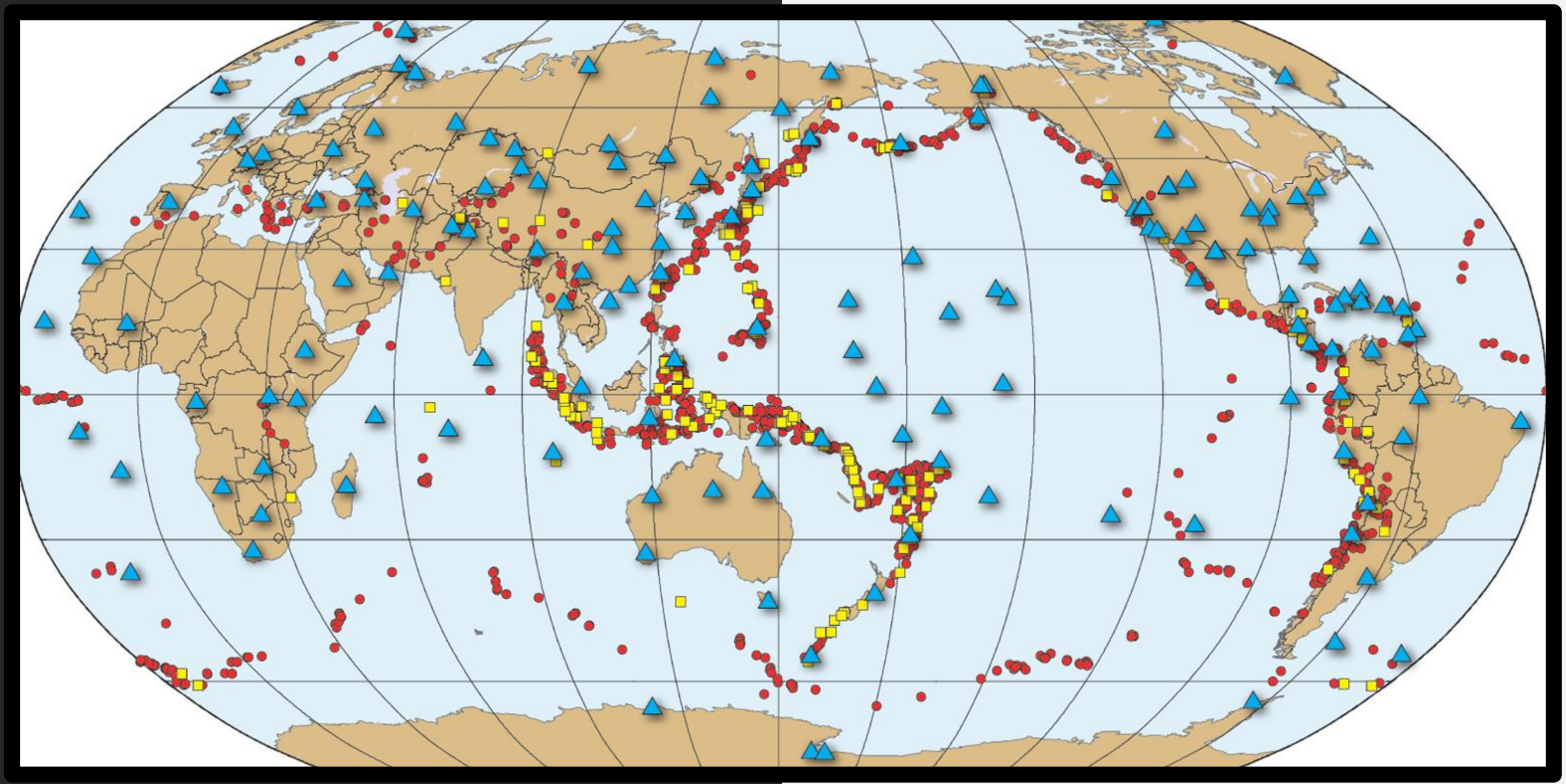

The Global Seismographic Network (GSN)

- David Wilson, Adam Ringler, Rob Anthony (USGS)
- Rob Mellors, Pete Davis, Dan Auerbach, Carl Ebeling (UCSD/IDA)
- Bob Busby, Andy Frassetto (IRIS)

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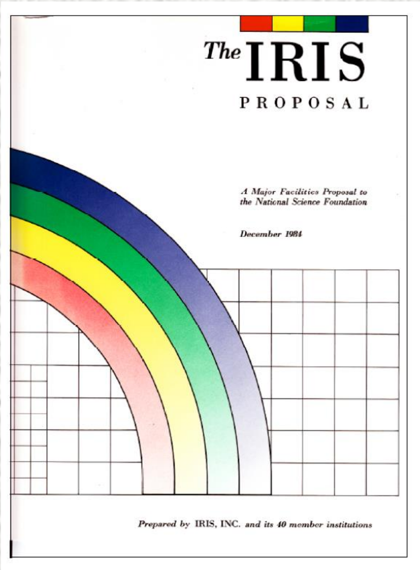
The Origin of the GSN



A proposed plan for installing a new Global Seismographic Network (GSN) was put forward in the Incorporated Research Institutions in Seismology (IRIS) proposal (1984) (the rainbow proposal) to the US National Science Foundation.

The network was to be built on the footprint of existing networks, so the proposal examined the current state of global monitoring.

WHAT DO WE HAVE NOW?

- The 120-station, analog-recording World Wide Standardized Seismic Network (WWSSN), installed 23 years ago, is an example of a global seismic network that has well served the nation's seismological needs.
- Several sparse networks of digital instruments operated by government agencies and universities. These include
  1. Global Digital Seismic Network (GDSN), which consists of:
     a. Seismic Research Observatories (SRO) — 11 installations;
     b. Abbreviated Seismic Research Observatories (ASRO) — 4 installations;
     c. Digital WWSSN (DWWSSN) — 13 installations.
  2. International Deployment of Accelerometers (IDA) — 18 installations, designed specifically to study the Earth's normal modes.
  3. GEOSCOPE — 5 installations, a developing broadband network operated by a consortium of French universities.
  4. Regional Seismic Test Network (RSTN) — 5 installations in North America only with real-time satellite telemetry.

The Origin of the GSN

WHY NOW?

- Recent results obtained from the analysis of available data demonstrate that significant advances in many problems of fundamental importance to earth sciences could be achieved with the data from a network such as proposed here.
- Technological developments make deployment of such a network operationally and economically feasible.

