Celebrating GEOSCOPE!

40 Years of Analyses of Seismic Sources with Global Broadband Data

Göran Ekström

1989 - my year with GEOSCOPE

Eos, Vol. 70, No. 28, July 11, 1989

Romanowicz & Ekström, 1989

Forum

Macquarie Earthquake of May 23, 1989

The Largest Strike-Slip Event in More Than 10 Years

PAGE 700

We read with great interest the news report in *Eos* (June 16, 1989) on the very large Macquarie earthquake of May 23, 1989, which left U.S. scientists divided as to whether this earthquake was of strike slip or thrust type or a mixture of both.

Indeed, we think we have the solution to this dilemma, since thanks to teletransmitted data from 11 Geoscope stations recording both very long-period and broad band data, we were able to obtain a reliable preliminary mechanism less than 48 hours after this earthquake occurred. Figure 1 shows this mechanism, which is a practically pure right-lateral strike slip, consistent with the general trend in the Macquarie ridge area as indicated from the CMT catalog for the past 10 years [*Dziewonski et al.*, 1989], and in particular, very similar to the mechanisms of the two largest events which occurred in this area in this time period (May 25, 1981 and July 7, 1982). By moment tensor inversion of very long-period Rayleigh waves, we obtained a moment of 2.2×10^{28} dyne-cm and a centroid time of 28 s, which yields a rating for this earthquake as "average-to-fast" with respect to the moment/duration relation. So far, we haven't found any conclusive evidence for strong horizontal directivity, while it seems that the rupture may have extended down to (or up from) at least 40 km. These features of the solution offer a good explanation as to why no tsunami was observed for this earthquake. The confidence in our "very-long period" solution comes from its very good compatibility with broad band data from the three teletransmitted Geoscope stations that lie within the epicentral distance range 30°-90° from the epicenter of the Macquarie event, both in terms of mechanism as well as source duration. For shallow earthquakes the earthquake depth and the vertical dip-slip components of faulting are poorly constrained by the very-long period data. The addition of only a few broad band seismograms in the analysis can remove this uncertainty. Figure 2 shows two examples of fits for SH waves obtained in a combined analysis of long-period surface waves and broad band body waves [*Ekstrom*, 1989]. The teleseismic

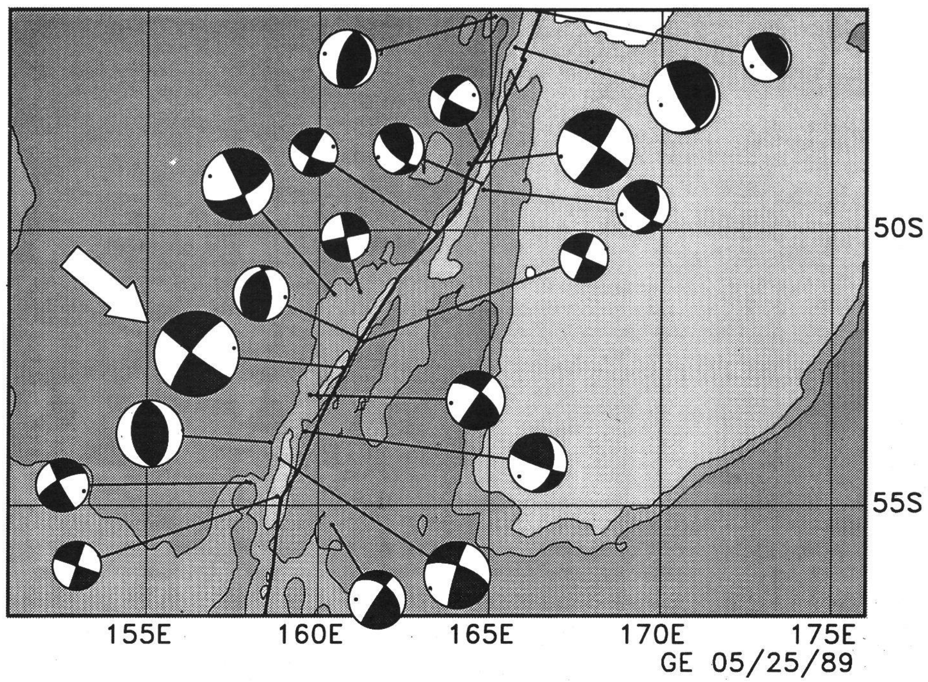


Fig.1. Mechanism of the Macquarie earthquake of May 23, 1989, as obtained from Geoscope very long-period data on May 25 and compared to the CMT catalog in this region for the past 10 years.

