cables



Ranasinghe et al., 2017

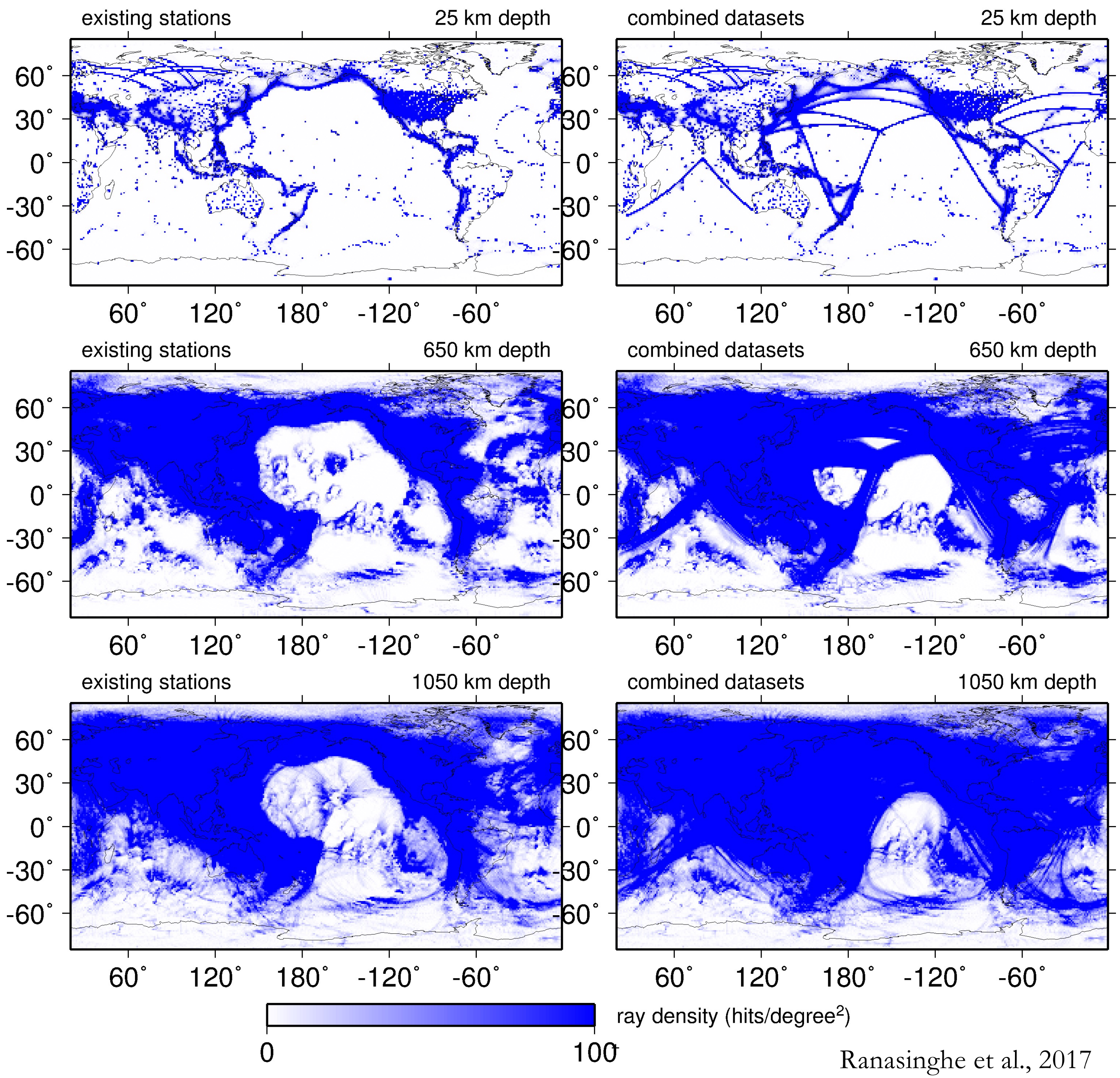
Two example sources – one in the Cook Inlet area of Alaska and one on the Korean Peninsula. Top figure shows rays to Global Seismographic Network (GSN) stations around the Pacific. Bottom figure shows rays for GSN stations plus the first generation of SMART cable sensors as proposed.



Ranasinghe et al., 2017

Example cross-sections through the mantle at two latitudes, showing ray coverage without (top) and with (bottom) SMART Cables.

Ray density without (left) and with (right) SMART Cables at three example depths.

