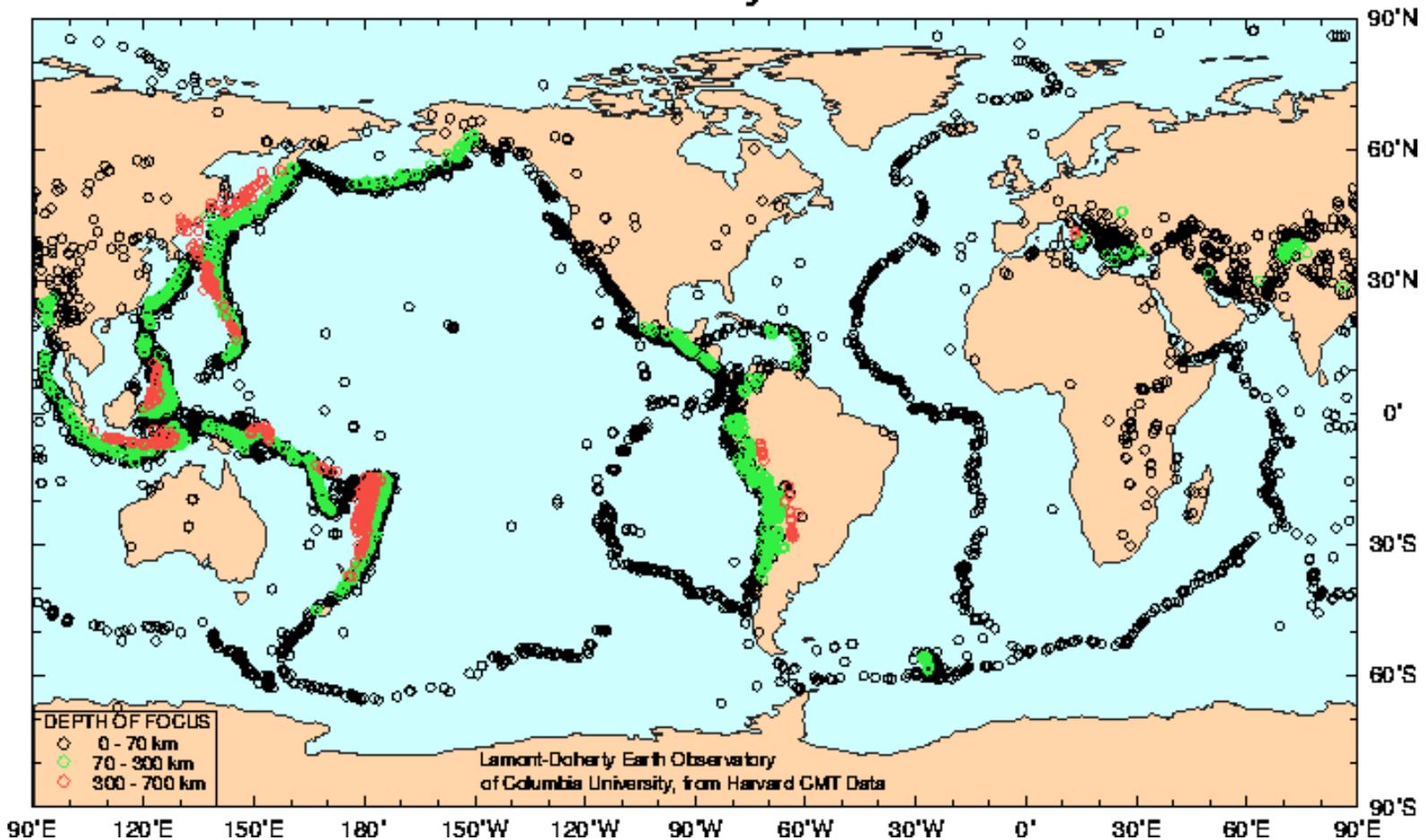


Global Nuclear Explosion Monitoring

Jay Zucca, Presenting
Lawrence Livermore National Laboratory
September 2006

Natural events occur world wide

World Seismicity 1977-1992



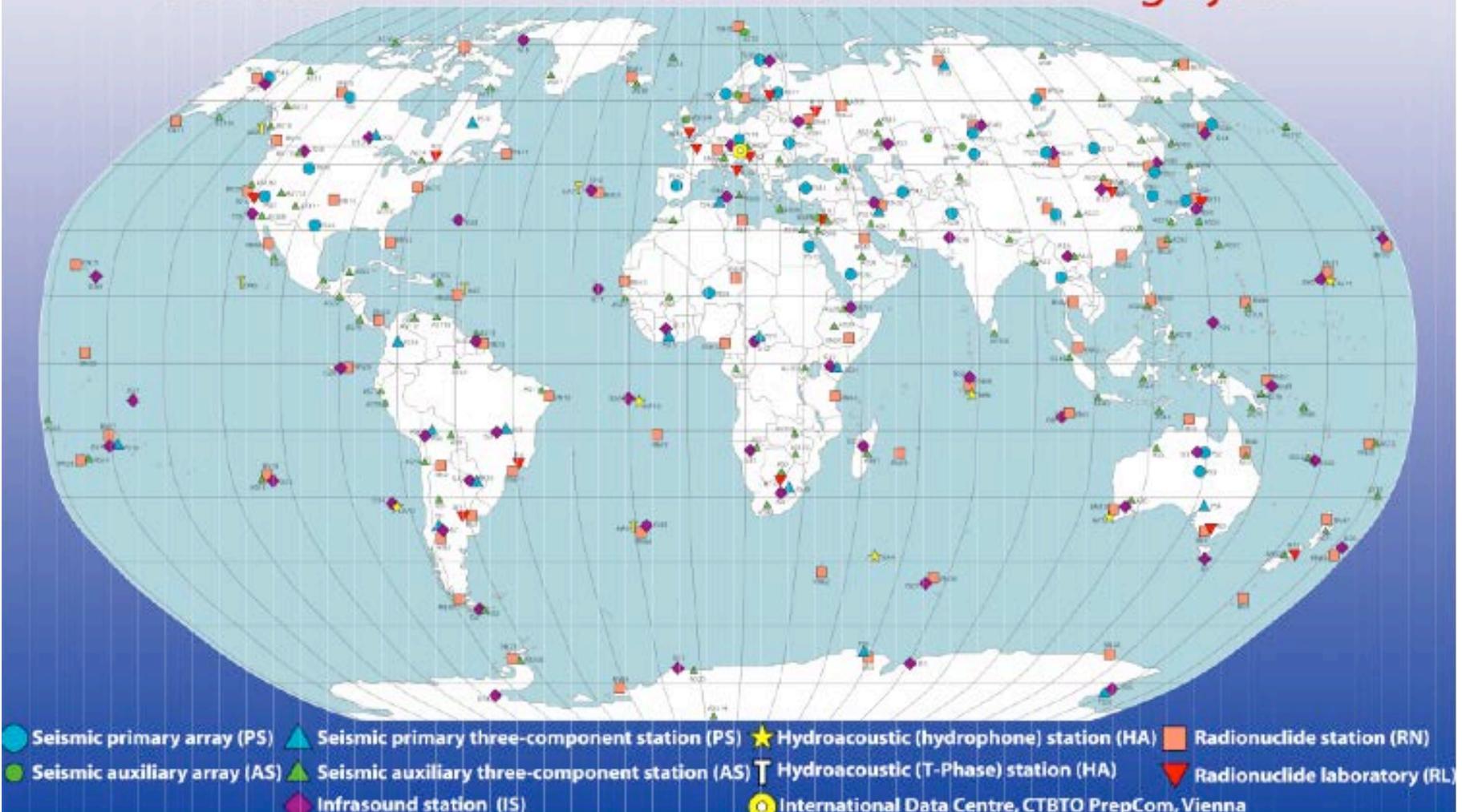
From Columbia University website

Networks such as the International Monitoring System can detect events down to a threshold



Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty (CTBTO)