- In the early/mid-1980's GEOSCOPE was deploying STS-1's and at the same time STS-1 electronics were being modified to record very long periods.
- Also, 24 bit digitizers were being developed to take advantage of a wider dynamic range.
- The IDA network of gravimeters had high fidelity long period recordings, but vertical component only, and the aging WWSSN analog instruments had noise levels that were too high at long periods for high quality normal mode measurements.
- **The successful deployment of the newly modified STS-1's in the GEOSCOPE network in the mid-80's showed that a global network of high quality, multi-component, long period recordings was a real possibility.**

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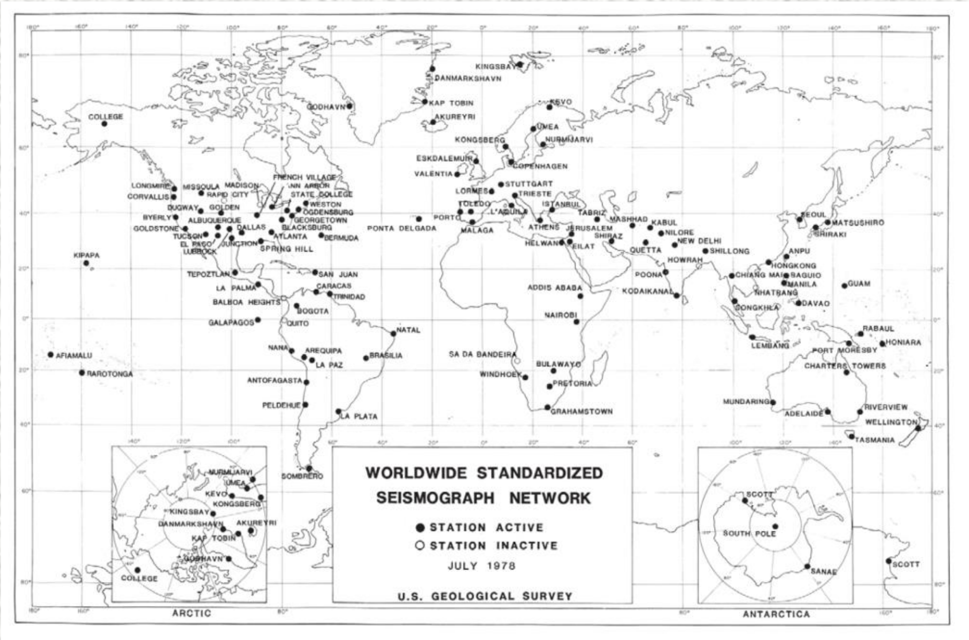
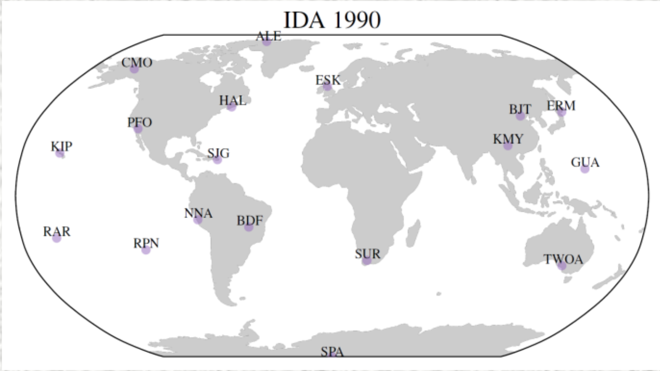
Major GSN milestones

1. 1980s - inception of the GSN based on preexisting networks.
2. 1990s - supplemental DoD funding to adapt to treaty monitoring tasks.
    - This was a significant engineering challenge to add a secondary sensor.
3. late 1990s - introduction of first non-seismic sensors (microbarographs).
4. post 2004 tsunami - USGS supplemental funding to expand to fully telemetered network, and the USGS NEIC moved to 24/7 operations shortly after.
5. late 2000s - introduction of second-generation digitizer (Q330HR)
6. mid 2010s - introduction of next generation of VBB sensors and infrasound

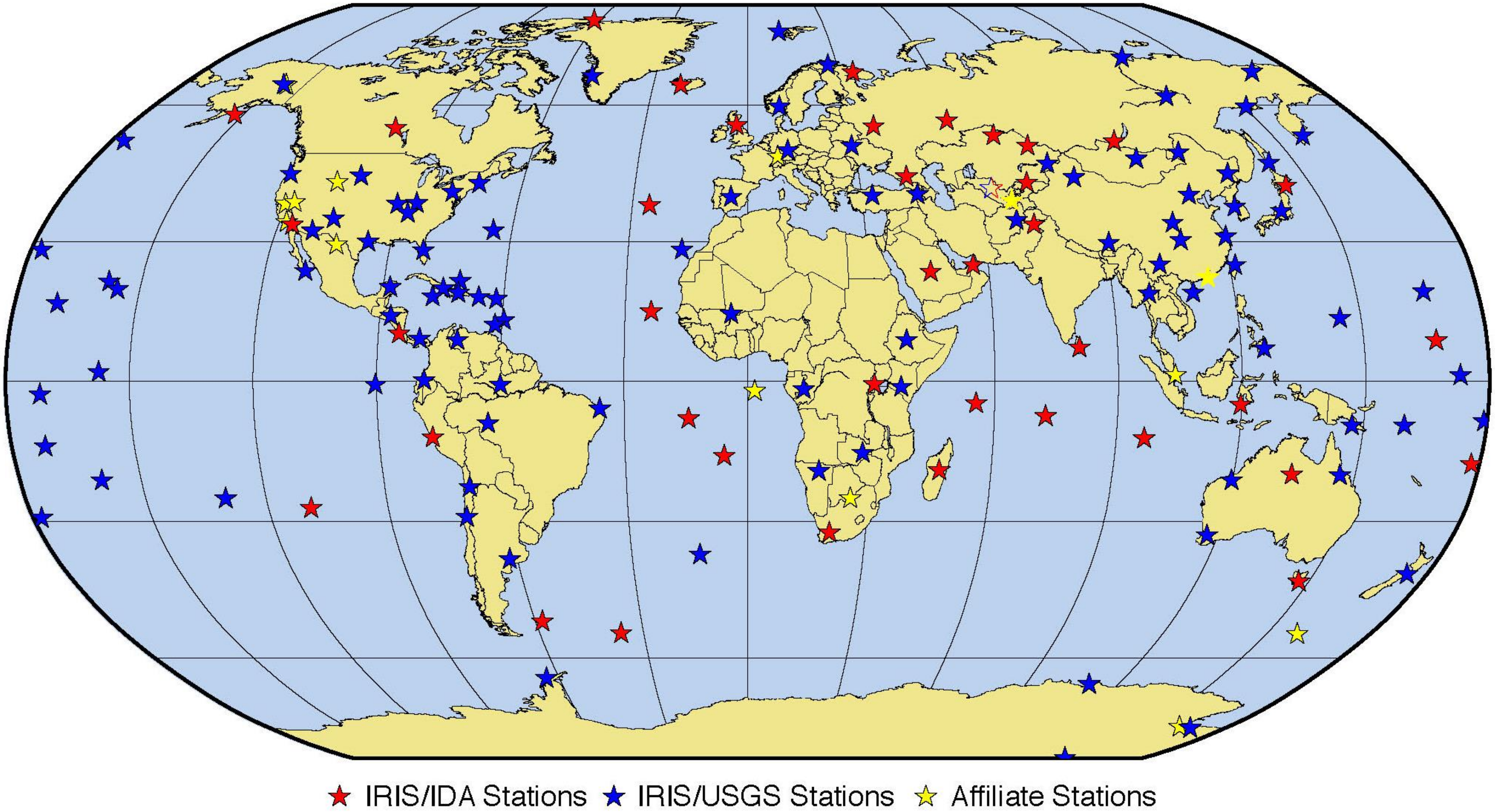


World-Wide Standardized Seismographic Network (WWSSN) in July 1978.
Reproduced from Peterson and Hutt (2014),