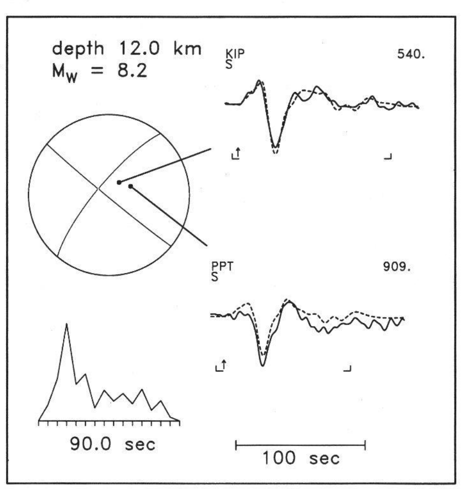
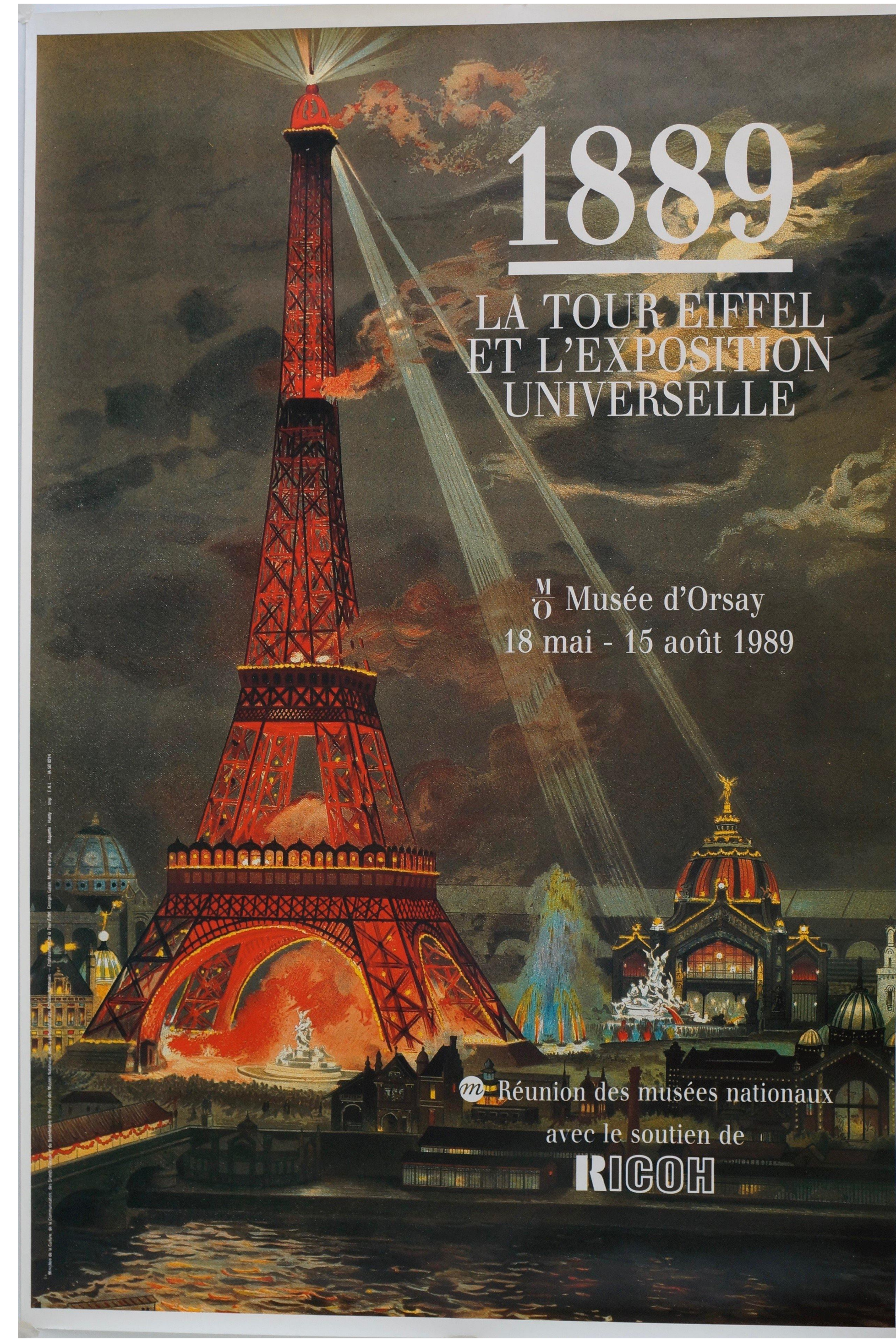


Fig. 2. Macquarie event of May 23, 1989: deconvolved S waves (solid lines) from broad band Geoscope records at stations PPT and KIP, and fit obtained by inversion, assuming the mechanism of Figure 1. Numbers indicate maximum amplitude in microns. The resulting source time function is also given.



Data compression
Time corrections
Multiplexing
Science!

Also 40 years of the Harvard/Global CMT Project!