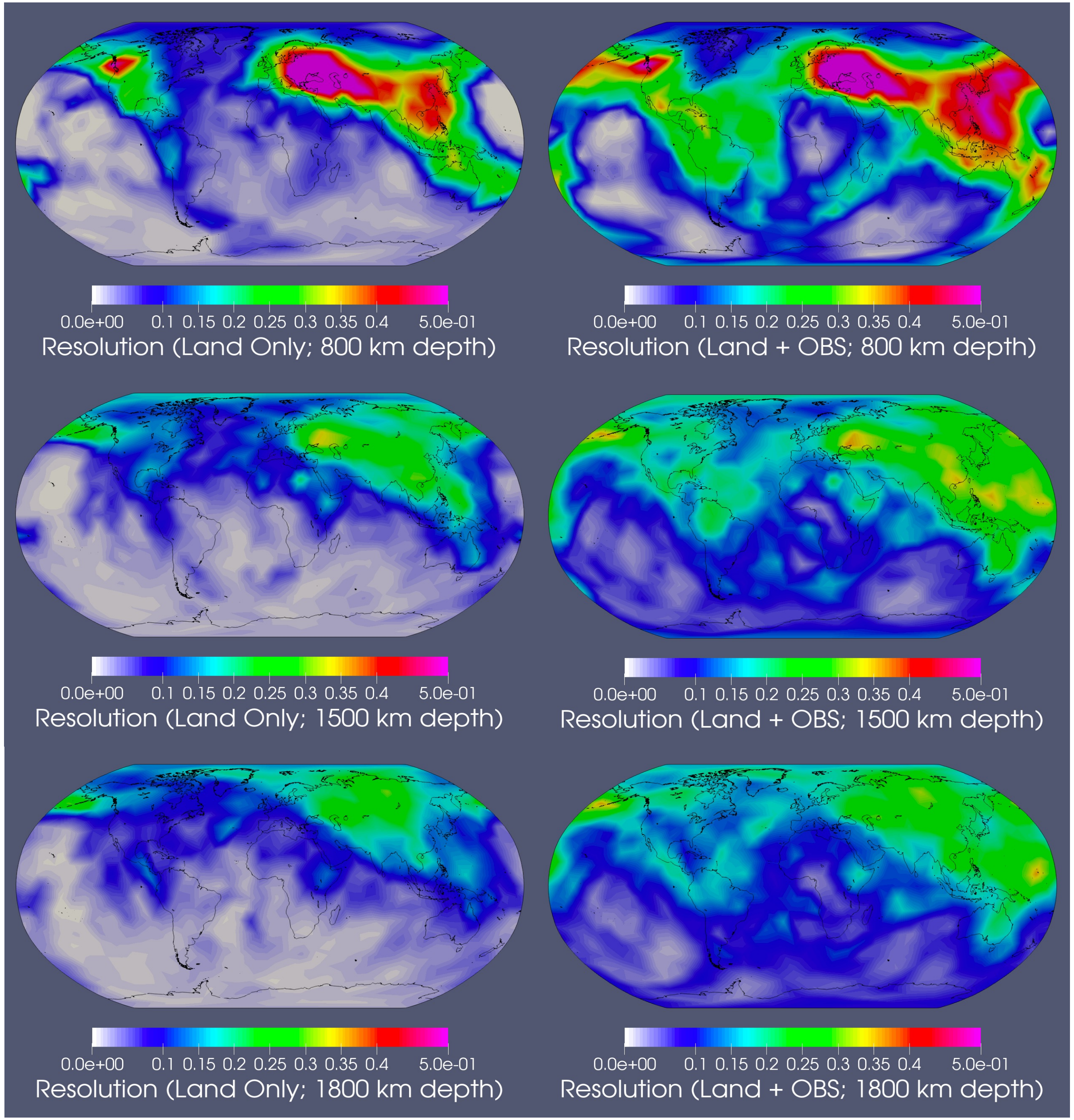


Ranasinghe et al., 2017

SALSA3D model resolution at three depths (800, 1500 and 1800 km, respectively) for tomographic results without (left) and with (right) notional SMART cable arrivals.

We used all M > 6.0 events in the database. Arrivals at land stations were real observations; we used arrival predictions for the cable sensors.

1 s uncertainty was applied to all cable arrivals.