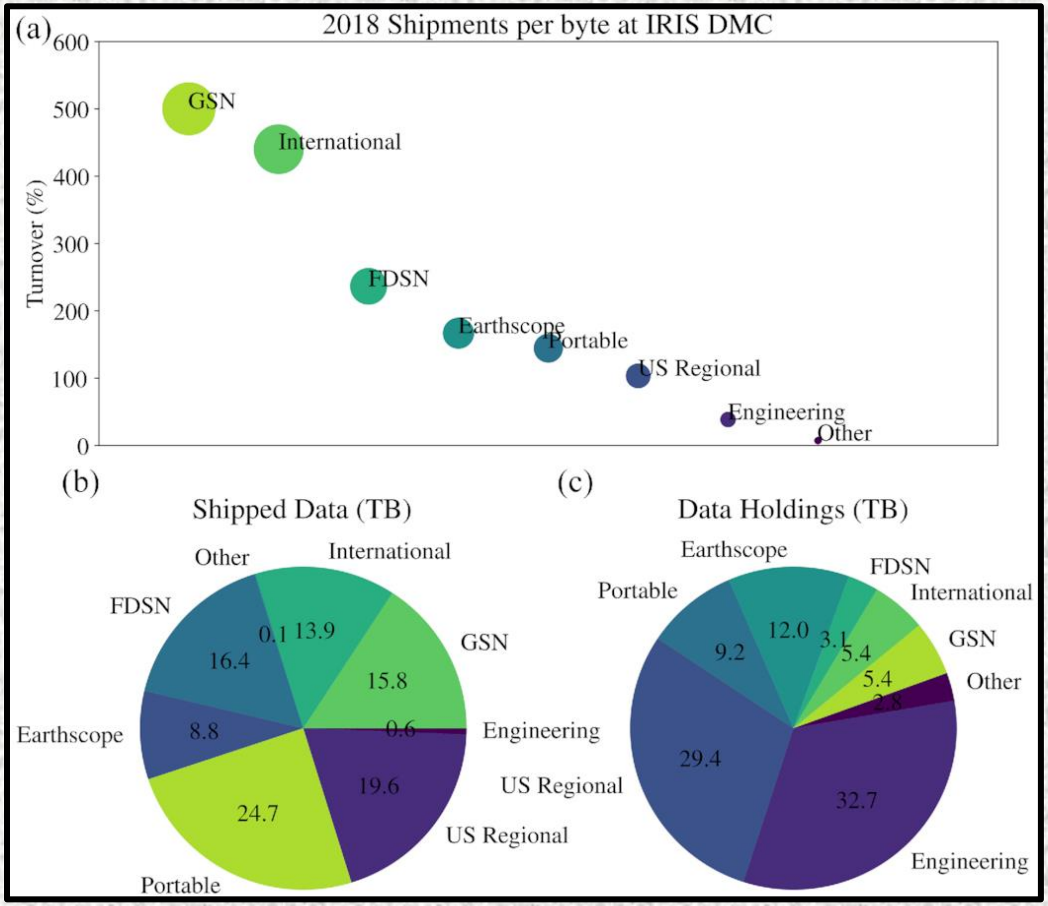
International Deployment of Accelerometers (IDA) network of LaCoste & Romberg gravimeters (network code ID) in 1990

The GSN today



The primary GSN operators are IRIS/IDA (netcode II) and the USGS (netcodes IU, IC, CU)
Two IU network stations are co-operated with GEOSCOPE and 3 with GEOFON.
Networks contributing affiliate stations include AU, BK, CI, GT, HK, IM, MS

GSN high data quality and demand



Shipments of data as compared to total holdings at the Incorporated Research Institutions for Seismology (IRIS) Data Management Center (DMC) for 2018.

(a) Turnover percentage by different data types, which data are shipped relative to total data holdings. Larger circles denote a higher percentage of requested data.

(b) Total shipped data by data type

(c) Total data holdings at the DMC.

From Ringler et al., Geophys J Int, Volume 220, Issue 1, January 2020, Pages 508–521, https://doi.org/10.1093/gji/ggz473

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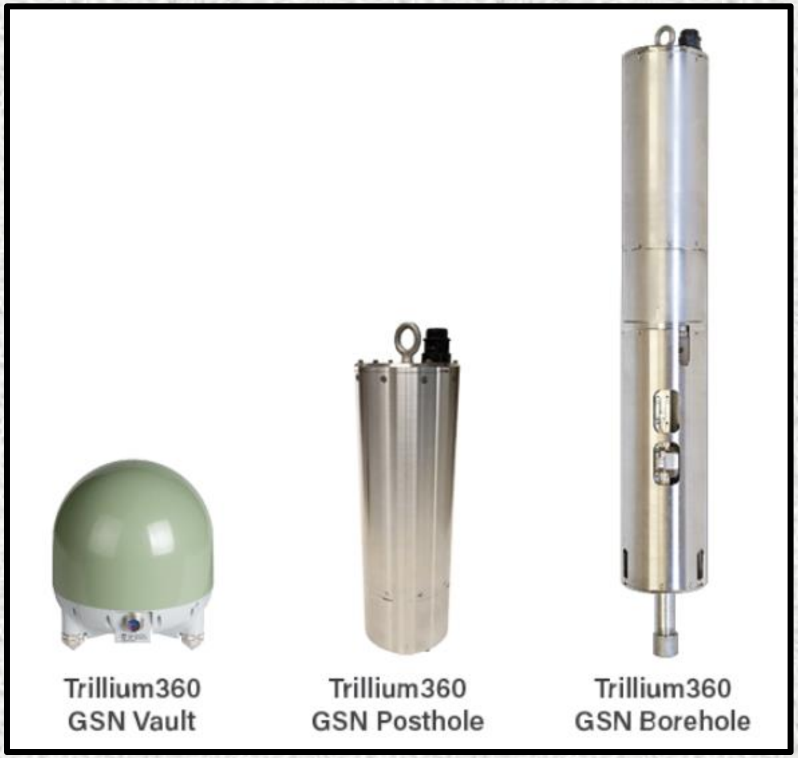
A new generation of Very Broadband (VBB) sensors