AN EXPERIMENT IN SYSTEMATIC STUDY OF GLOBAL SEISMICITY: CENTROID-MOMENT TENSOR SOLUTIONS FOR 201 MODERATE AND LARGE EARTHQUAKES OF 1981

Adam M. Dziewonski and John H. Woodhouse

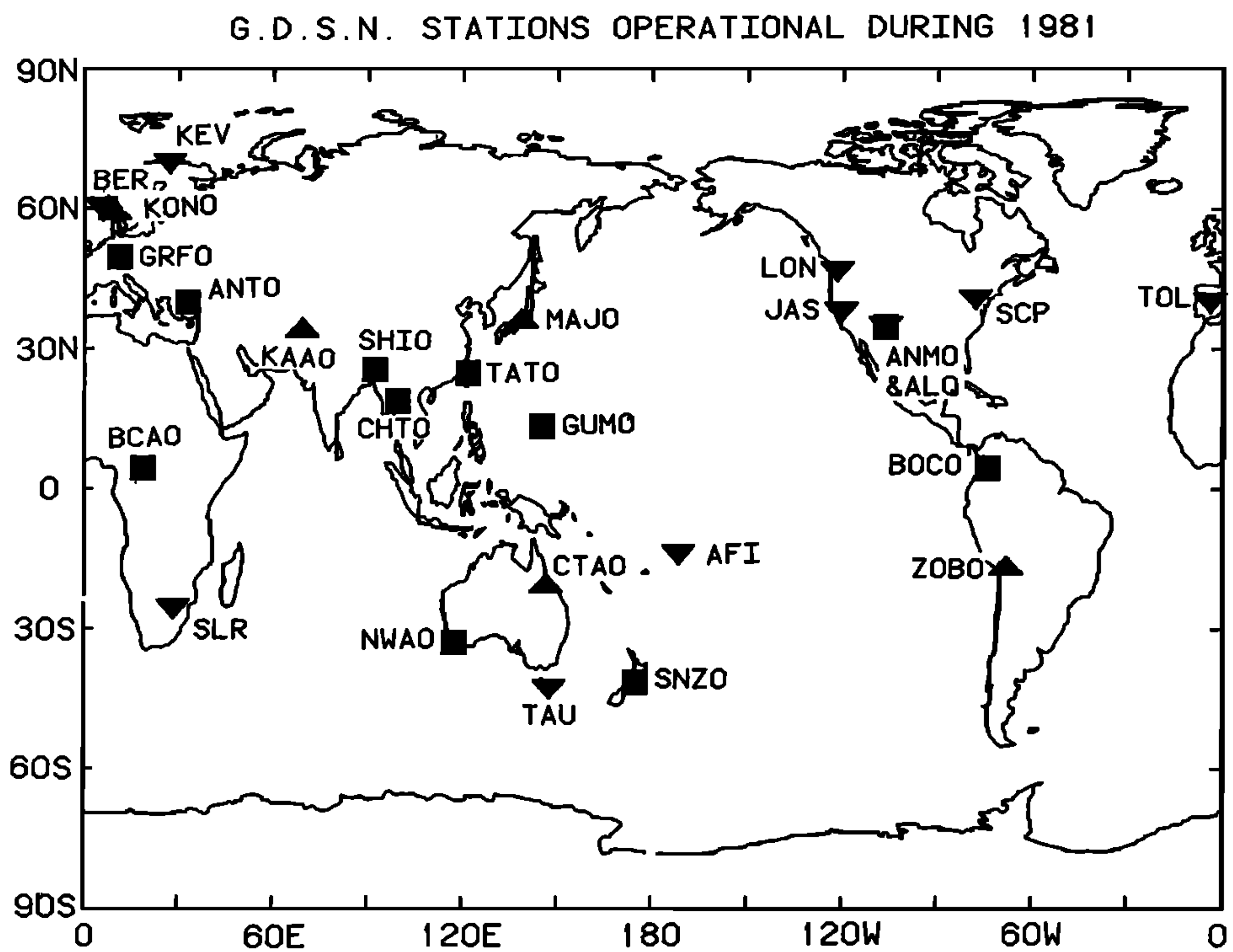
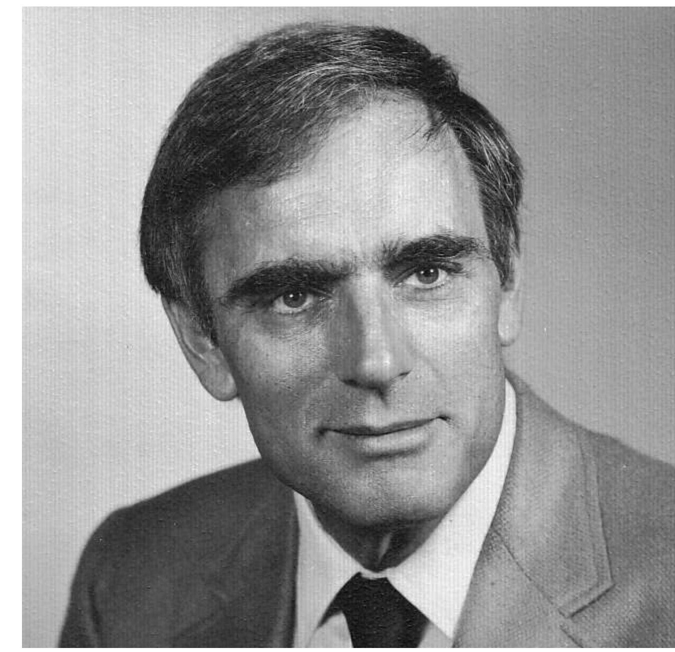