Facilities of the CTBT International Monitoring System



Example of a seismic station



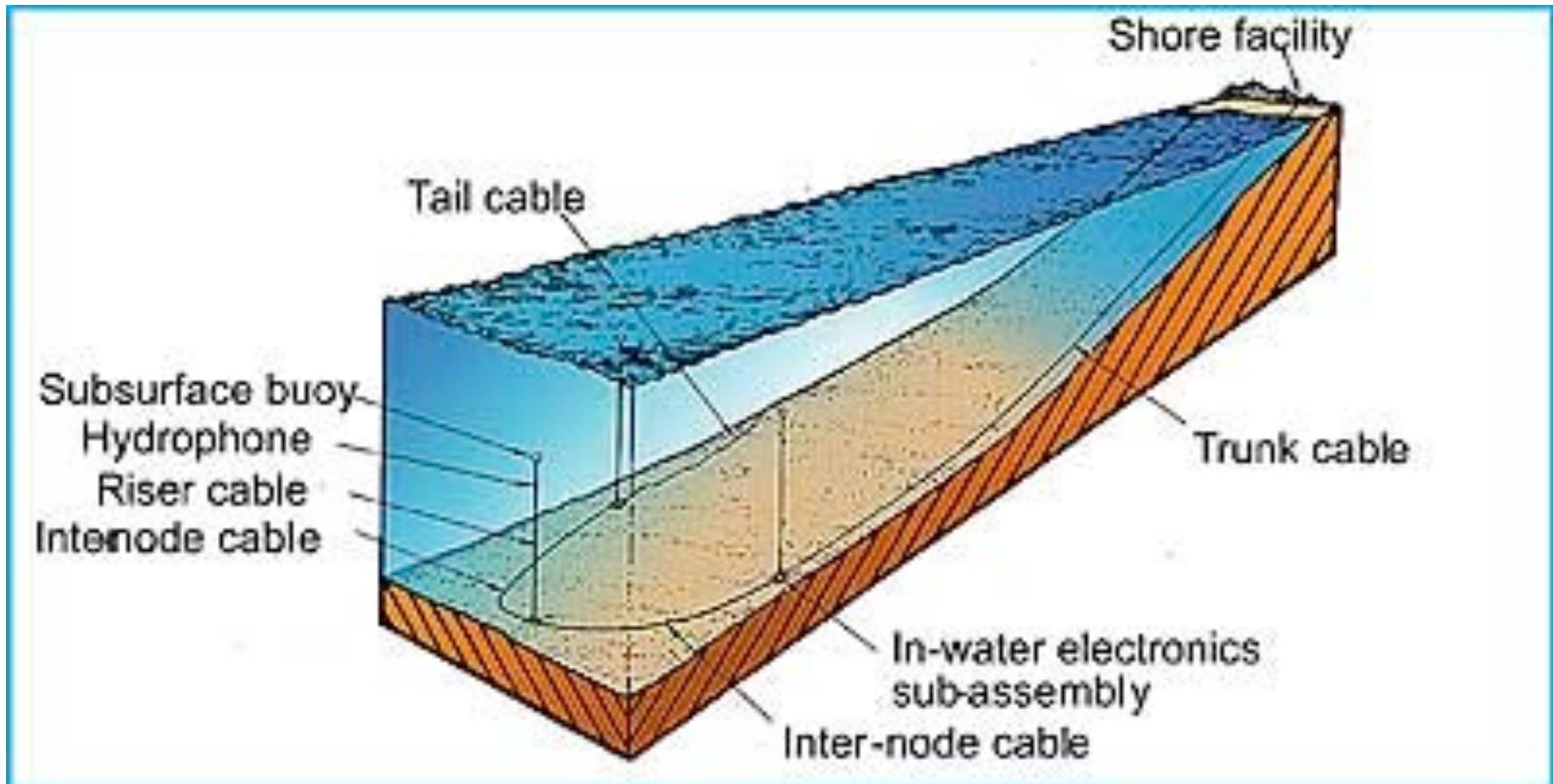
From CTBTO website

Example of an Infrasound/Radionuclide Station

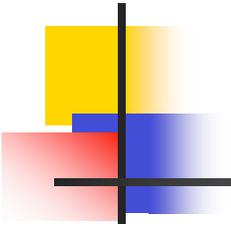


From CTBTO website

Example of a hydroacoustic station



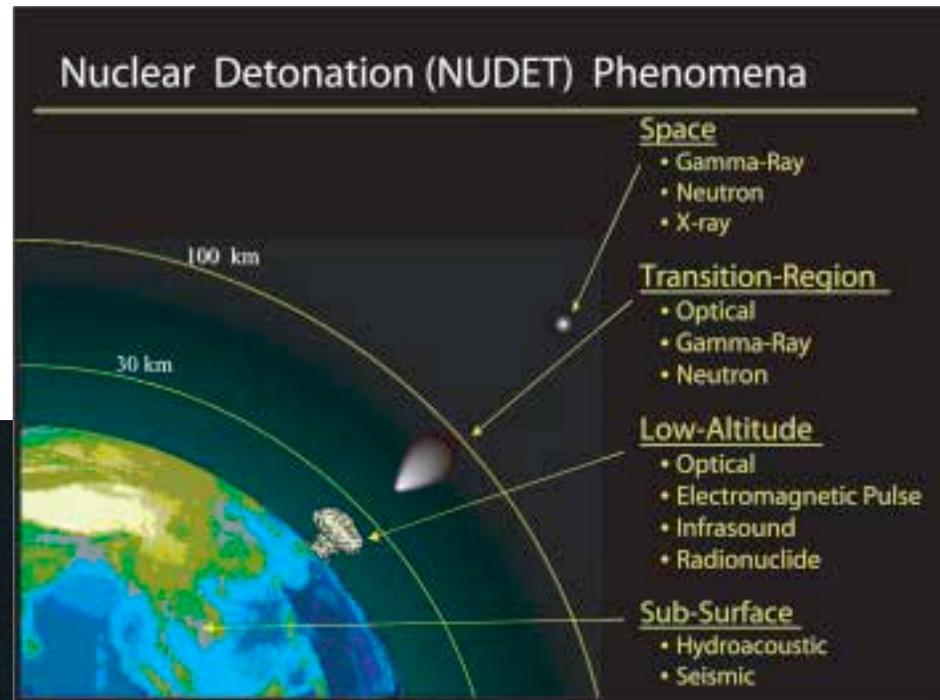
From CTBTO website



As part of the overall nuclear non-proliferation program, the U.S. Government monitors for potential nuclear weapons testing

- **Various Executive Branch agencies contribute to this mission:**
 - Air Force Technical Applications Center
 - Air Force Geophysics Laboratory
 - Department of Energy's National Nuclear Security Administration
 - Lawrence Livermore National Laboratory
 - Los Alamos, Sandia, and Pacific Northwest National Laboratories