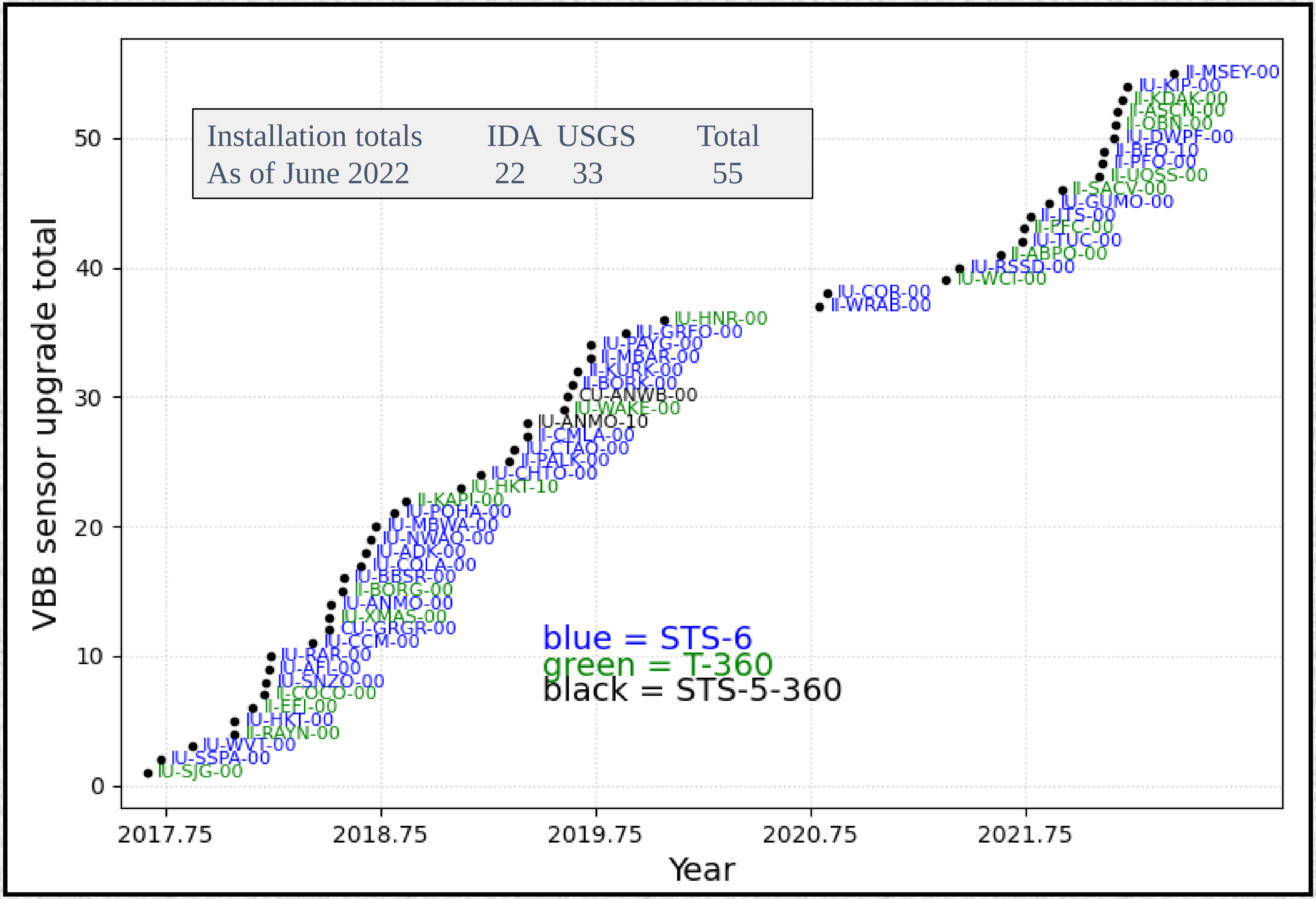
- From a US Dept. of Energy award, the USGS was able to fund the development of and purchase Streckeisen STS-6A borehole instruments and purchase Trillium T-360 borehole and T-360 vault instruments.

- Current GSN upgrades are focused on infrastructure upgrades (new boreholes and postholes) and deploying the new STS-6A and T-360 instruments.

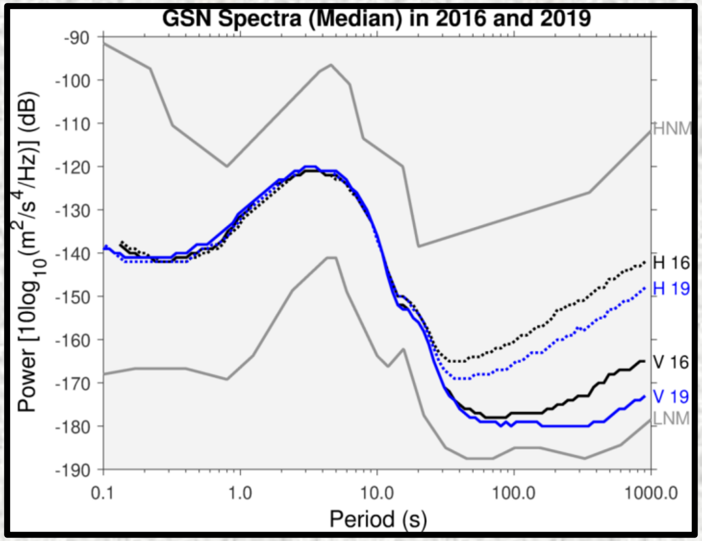
The STS-6A borehole



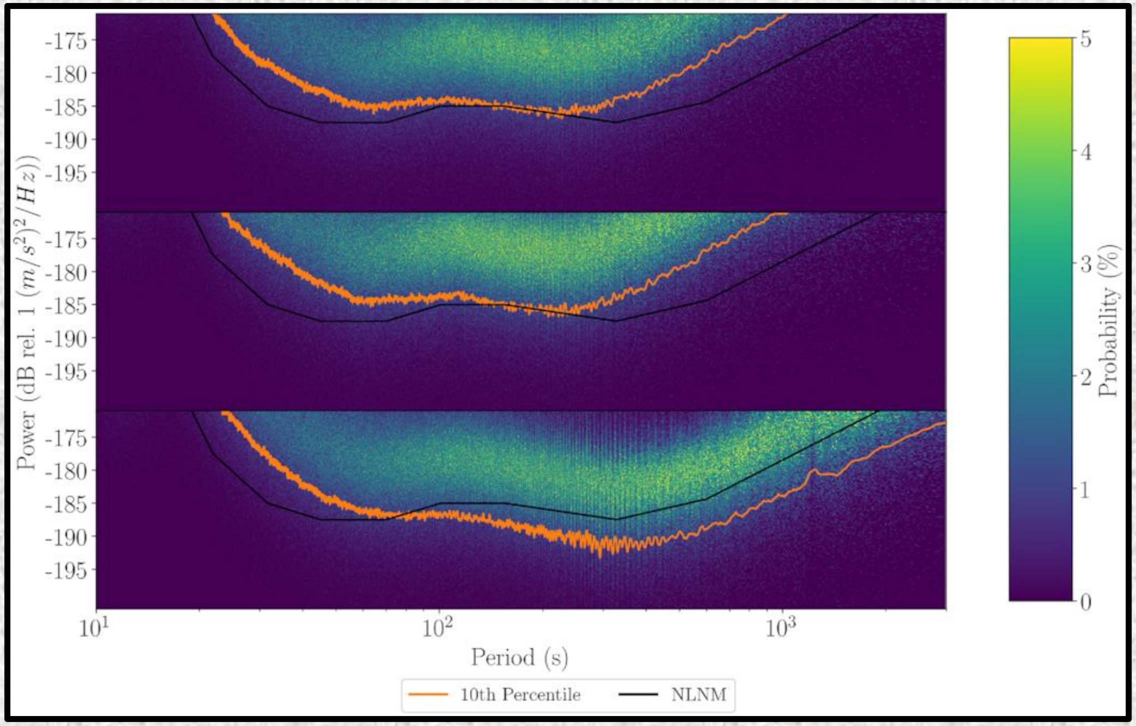
A new generation of Very Broadband (VBB) sensors