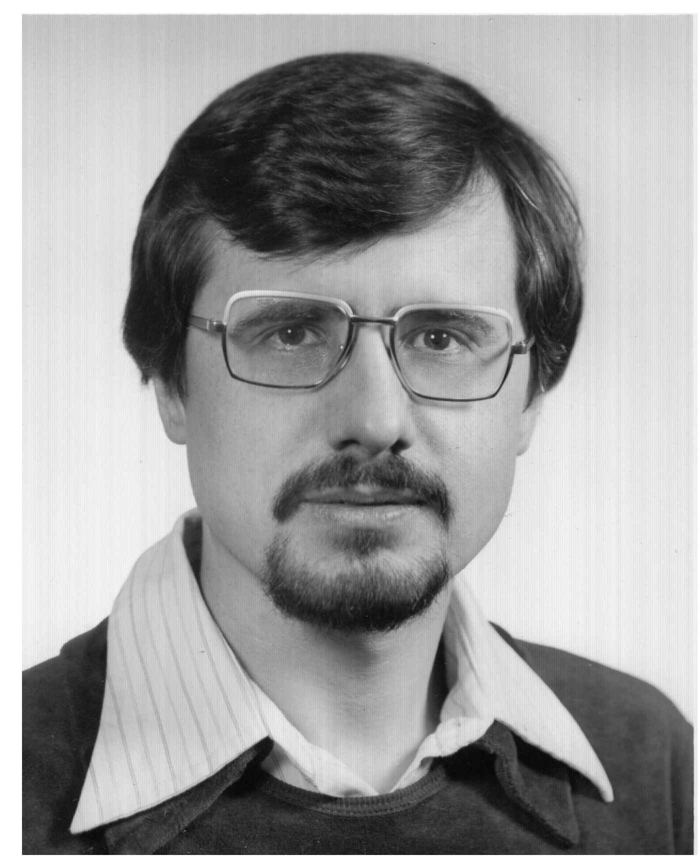
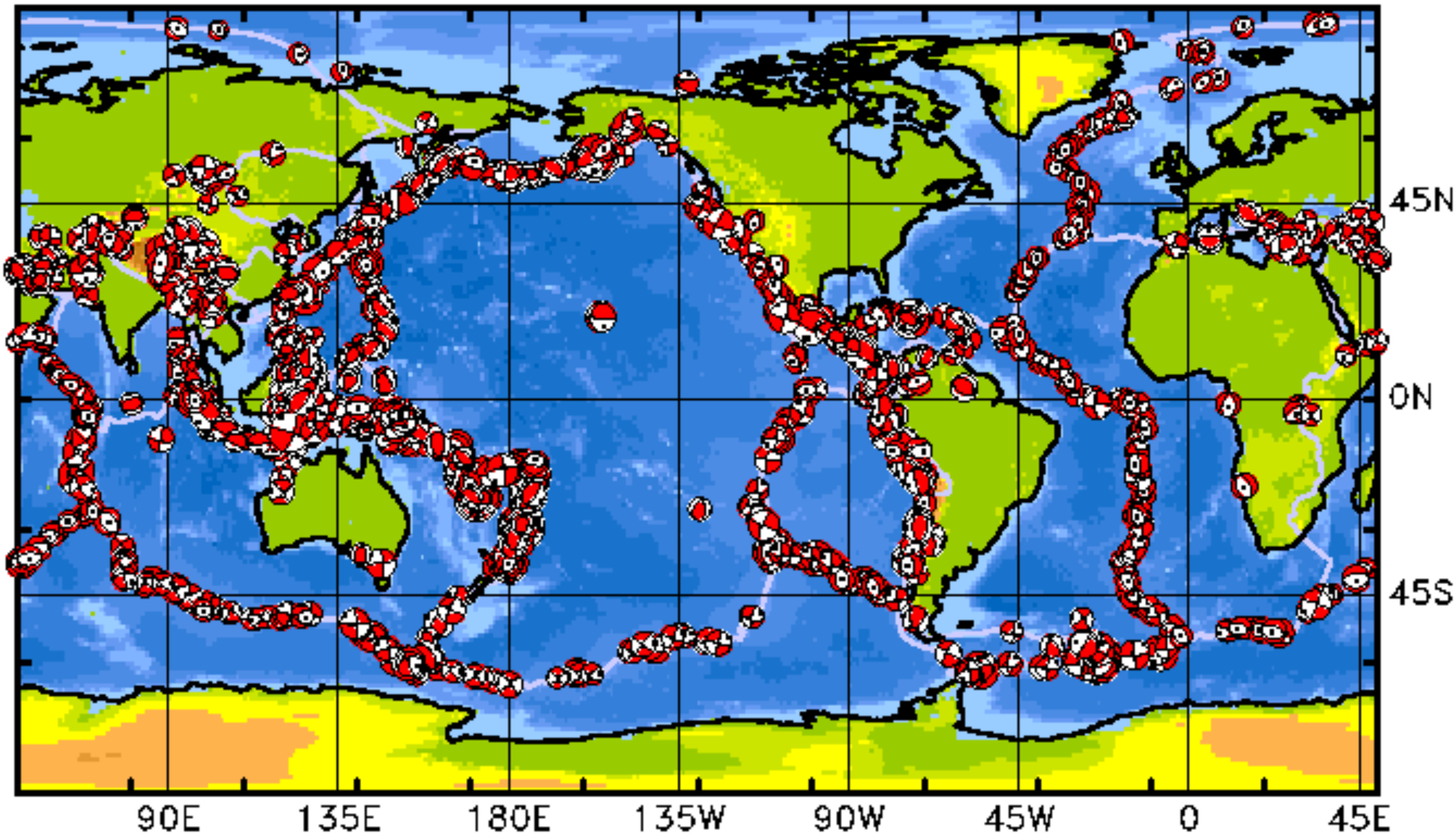


Fig. 1. Distribution of stations of the Global Digital Seismograph Network operational during 1981. Squares, SRO; up-triangles, ASRO; and down-triangles, DWWSSN stations.

