Better Seismic Event Locations Using Geographically Registered Master Events

2023 MTV Workshop

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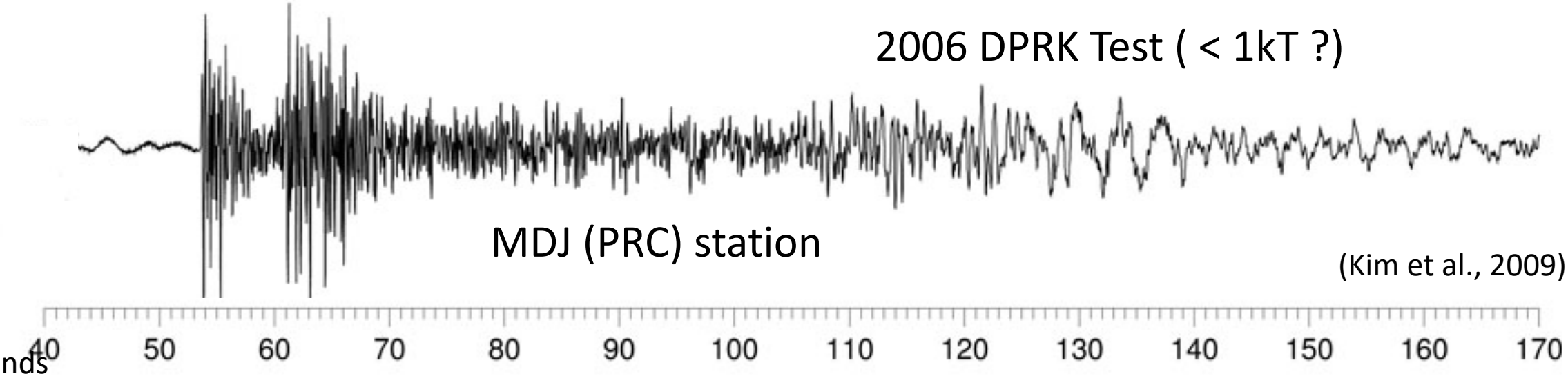
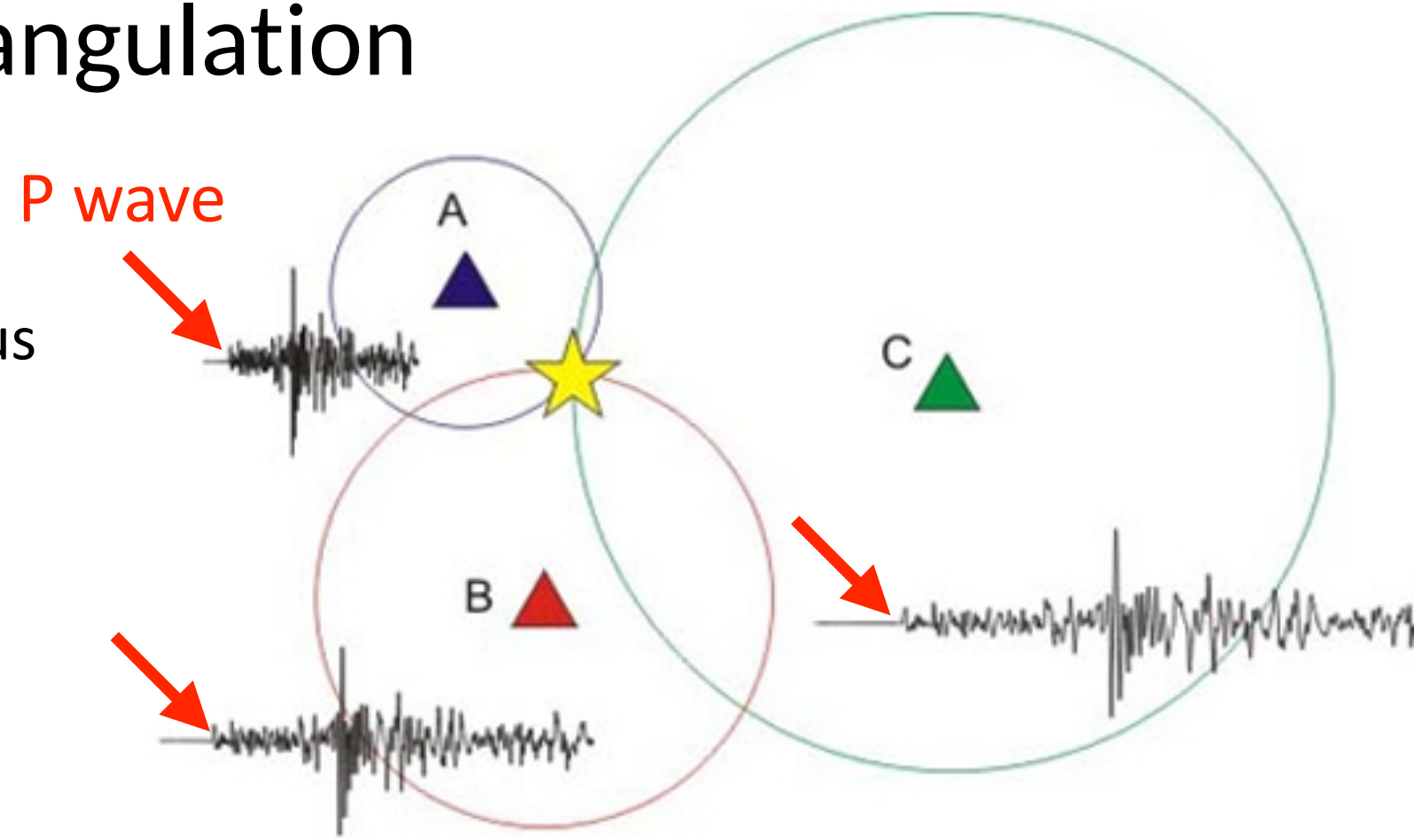
Introduction and Motivation

Elastic waves recorded by seismometers are used to (1) detect, (2) locate, and (3) characterize/discriminate seismic events (earthquakes, explosions, cavity collapses, volcanic unrest, bolides, landslides, …)



Classic (and current) methods of event location use delay-time triangulation

Challenges:
(1) The Earth is heterogeneous
(2) Different types of waves
(3) The Earth is attenuating
(4) The Earth is anisotropic
(5) Signals are noisy