The new VBB installations and infrastructure upgrades are lowering the noise floor of the GSN



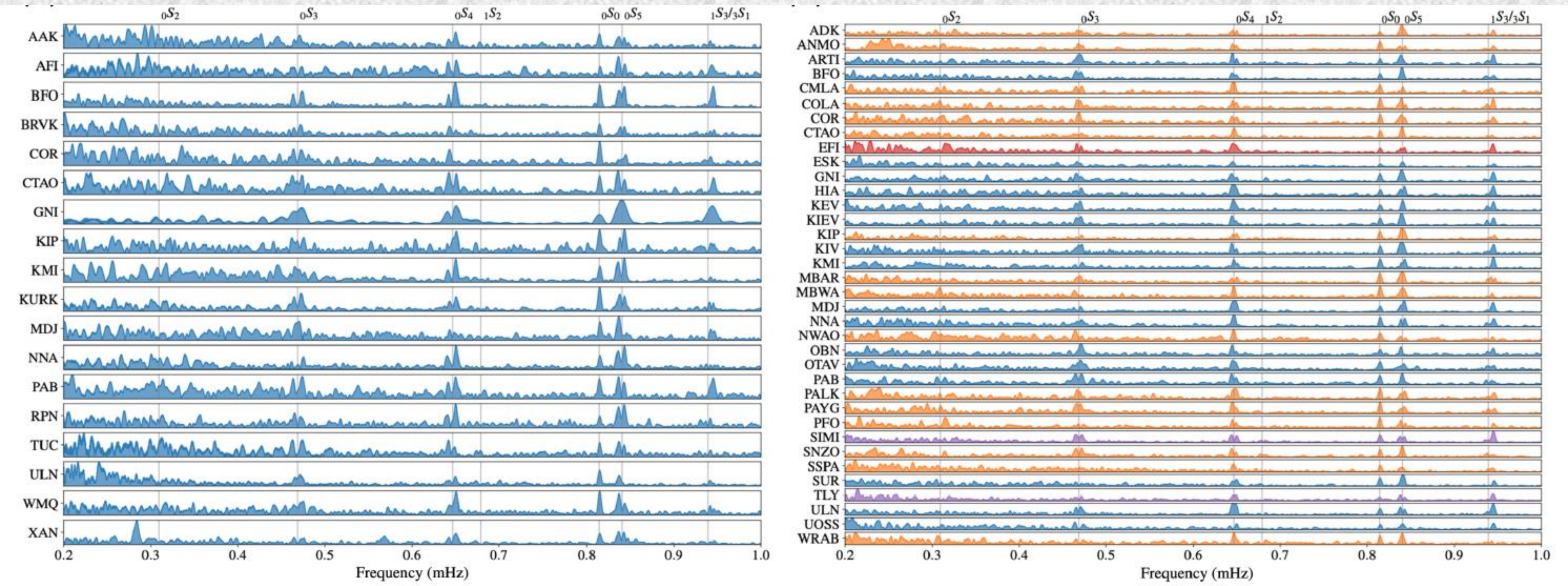
Median power spectral density (PSD) estimates for all GSN primary sensors show a significant long period decrease in recent years. (plot courtesy of A. Frassetto, IRIS)



Power spectral density (PSD) estimates colored by density from the Streckeisen STS-6A at ANMO (Albuquerque, New Mexico) at 188 m depth from 14 July 2018 to 1 March 2019. The 10th percentile of all shown PSD estimates is orange.

From Ringler et al., Geophys J Int, 2020

GSN upgrades enable new observations



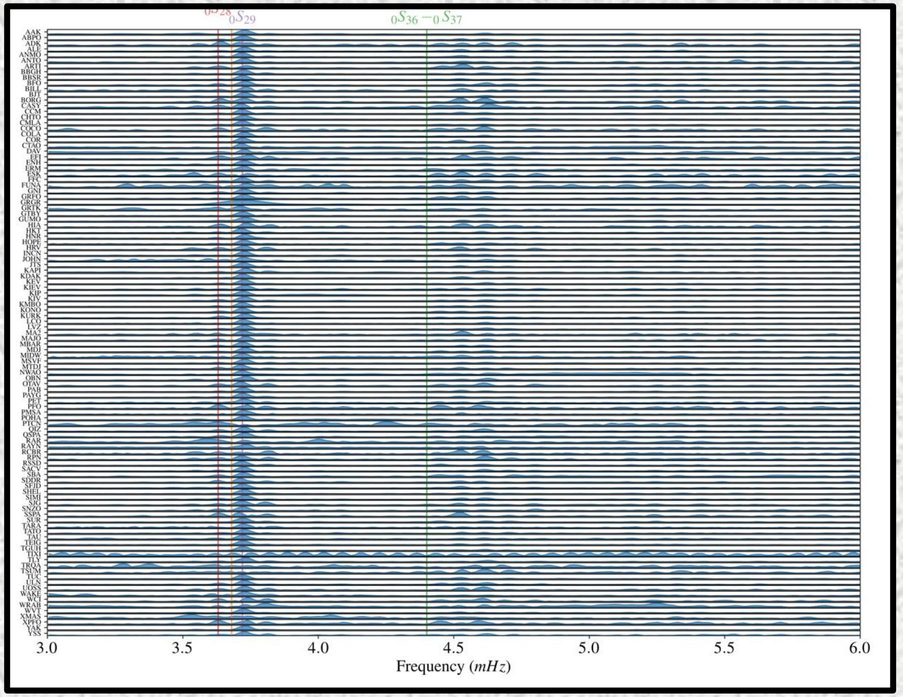
Left: GSN stations where the vertical component was able to resolve normal modes below 1 mHz for the Mw 8.2 Iquique Chile earthquake on 1 April 2014

Right: Same as left, but for the Mw 8.2 Perryville, Alaska, earthquake on 29 July 2021

Spectra are colored by instrument type: Streckeisen STS-1 (blue), Streckeisen STS-6 (orange), Nanometrics T-360GSN (red), and other sensors (purple).