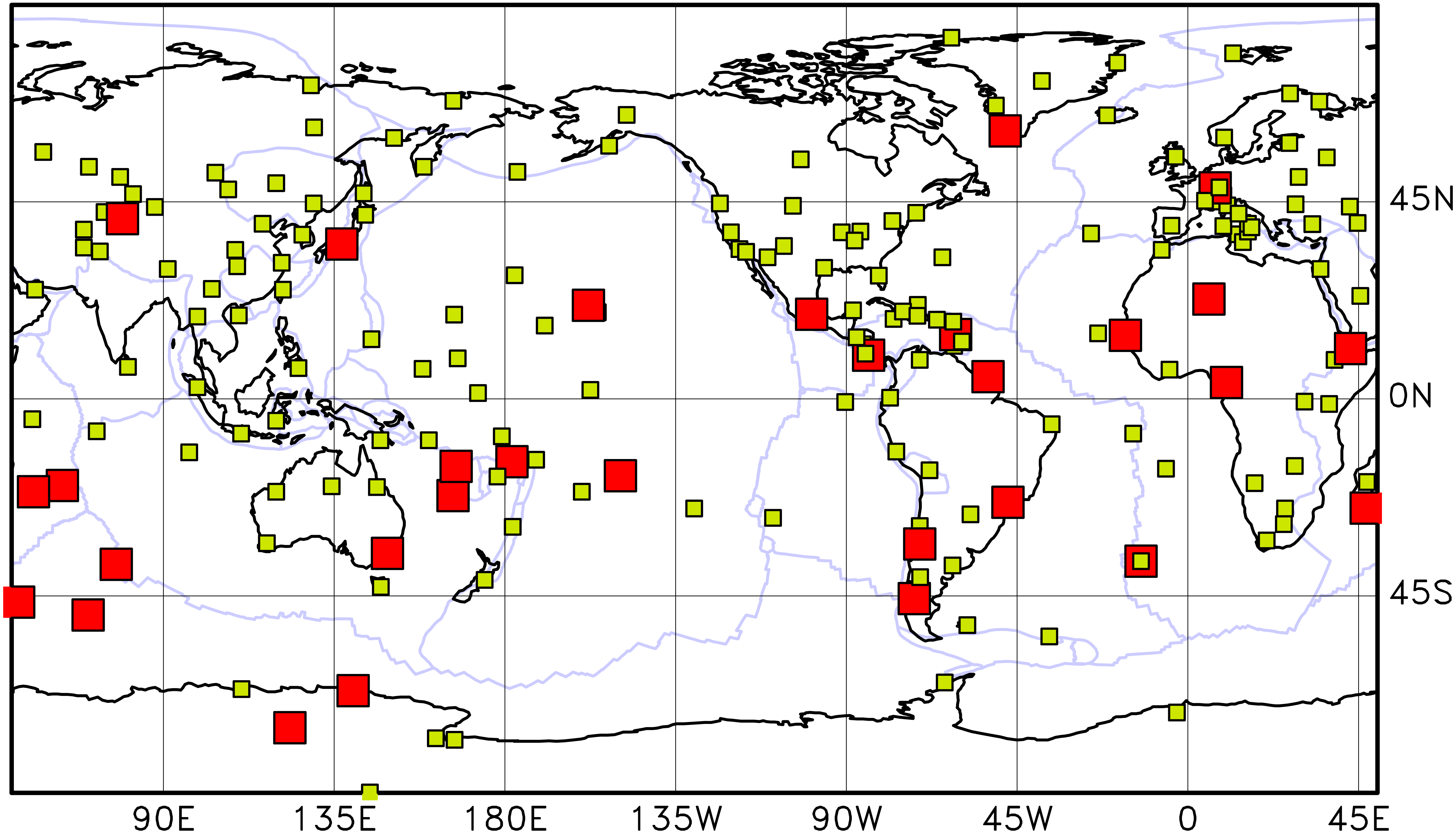




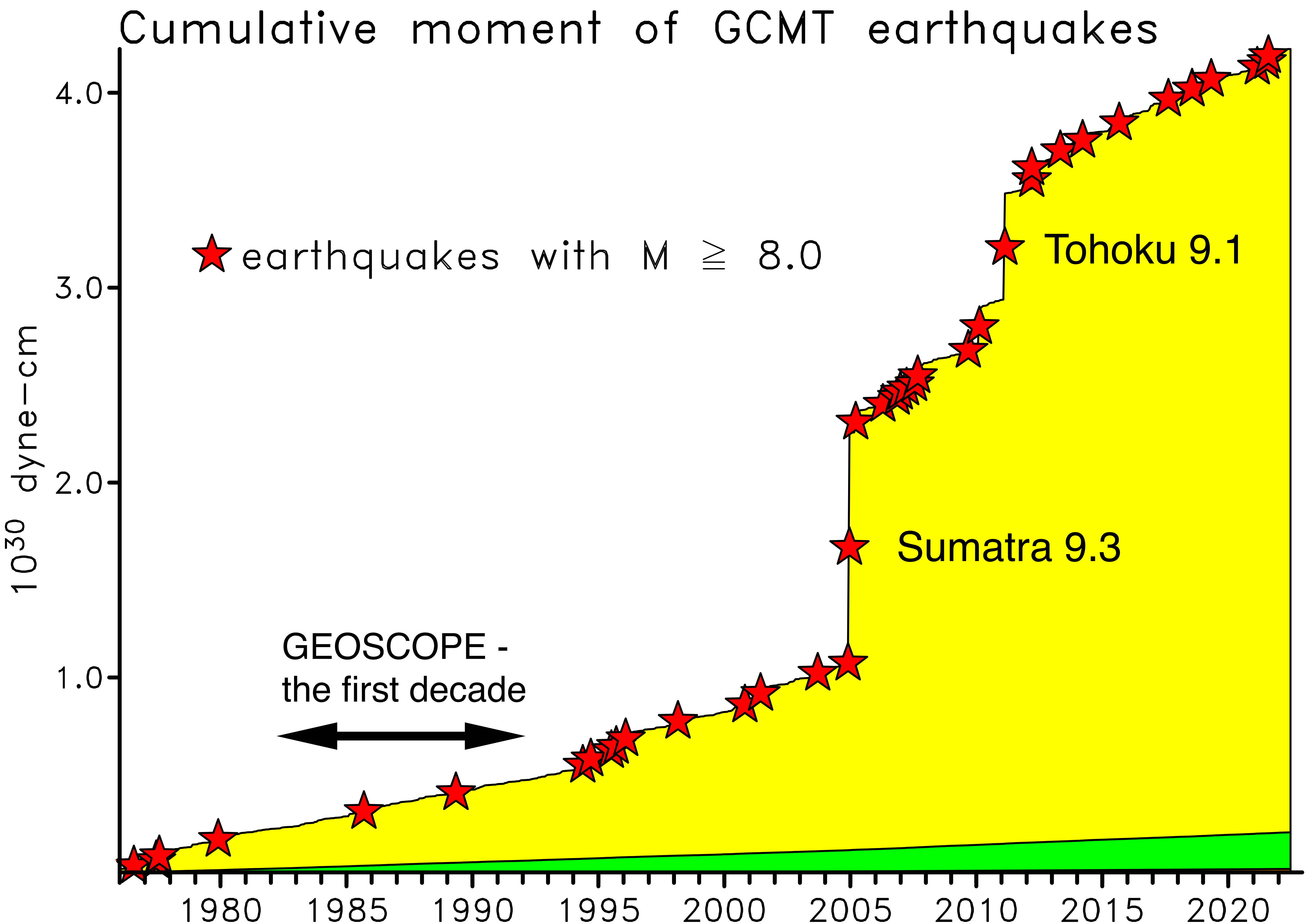
2849 Global CMT earthquakes analyzed for 2021