British Geological Survey

CTBTO Monitoring

Seismic Stations:

50 Primary
120 Auxiliary

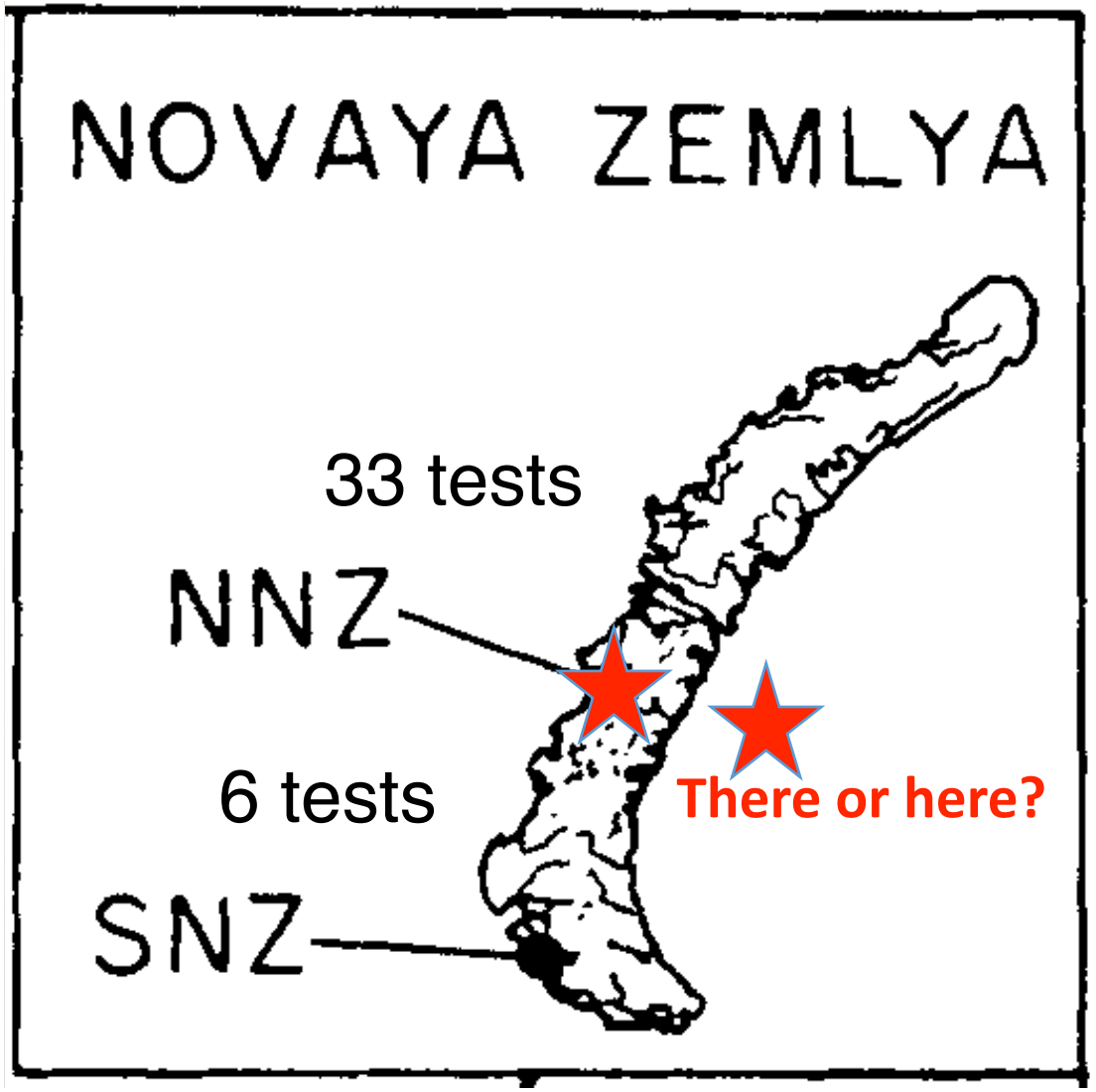
The International Data Center generates a global Reviewed Event Bulletin. It complements catalogs by the USGS and many national and regional agencies, and classified ones by AFTAC and analogous organizations.

Mission Relevance

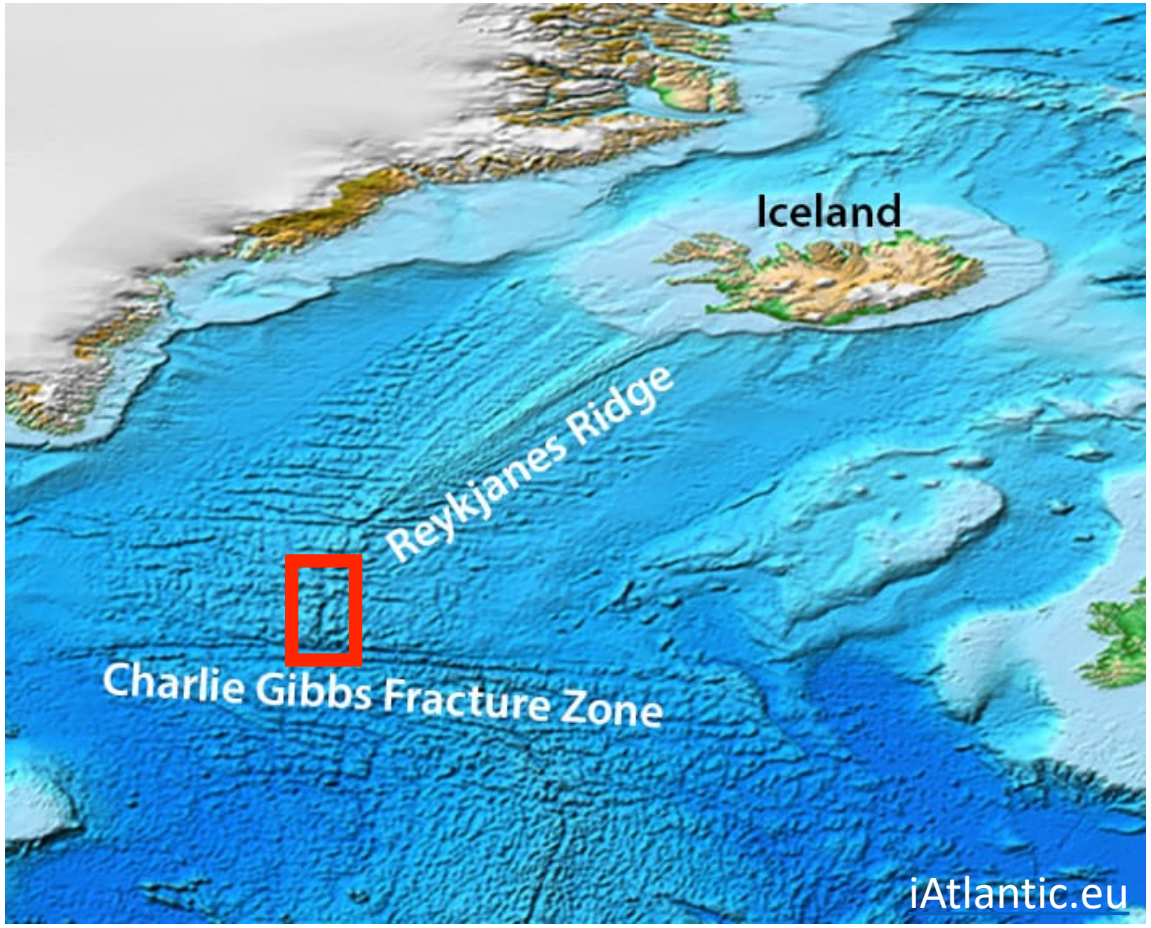
Accurate and precise locations of earthquakes and explosions are essential for seismic discrimination, tectonic interpretation, earthquake hazard assessment, and tomographic imaging of Earth's internal structural heterogeneity.