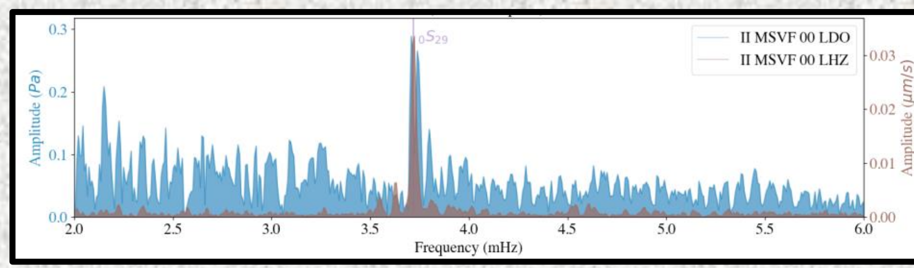
(from Ringler et al., The Seismic Record, 2022)

GSN novel observations



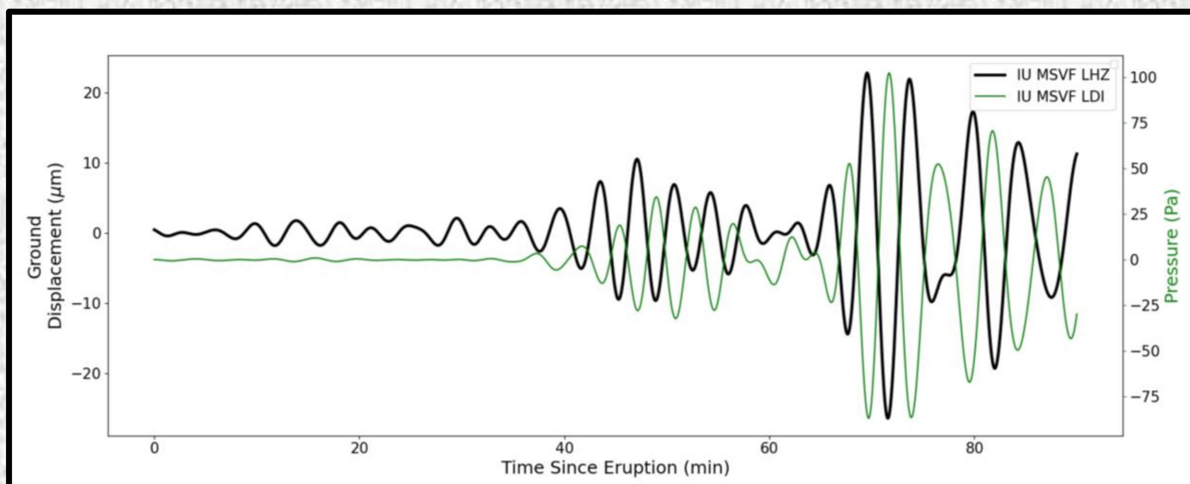
The Global Seismographic Network Revealed Atmospherically Coupled Normal Modes Excited by the 2022 Hunga Tonga Eruption