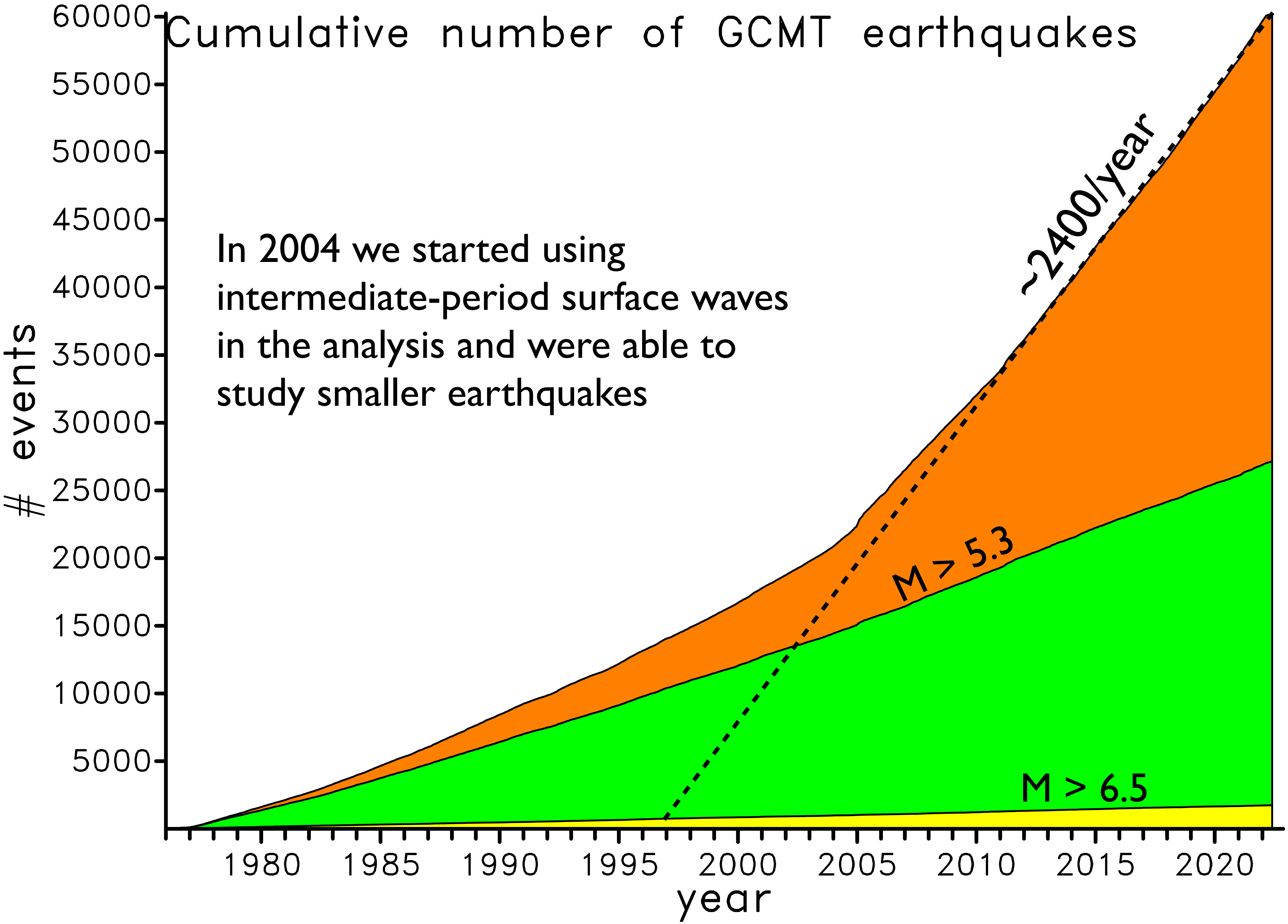


194 stations used in 2021 - 31 GEOSCOPE stations



> 100,000 GEOSCOPE seismograms included in the analysis


Cumulative moment of GCMT earthquakes
earthquakes with M ≧ 8.0
Tohoku 9.1
Sumatra 9.3
GEOSCOPE -
the first decade
10^{30} dyne−cm
4.0
3.0
2.0
1.0
1980
1985
1990
1995
2000
2005
2010
2015
2020