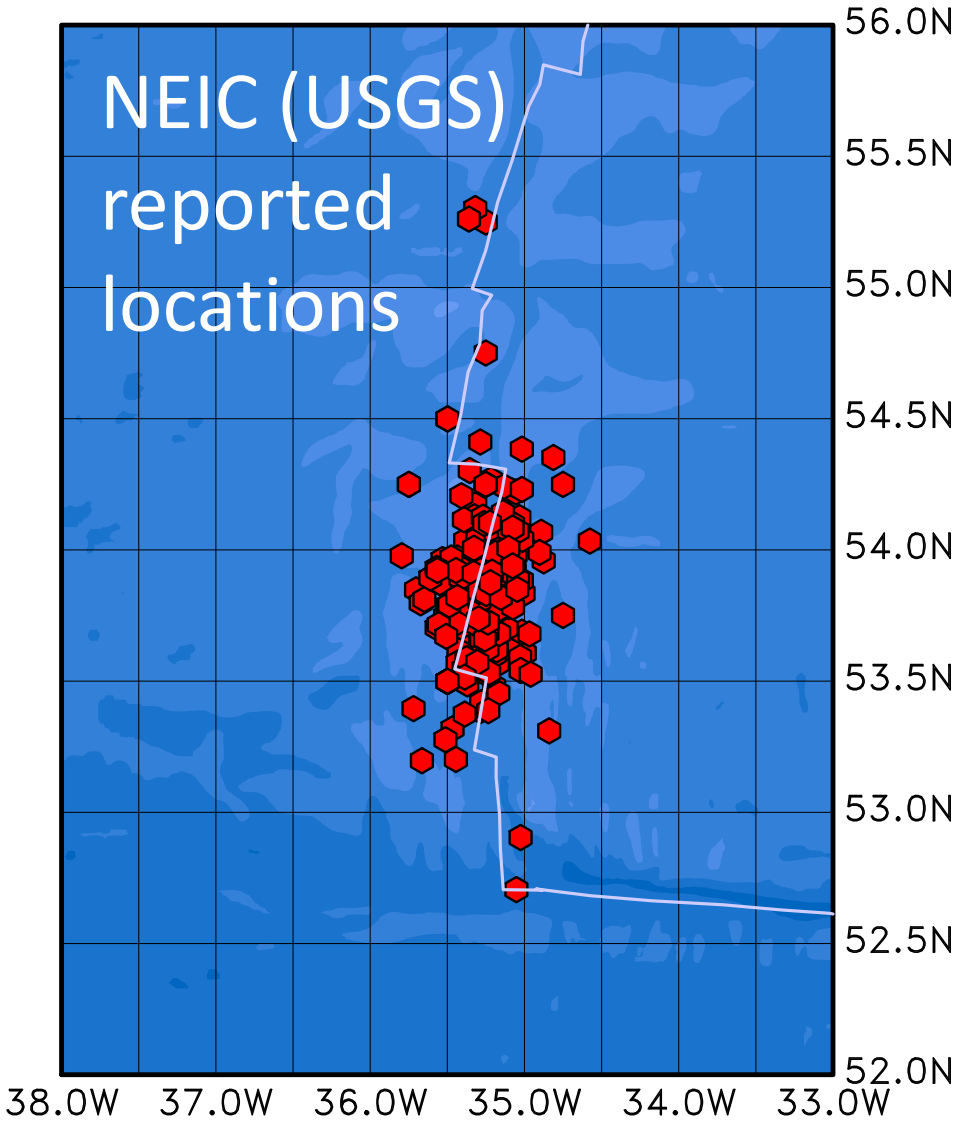
CTBT On-Site Inspection area is limited to 1000 square km.

Typical location error/uncertainty is 20+ kilometers.