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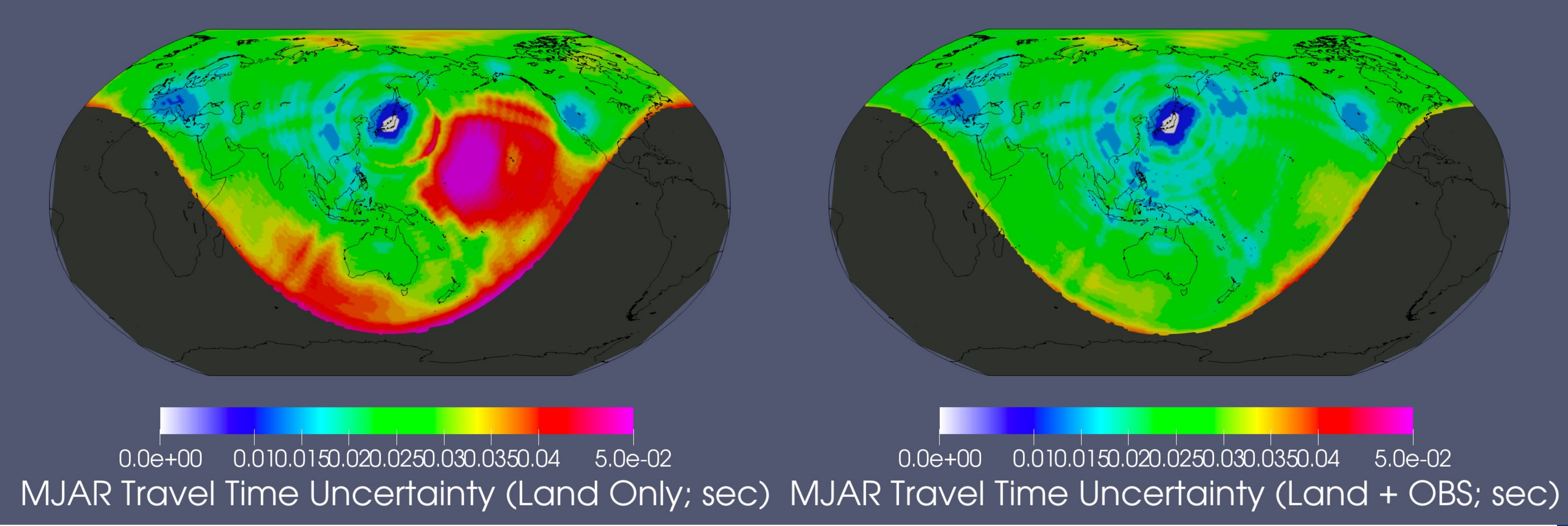

Comparison of travel time uncertainties for station MJAR (in Japan) without (left) and with (right) SMART Cables arrivals for global teleseisms informing the SALSA3D model.

Absolute values of uncertainties are underestimated due to choice of model damping parameters, but the qualitative patterns and relative values would not change.

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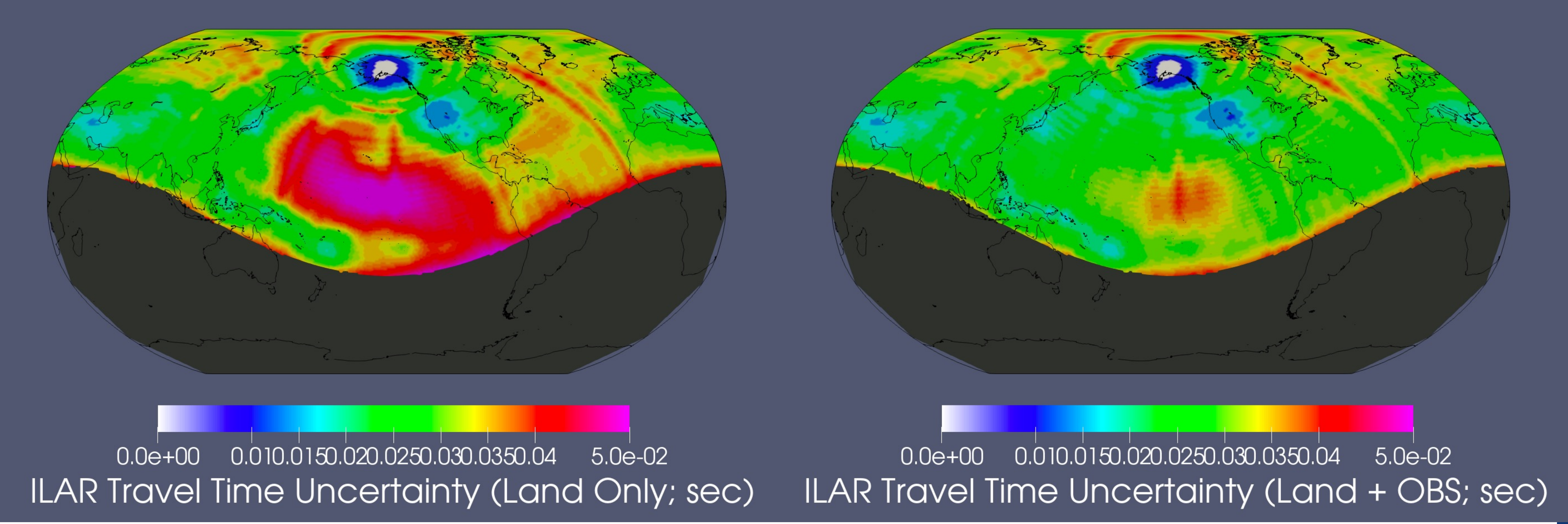

Comparison of travel time uncertainties for station ILAR (in Alaska) without (left) and with (right) SMART Cables arrivals for global teleseisms informing the SALSA3D model.