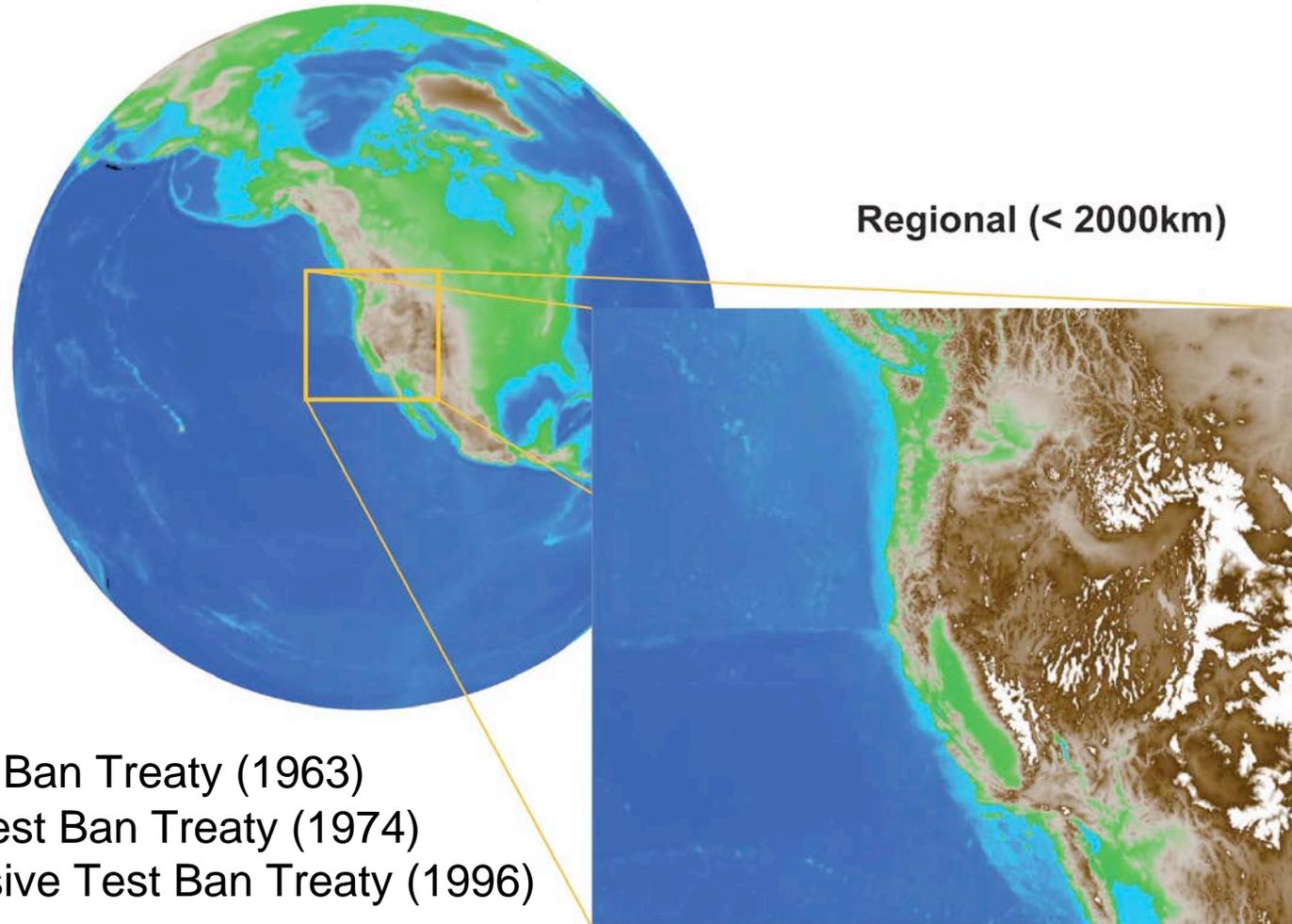
U.S. sponsors satellite monitoring



From NNSA NEM Strategic Plan

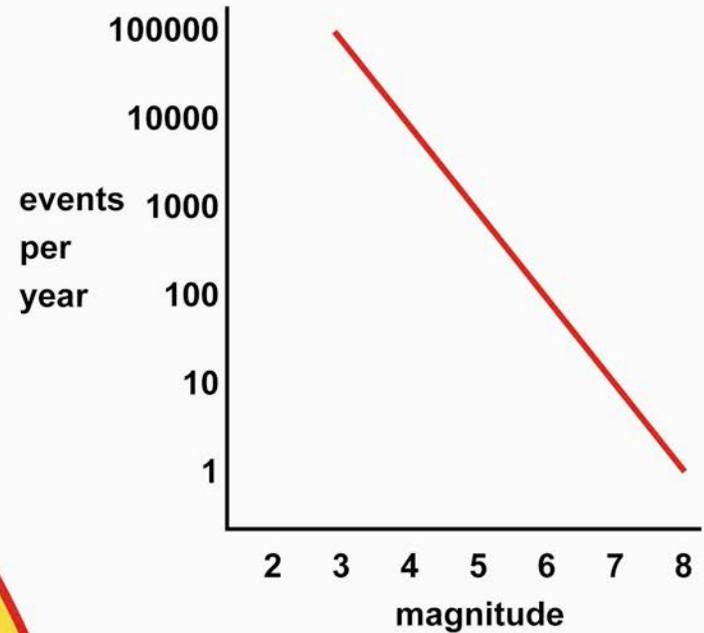