II-MSVF Spectra

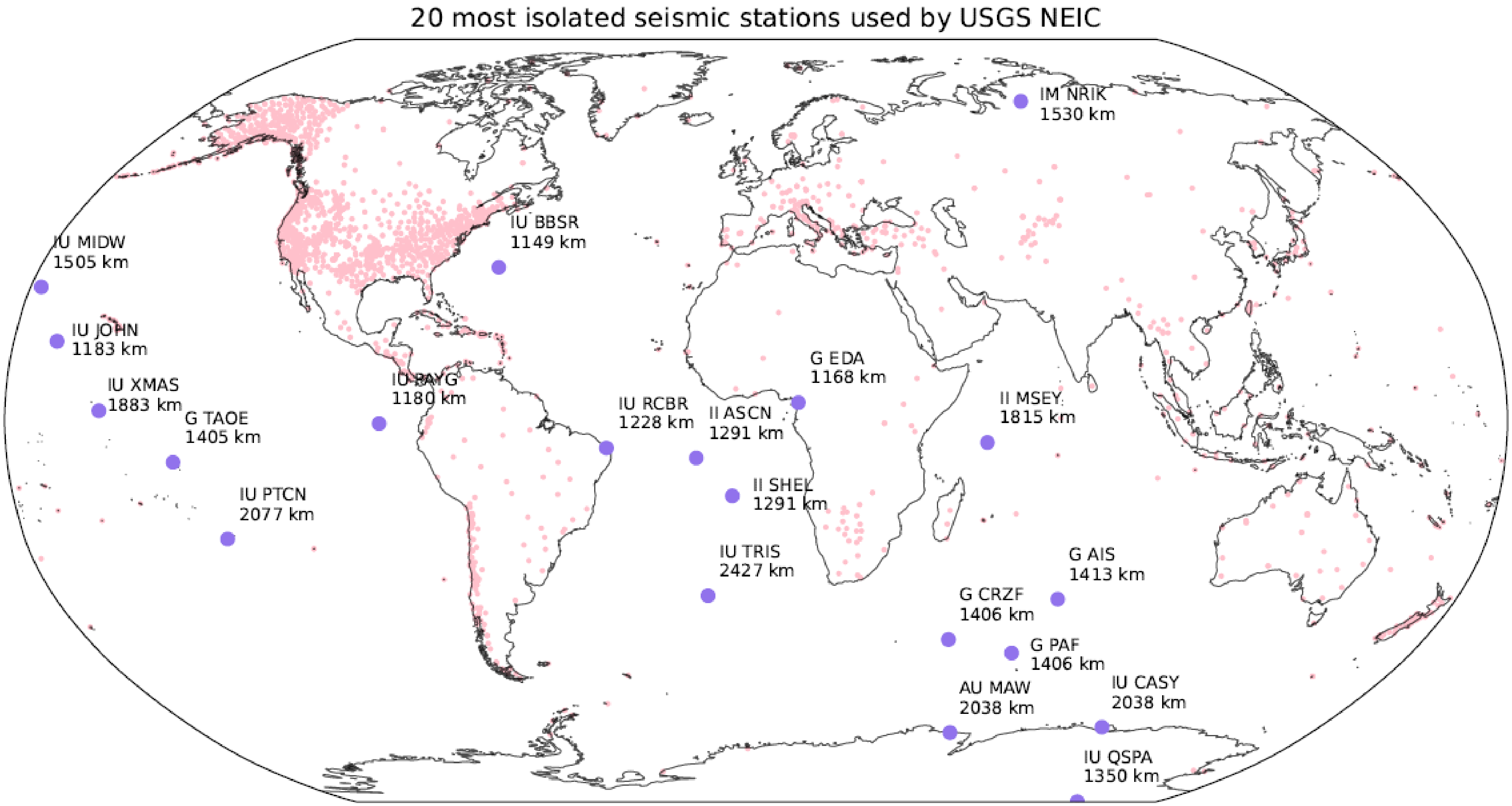


86.6% of GSN stations observe a peak with an SNR > 3 between 3.5 and 3.8 mHz

Mean Frequency is 3.721 mHz

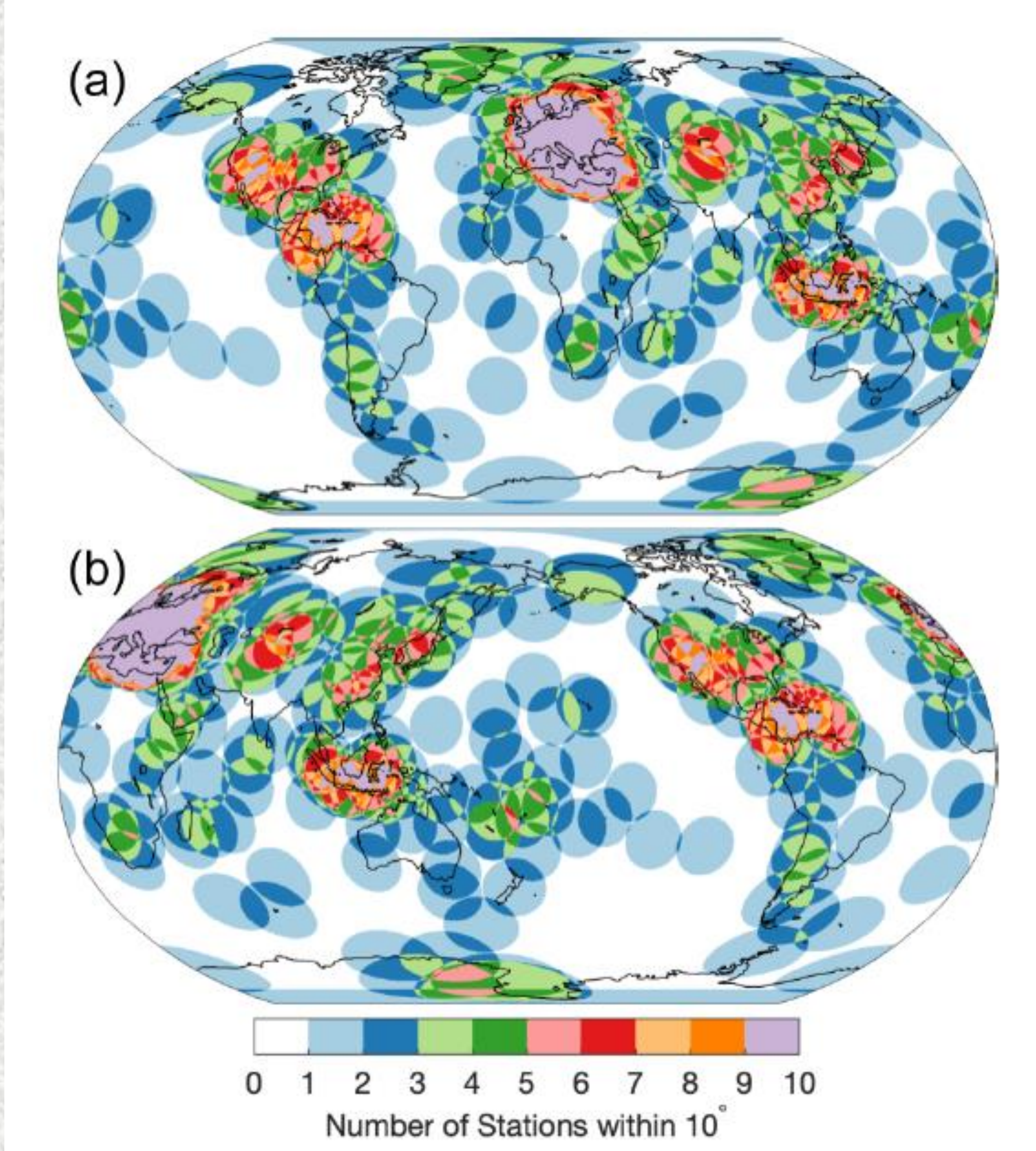


GSN global coverage limitations



Map of stations used by the U.S. Geological Survey (USGS) National Earthquake Information Center (NEIC) in their automatic picking and association algorithms as of 24 June2021 (figure courtesy of Will Yeck, USGS).

GSN global coverage limitations



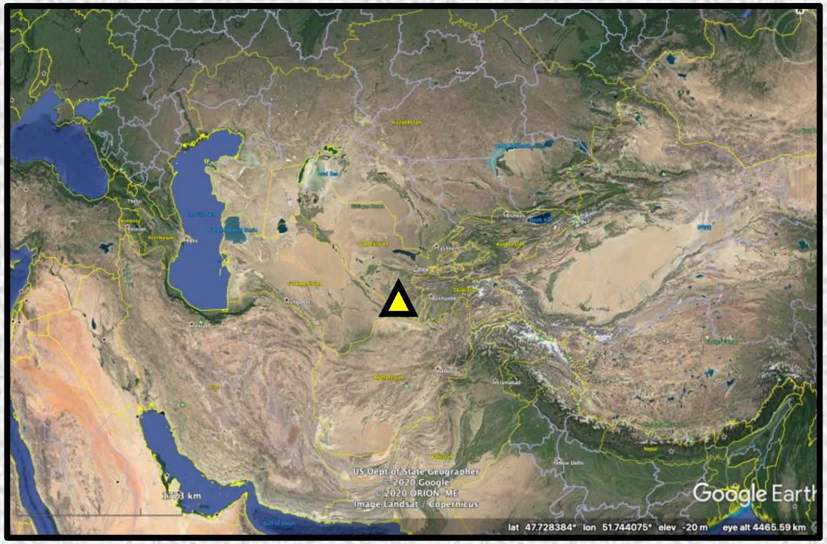
Stations from the Global Seismographic Network (GSN), GEOSCOPE, GeoFon, and Mediterranean networks showing the geographical density of stations. (a) Africa centered; (b) Pacific centered. Color contours show the number of stations within 10 degrees of any other global station.
Figure modified from Kohler et al. (2020).

How should the GSN venture into the oceans? (there is interest from NSF and impressive progress at international groups like Ifremer and JAMSTEC)

GSN future improvements and challenges

- USGS GSN base funding remains relatively flat
- NSF funding for GSN through IRIS/IDA is constantly scrutinized
- Currently, the only planned new GSN station is in Uzbekistan (below), and that is a replacement for the old ABKT in Turkmenistan
- Perhaps network operators (II,IU,G,GE) could work together to upgrade existing sites or trade underperforming stations for new locations

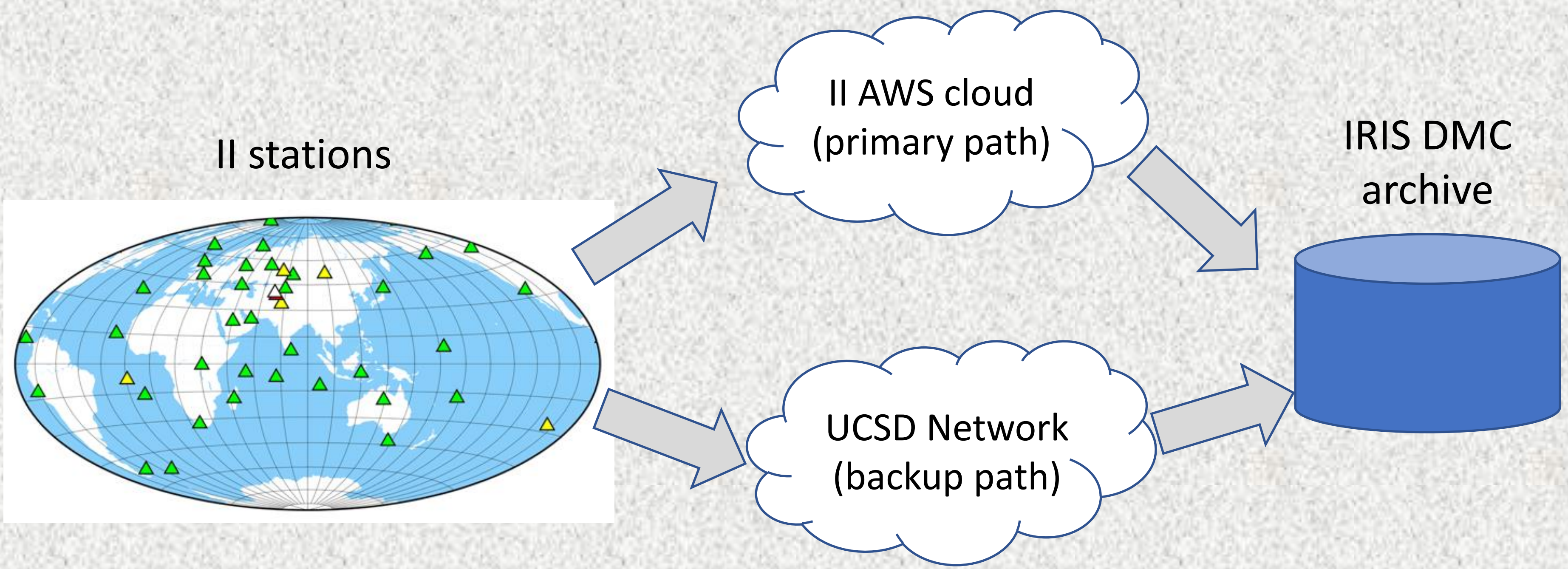
Members of the Uzbekistan Ministry of Emergency Situations, UCSD staff, and US Embassy staff.