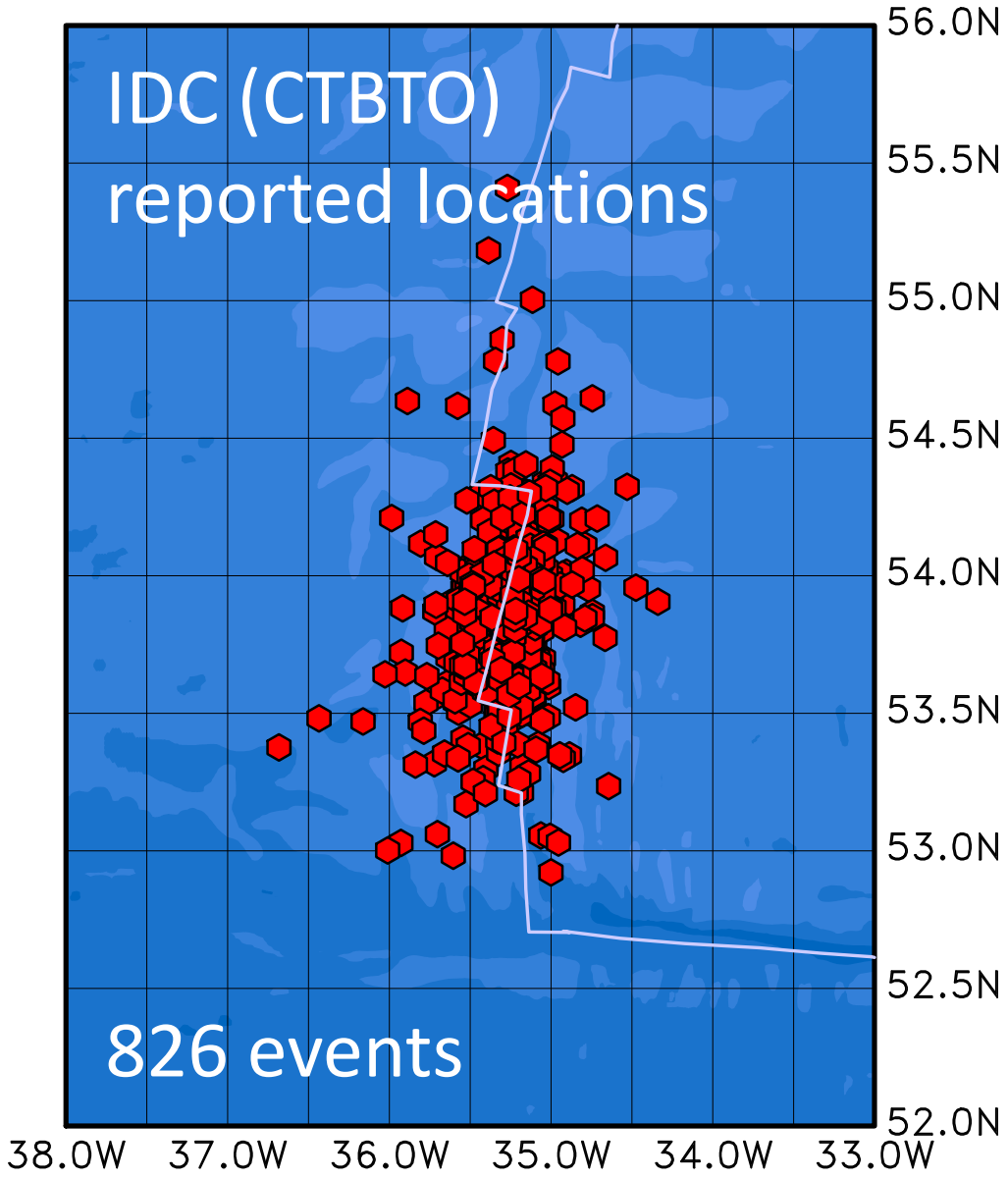


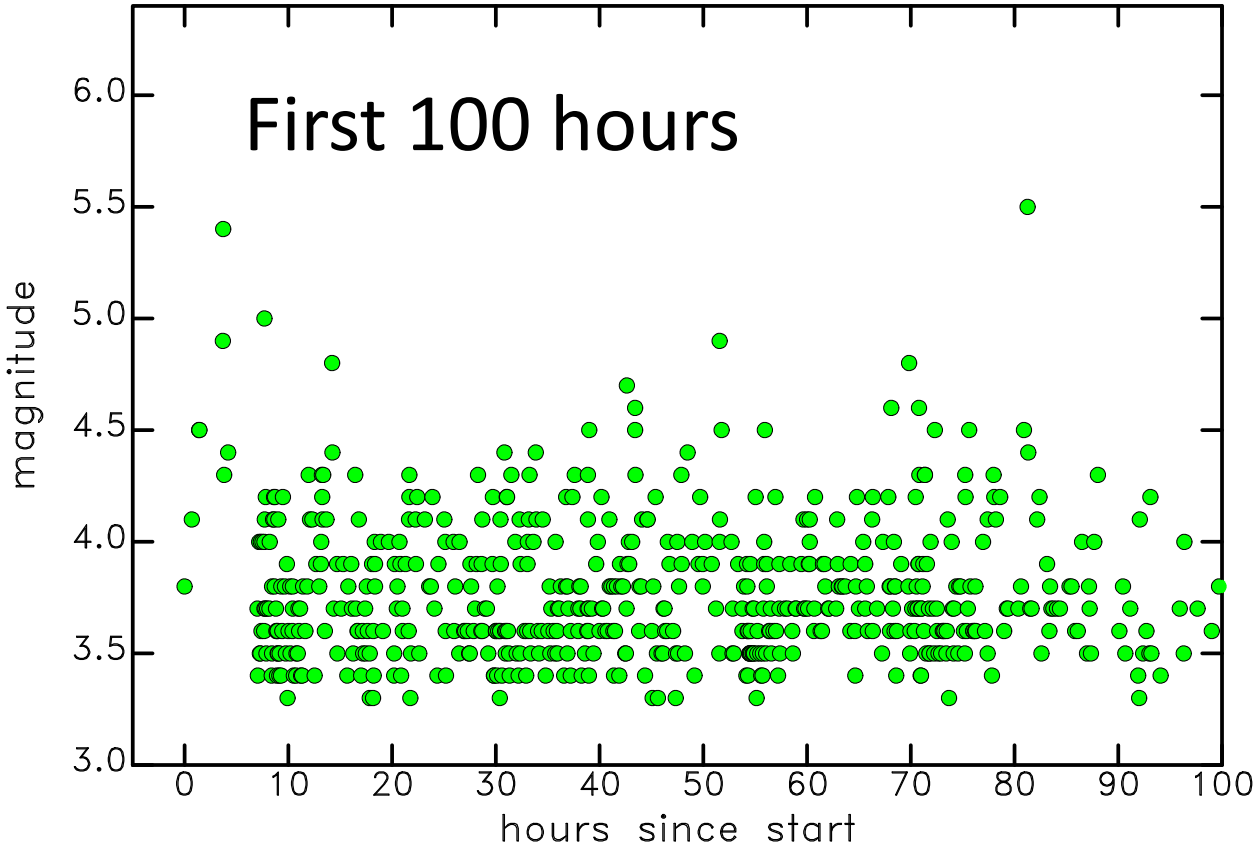
A seismic swarm on the Reykjanes Ridge, September 2022