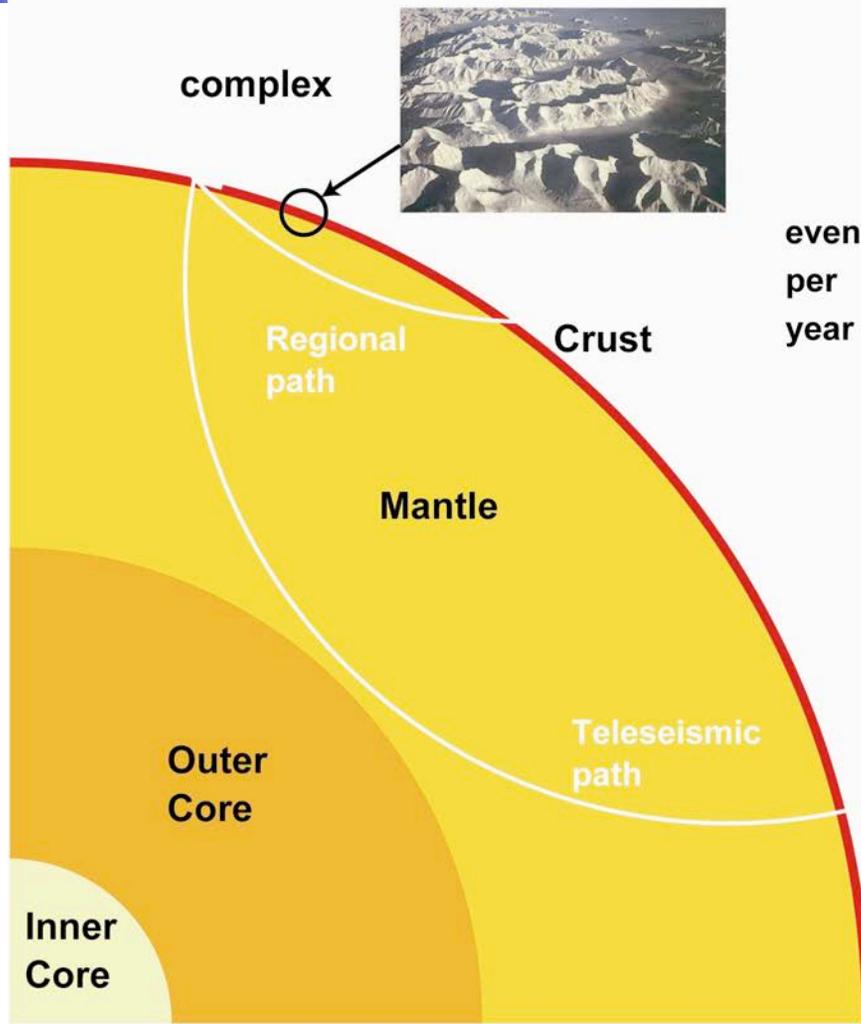
The progression of test ban treaties is driving monitoring from teleseismic to regional distance

Teleseismic (Global)