Absolute values of uncertainties are underestimated due to choice of model damping parameters, but the qualitative patterns and relative values would not change.

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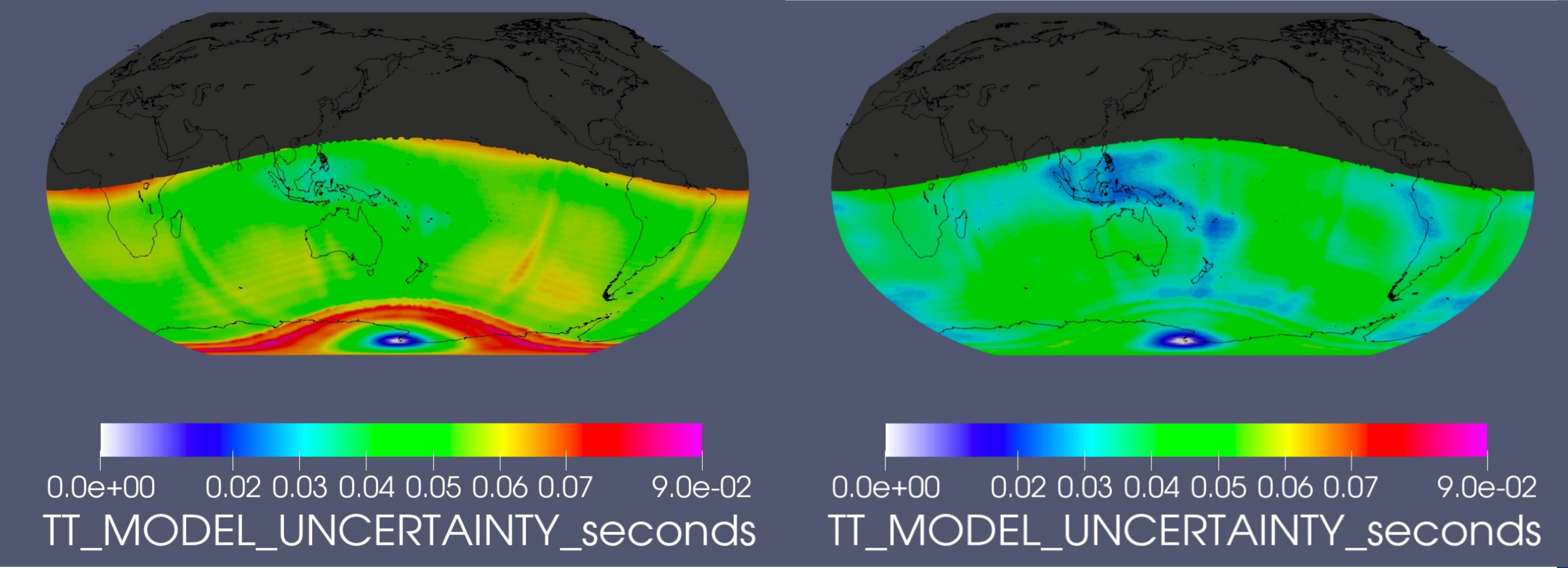

Comparison of travel time uncertainties for station VNDA (in Antarctica) without (left) and with (right) SMART Cables arrivals for global teleseisms informing the SALSA3D model.

Absolute values of uncertainties are underestimated due to choice of model damping parameters, but the qualitative patterns and relative values would not change.

Summary:

- Global tomographic models, including the SALSA3D model, suffer from heterogeneous source and receiver distribution, with sensors largely restricted to specific regions.
- The addition of seafloor seismometers can greatly enhance ray coverage to fill in the blanks, but most ocean deployments are spatially and temporally limited, reducing the opportunities to exploit potentially important events.
- The drive towards SMART Cables can significantly enhance our ability to probe the subsurface more uniformly, leading to more complete models.
- Improved model resolution and model covariance calculations can significantly reduce travel-time uncertainties over large swaths of the Earth, leading to the potential to improve event location confidence.

Coming soon: Review article about the SMART Cables initiative and latest developments, pending final revisions: Howe et al. (2021), SMART Subsea Cables for Observing the Earth and Ocean, Mitigating Environmental Hazards, and Supporting the Blue Economy, *Frontiers in Earth Science* special issue on seafloor seismology.