Classic swarm behavior: many earthquakes of similar size





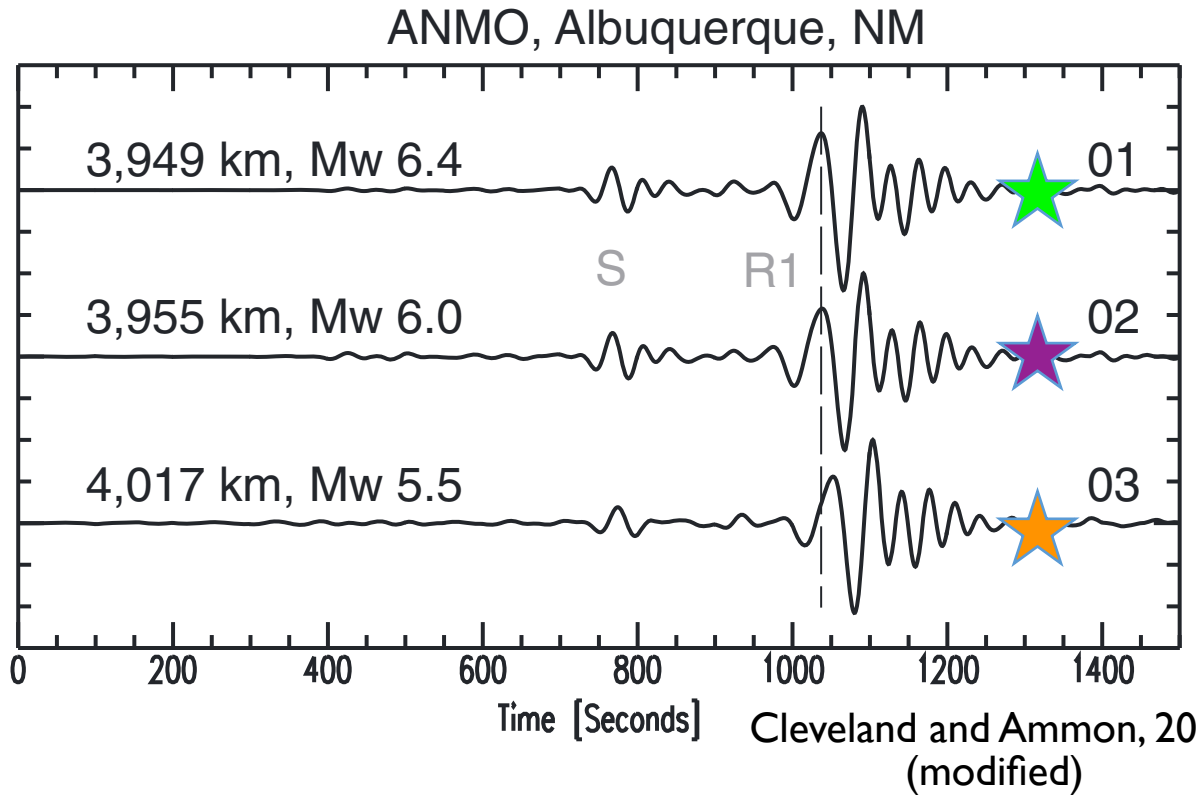
Technical Approach

Station ANMO

Seismic events

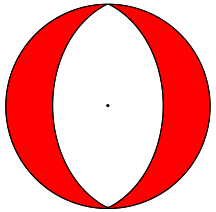
(1) Cross correlate signals for high-precision differential delay times

(2) Solve for relative locations of events in cluster



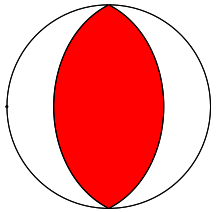
Cleveland and Ammon, 2013 (modified)

Focal mechanisms (`stress release')