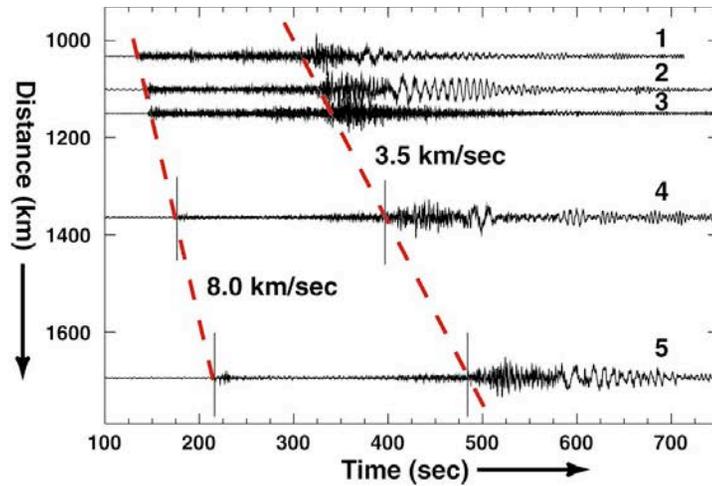
- Limited Test Ban Treaty (1963)
- Threshold Test Ban Treaty (1974)
- Comprehensive Test Ban Treaty (1996)

Why are regional monitoring and calibration difficult problems?

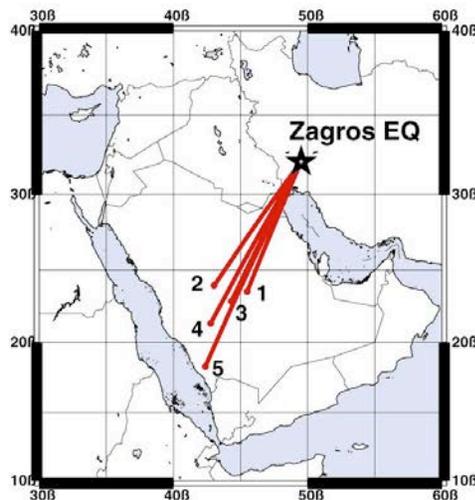


- the number of events increases exponentially with decreasing magnitude
- smaller events have to be observed on shorter paths confined to the upper mantle and crust

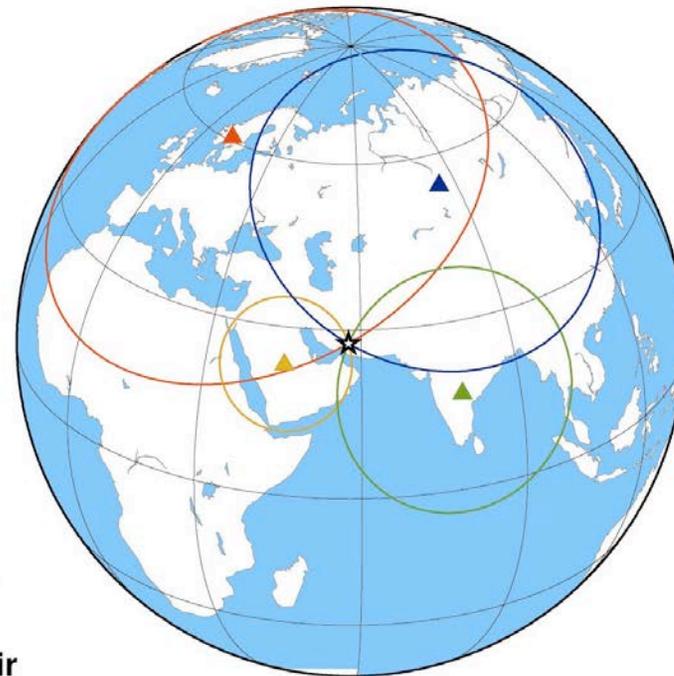
Event location is performed by triangulation of seismic wave arrival times