GSN future improvements and challenges

A continuous cycle of modernizing equipment and systems:

- Possible improvements in global telemetry as new satellite telemetry options come online?
- Timeline for the next generation of GSN digitizers?
- Migrating acquisition and processing into a distributed or cloud model (below).



AWS - Amazon Web Services
IRIS - Incorporated Research Institutions in Seismology
UCSD – University of California San Diego

Now running II data collection servers in cloud; (as well as to physical disks at UCSD). Provides redundancy to the data path in case of local (UCSD) network issues

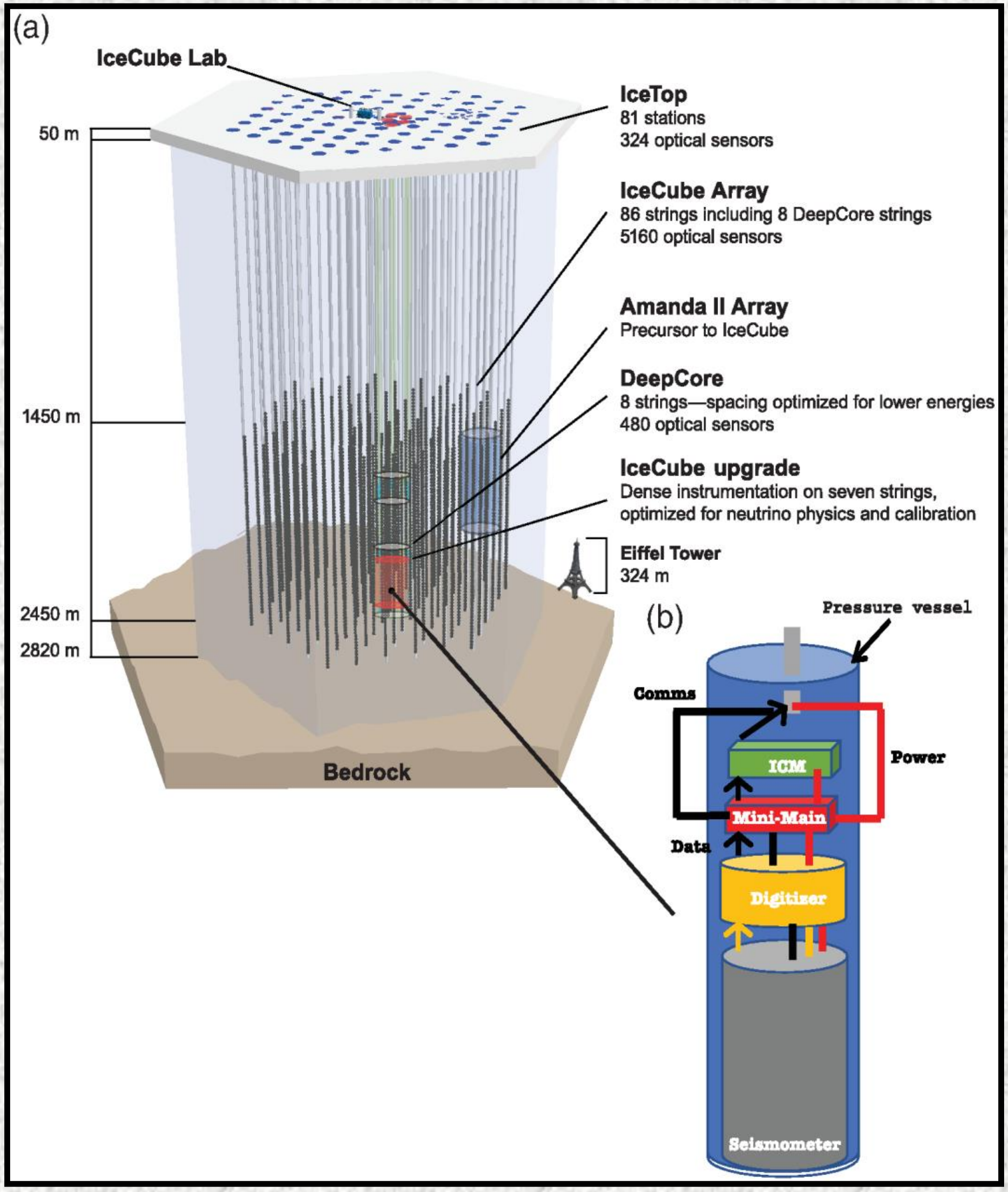
GSN future improvements and challenges

Continued infrastructure improvements and new sensor installations

For example:

- IU-TSUM (Tsumeb, Namibia) – We have completed drilling, casing, and grouting of a 100m borehole (Sept. 2021). Completion of the concrete pad around the borehole and installation of conduit done Oct. 1, 2021. New sensor to be installed summer 2022.

GSN future improvements and challenges



New Collaboration opportunities:

IU-QSPA (South Pole, Antarctica) An extension to the hatch is needed, the vault is now 40ft below the surface. Long-term we will likely need a new vault and new borehole drilled in order to emplace a new sensor. We have been interacting with the IceCube neutrino detector group and we may have an opportunity to install a very deep sensor (2500m!) in the future.

Anthony, R. E., A. T. Ringler, M. DuVernois, K. R. Anderson, and D. C. Wilson (2021). Six Decades of Seismology at South Pole, Antarctica: Current Limitations and Future Opportunities to Facilitate New Geophysical Observations, Seismol. Res. Lett. 92, 2718–2735, doi: 10.1785/0220200448.

Thank You!

These great data and networks have been made possible by the dedicated staff at ASL, IDA, IRIS, GEOSCOPE, BFO. We have also benefited from the technological advances made by GEOSCOPE, E. Wielandt, G. Streckeisen, J. Steim, J. Berger, T van Zandt, and others. Many of the improvements in the data have been motivated by data users from the Lamont CMT project, USGS NEIC, IPGP, and IDA.

We look forward to many more decades of collaborating with GEOSCOPE