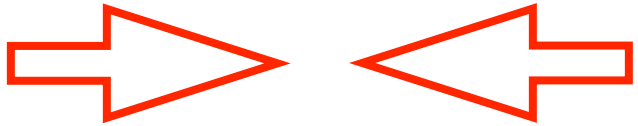


Horizontal extension

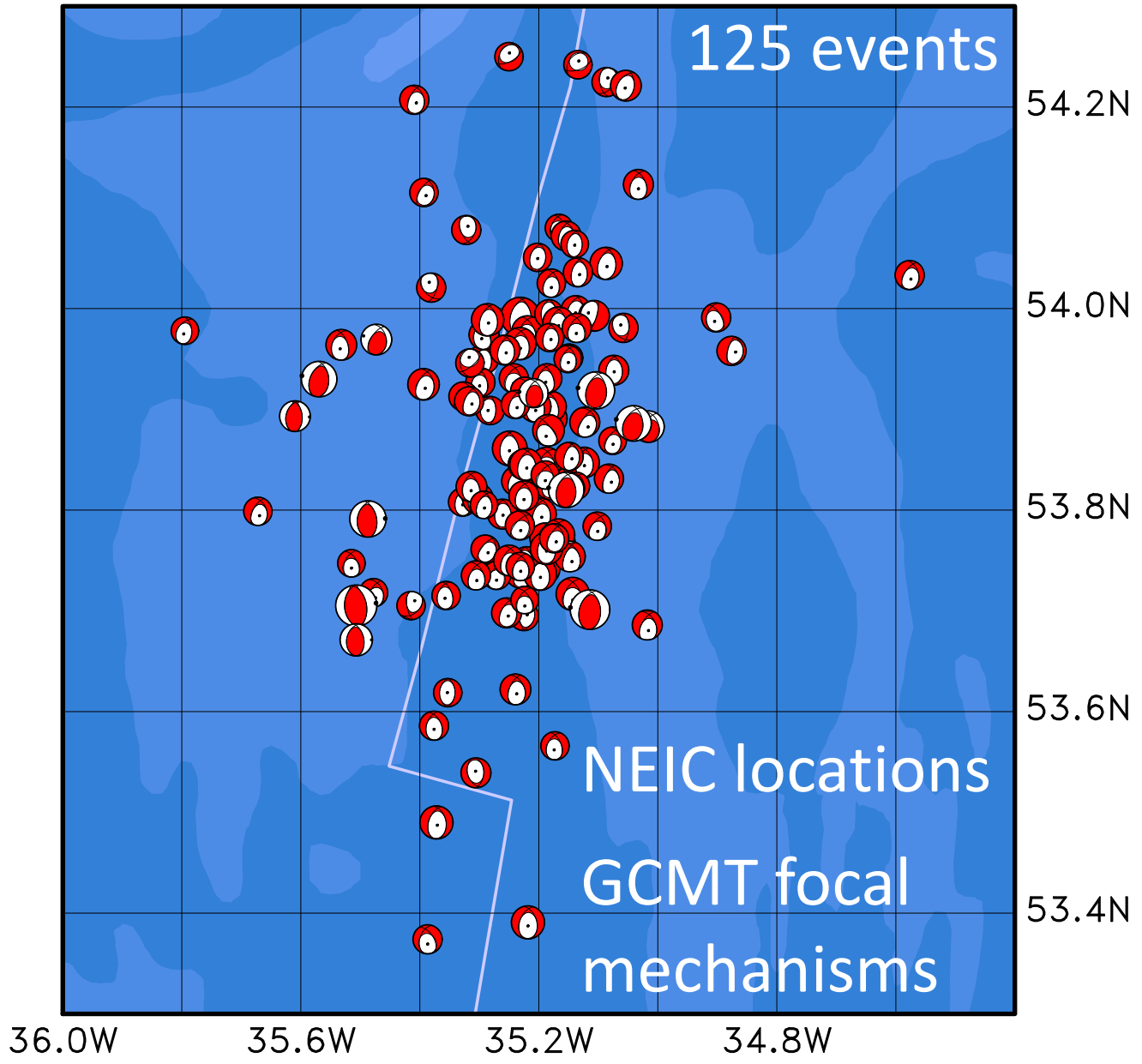
expected



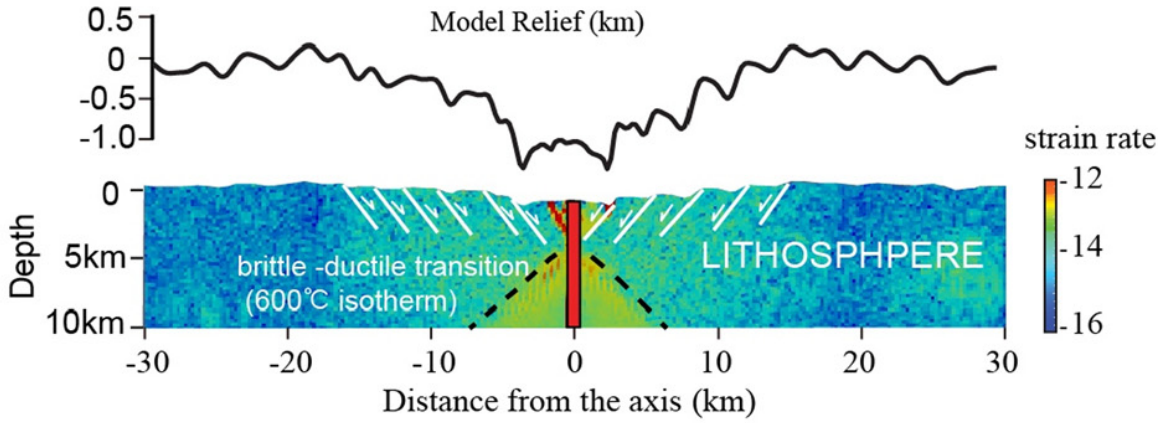
Horizontal compression

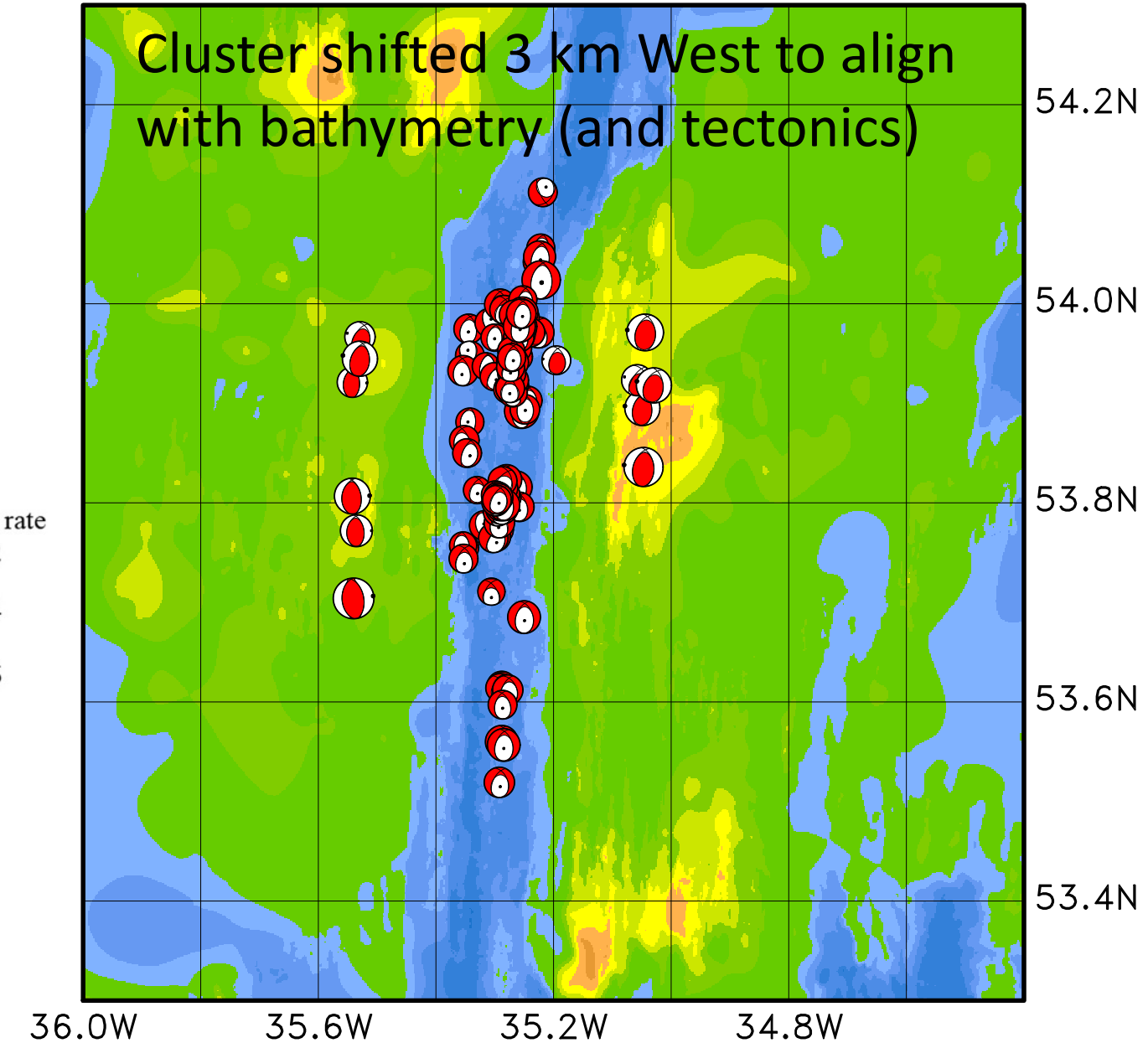


not expected

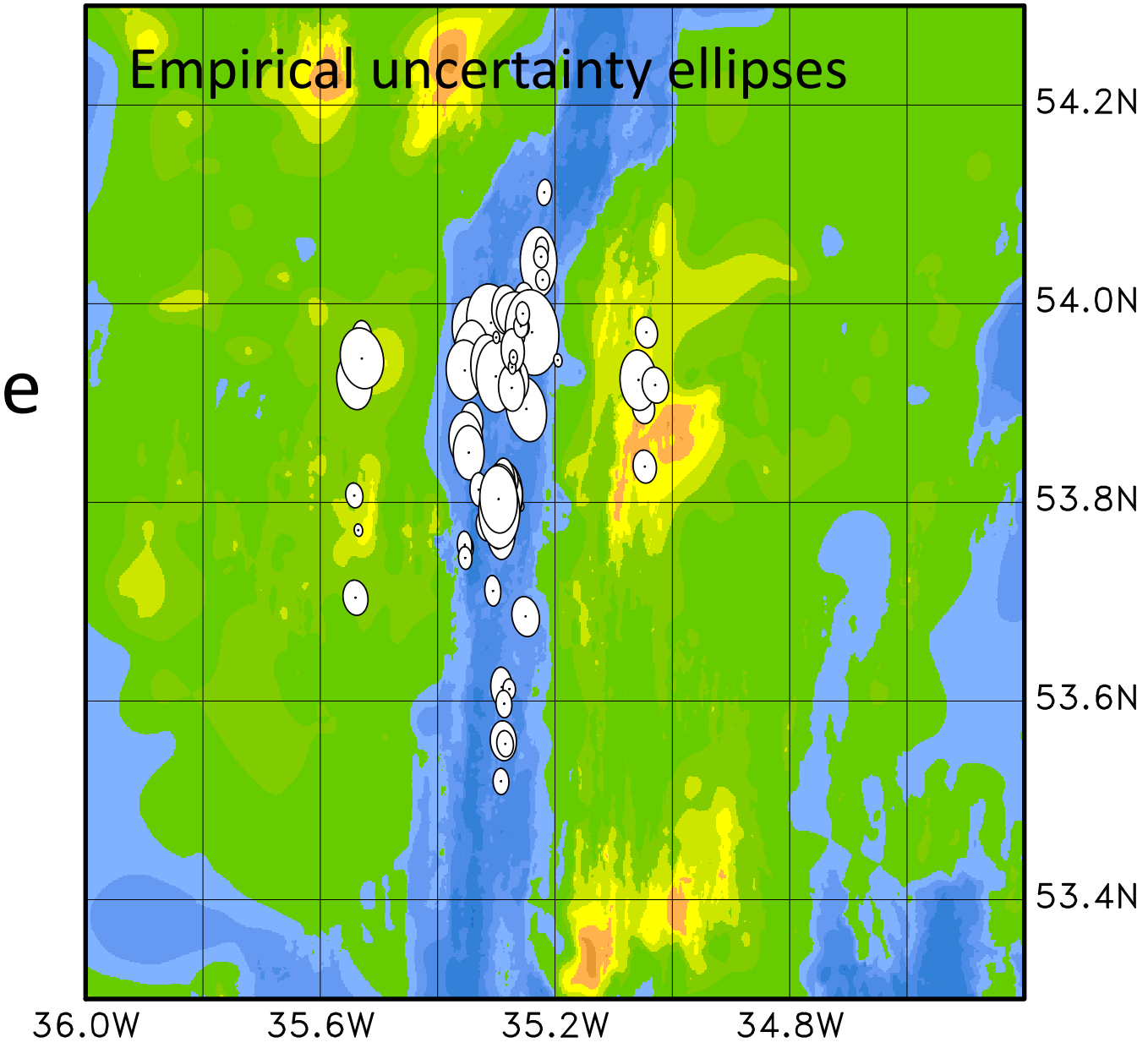


Cluster relocation and alignment with detailed bathymetry

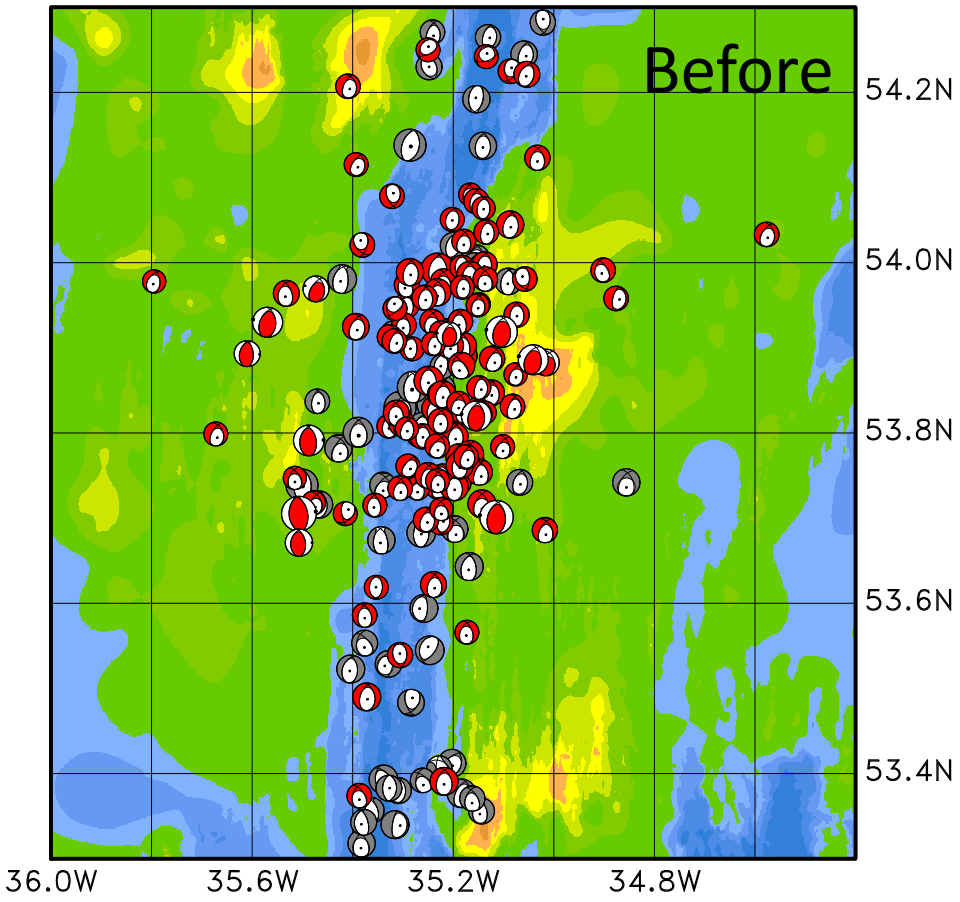


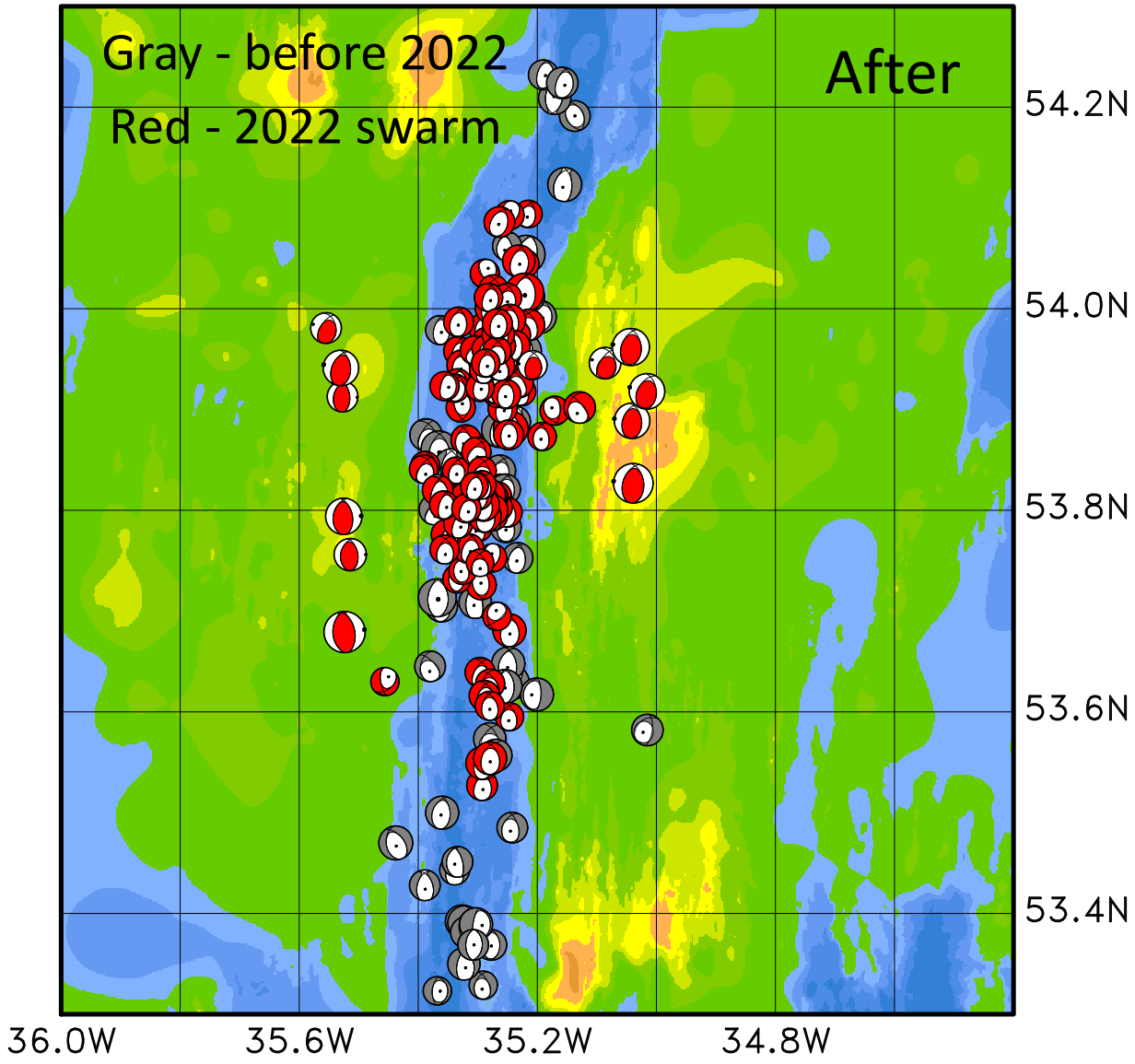


The best-located and geographically referenced earthquakes become `master events' for relative location of additional events



Relocation of all earthquakes in GCMT catalog (1976-2022) using geographically registered master events





Conclusions

(General) - a cluster of master events can be defined by geographically registering a cluster of internally well-located events with tectonic features

(General) - location w.r.t. a master-event cluster can reduce location uncertainty by a factor of 5

(Specific) - precise locations allows identification of earthquakes showing `wrong' state of stress 20 km off ridge axis - probably reflecting bending stresses in the lithosphere

Next Steps

(Scientific) - explain the occurrence and locations of the anomalous compressional earthquakes

(Technical) - improve estimates of location uncertainty and refine criteria for successful geographical registration

(General) - contribute event information to IASPEI ground-truth reference-event database

(General) - develop and demonstrate approaches to making master-event-cluster location operational

Acknowledgements

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