Different seismic waves travel at different speeds

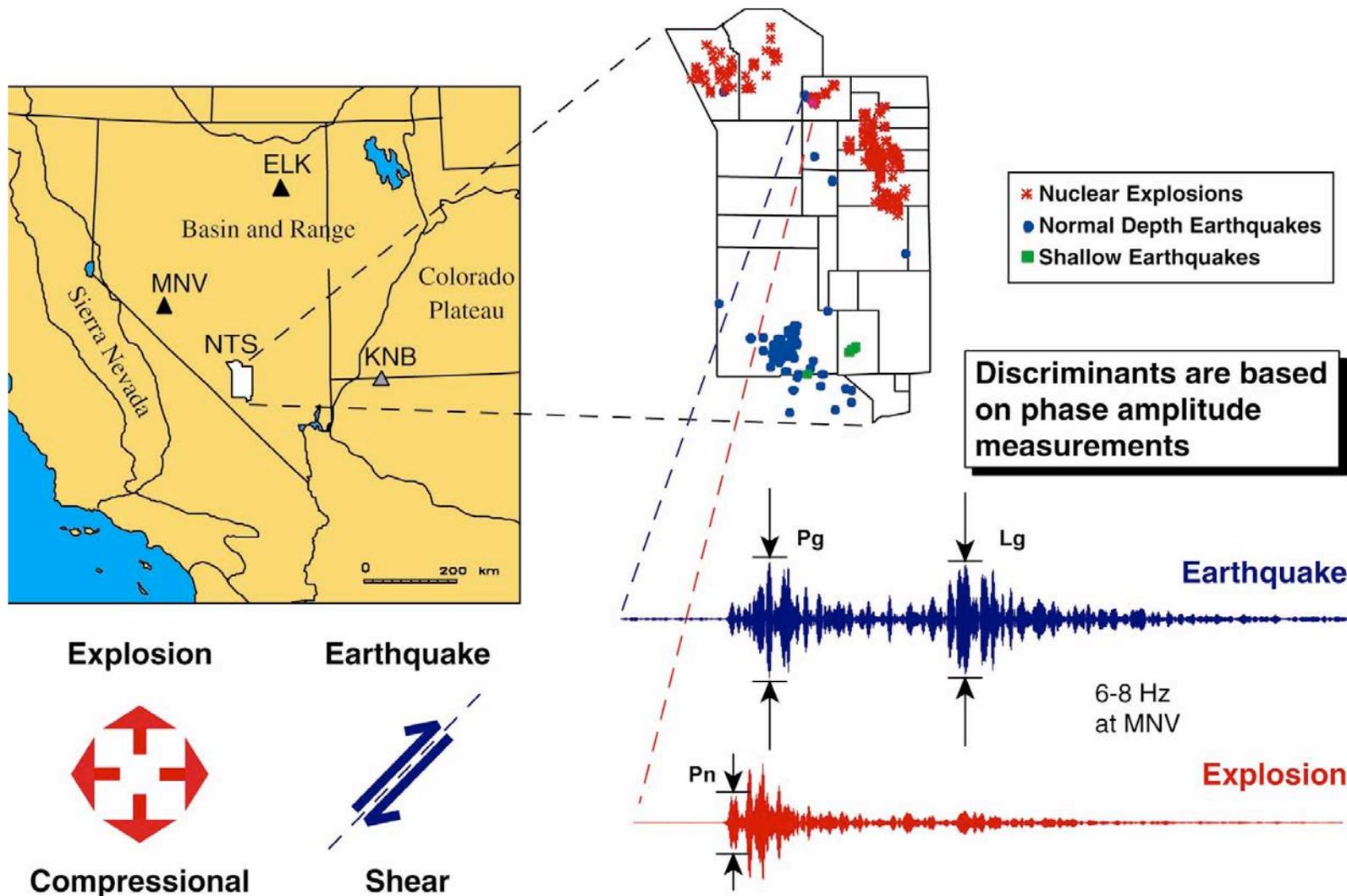


The travel times of seismic waves increase with distance from their source, and ...



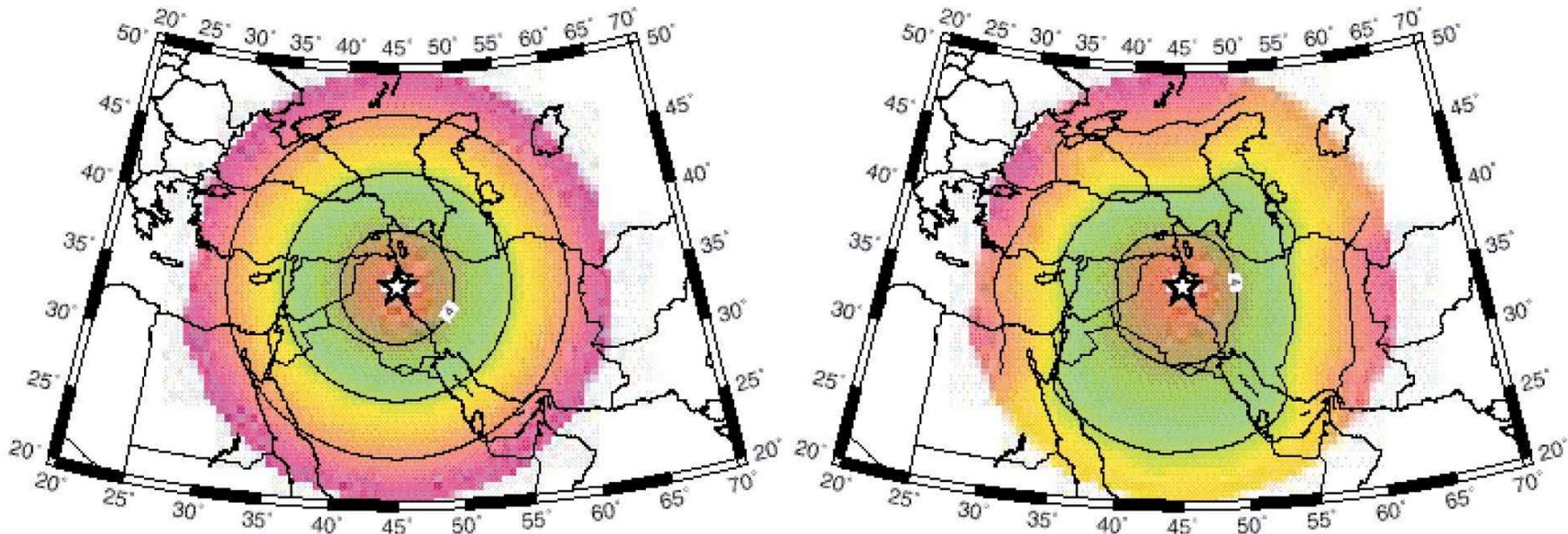
... measured arrival times are used to estimate the source origin time and triangulate the source location

Event discrimination is performed by measuring the relative amplitudes of different seismic waves



The Knowledge Base is needed because wave propagation in the earth is not uniform

Seismic travel times from a point in the Middle East

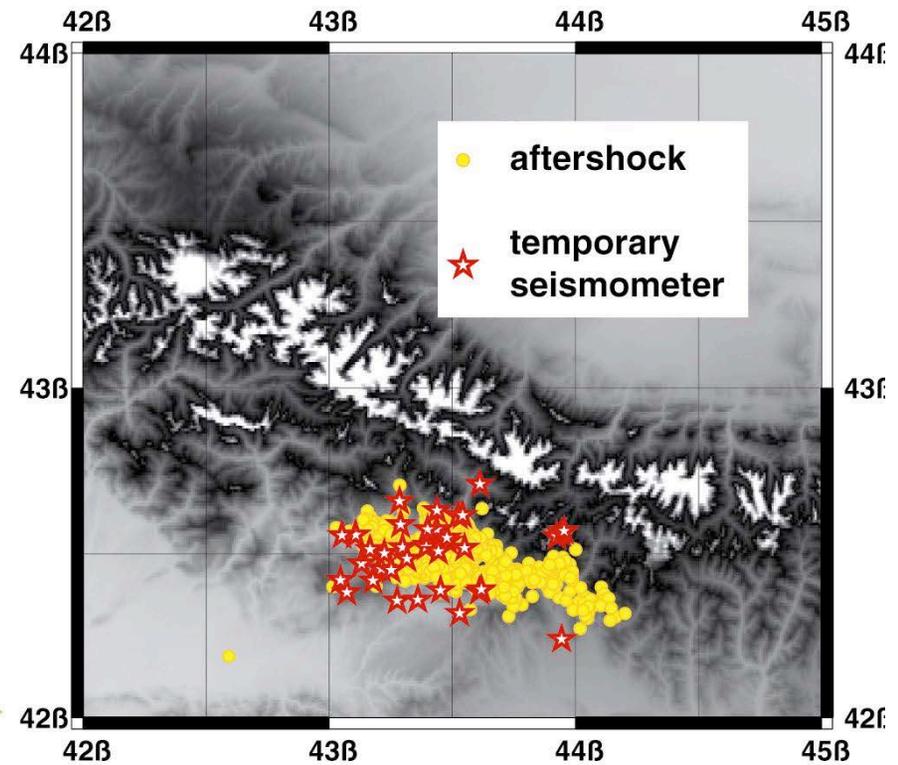
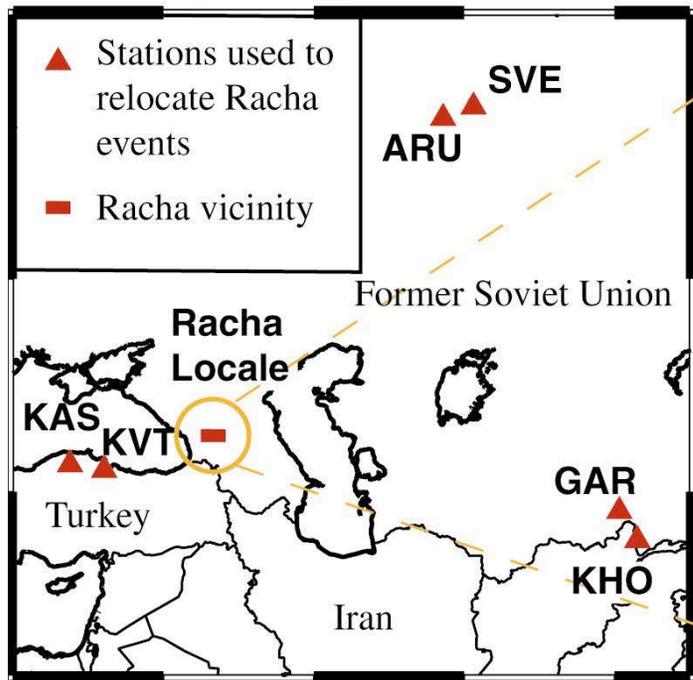


Assumed Uniform World

The Actual Situation

End-to-end tests validate calibrations: earthquake aftershocks test location capability

Racha, Georgia

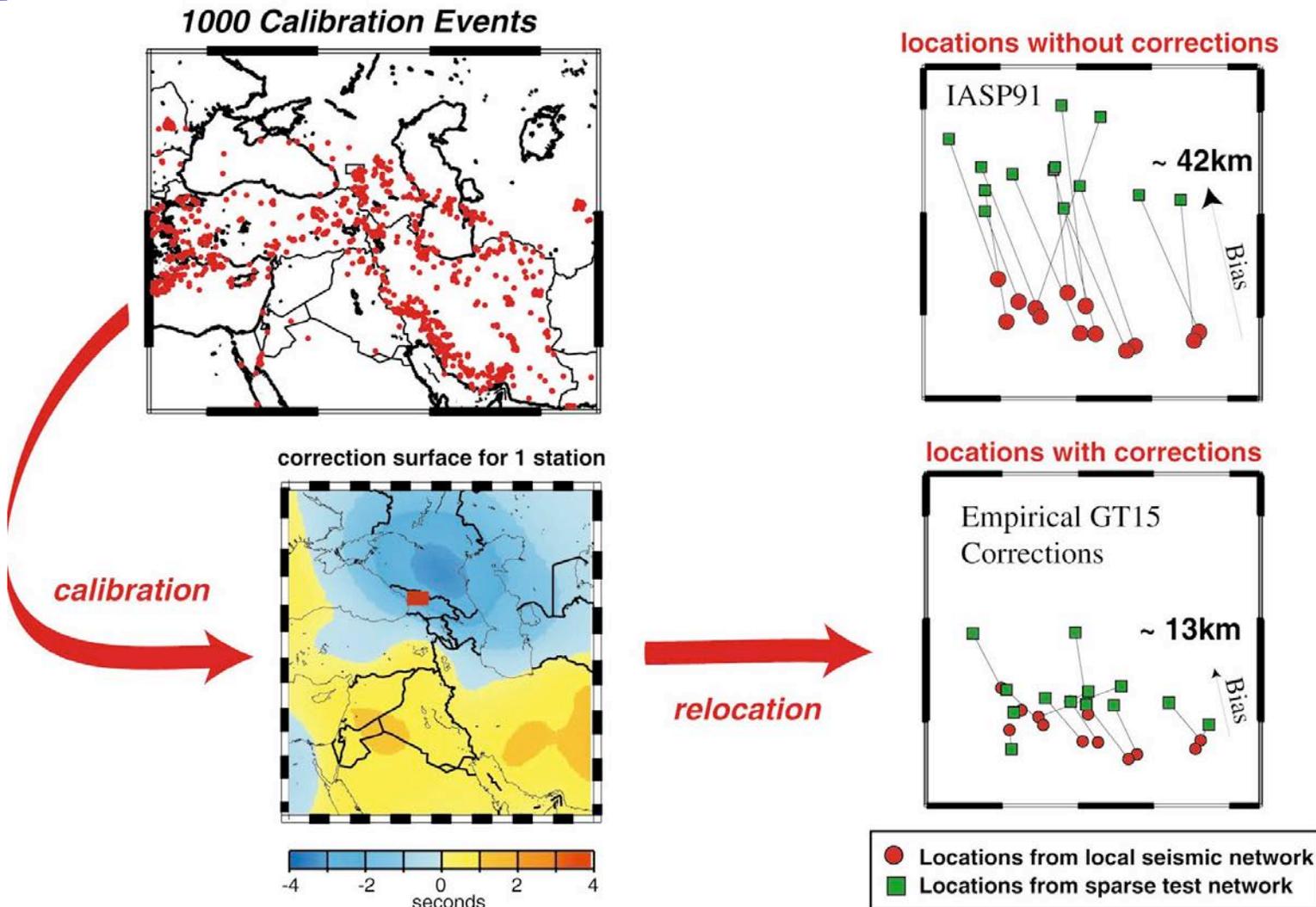


1991 Aftershock Sequence

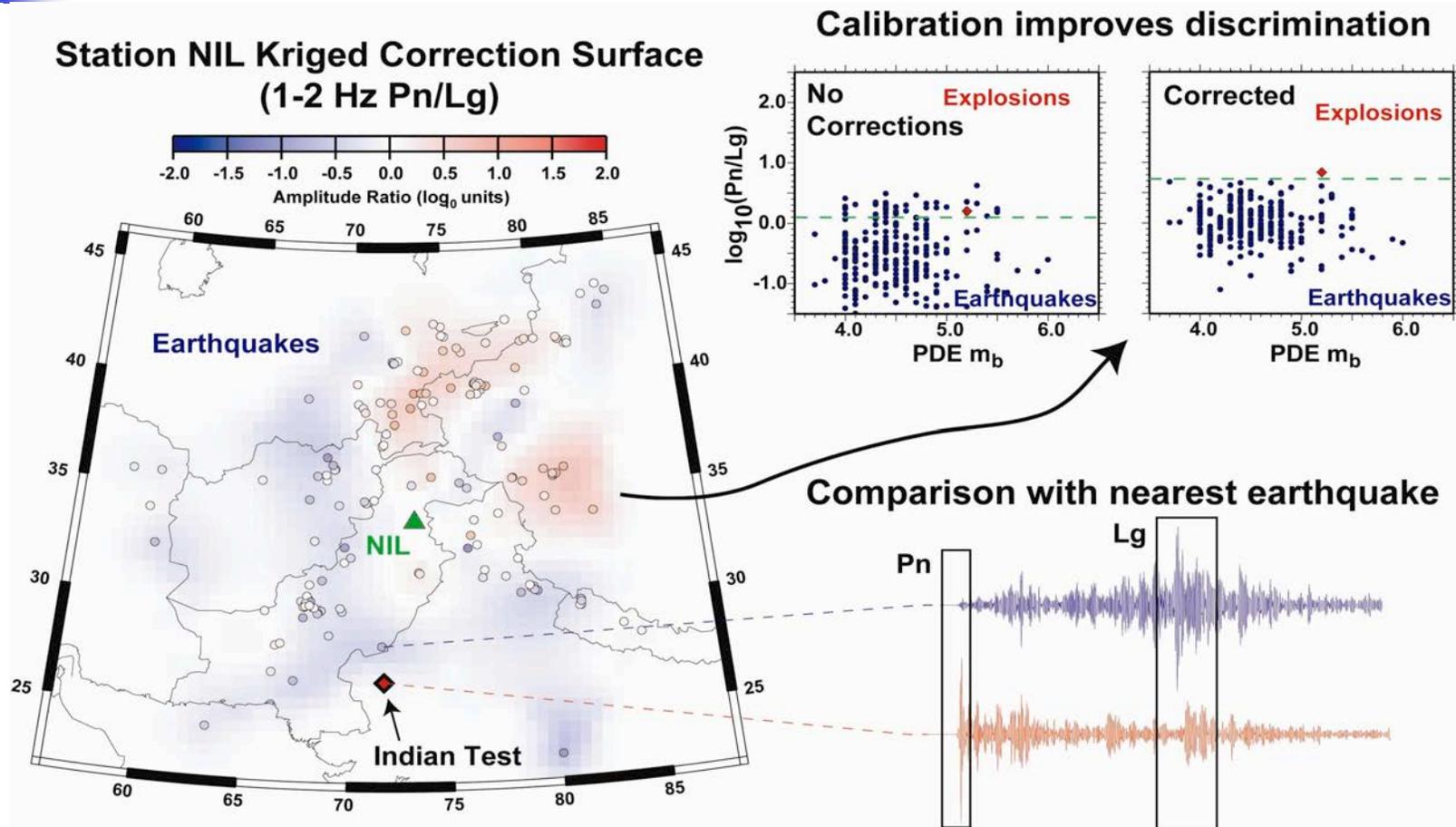
- 13 events with known locations
- sparse network relocation

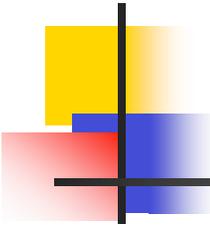
Ground truth from a dense local network

Relocating the Racha earthquake sequence with and without corrections shows calibration value



Path corrections significantly improve discrimination





Conclusion

- **Nuclear explosion monitoring is well developed across many technologies worldwide**