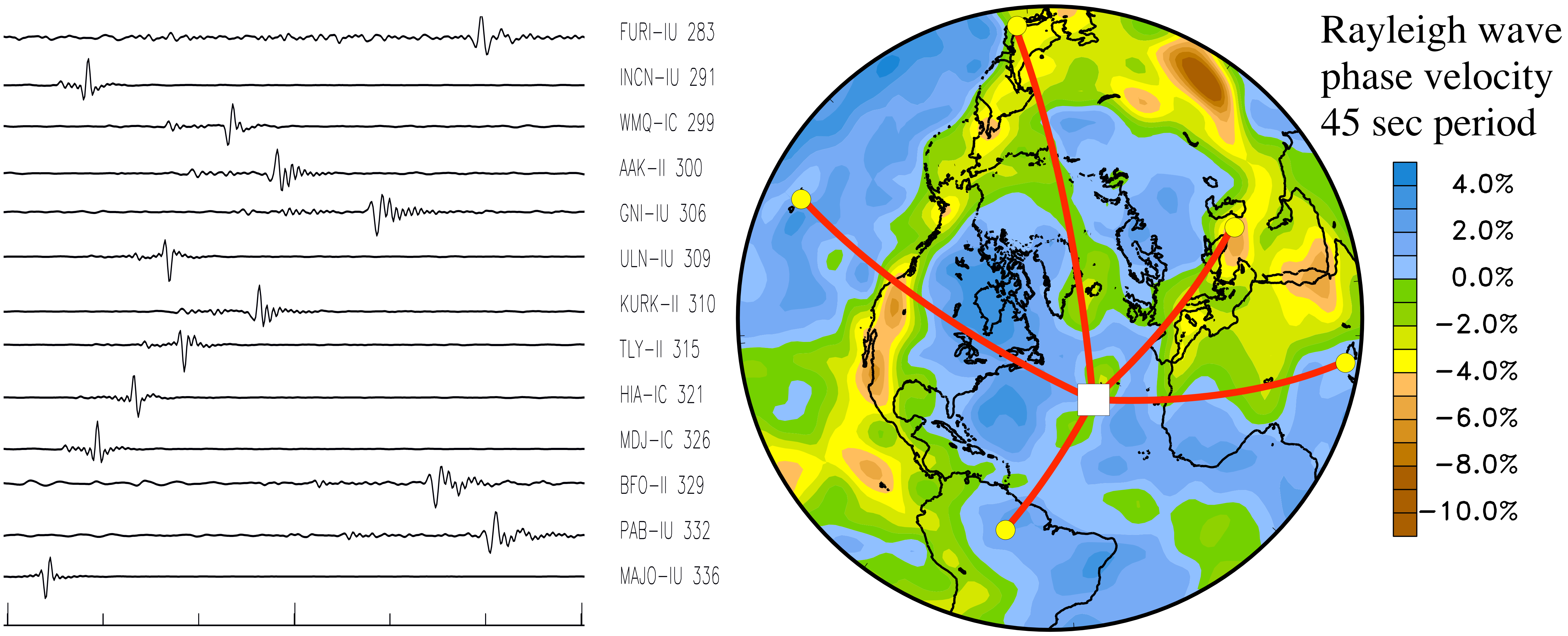


Cumulative number of GCMT earthquakes
In 2004 we started using
intermediate-period surface waves
in the analysis and were able to
study smaller earthquakes
~2400/year
M > 5.3
M > 6.5
events
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
1980
1985
1990
1995
2000
2005
2010
2015
2020
year

Global source studies using intermediate-period (30-150 sec) surface waves

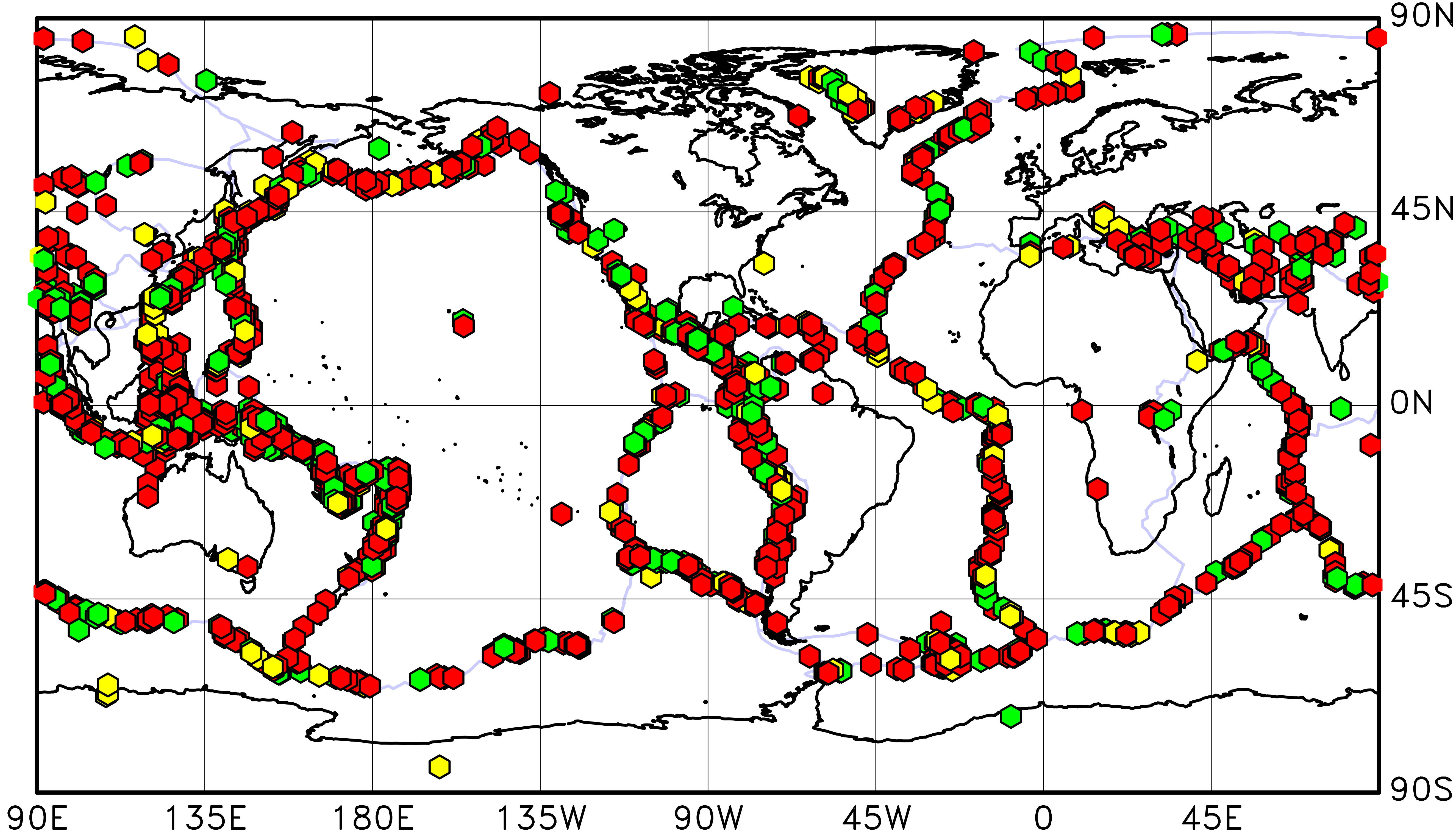
1. Detecting and locating earthquakes
2. Unusual sources (potpourri)
3. Better locations?

Detecting and locating earthquakes by back-propagating surface waves

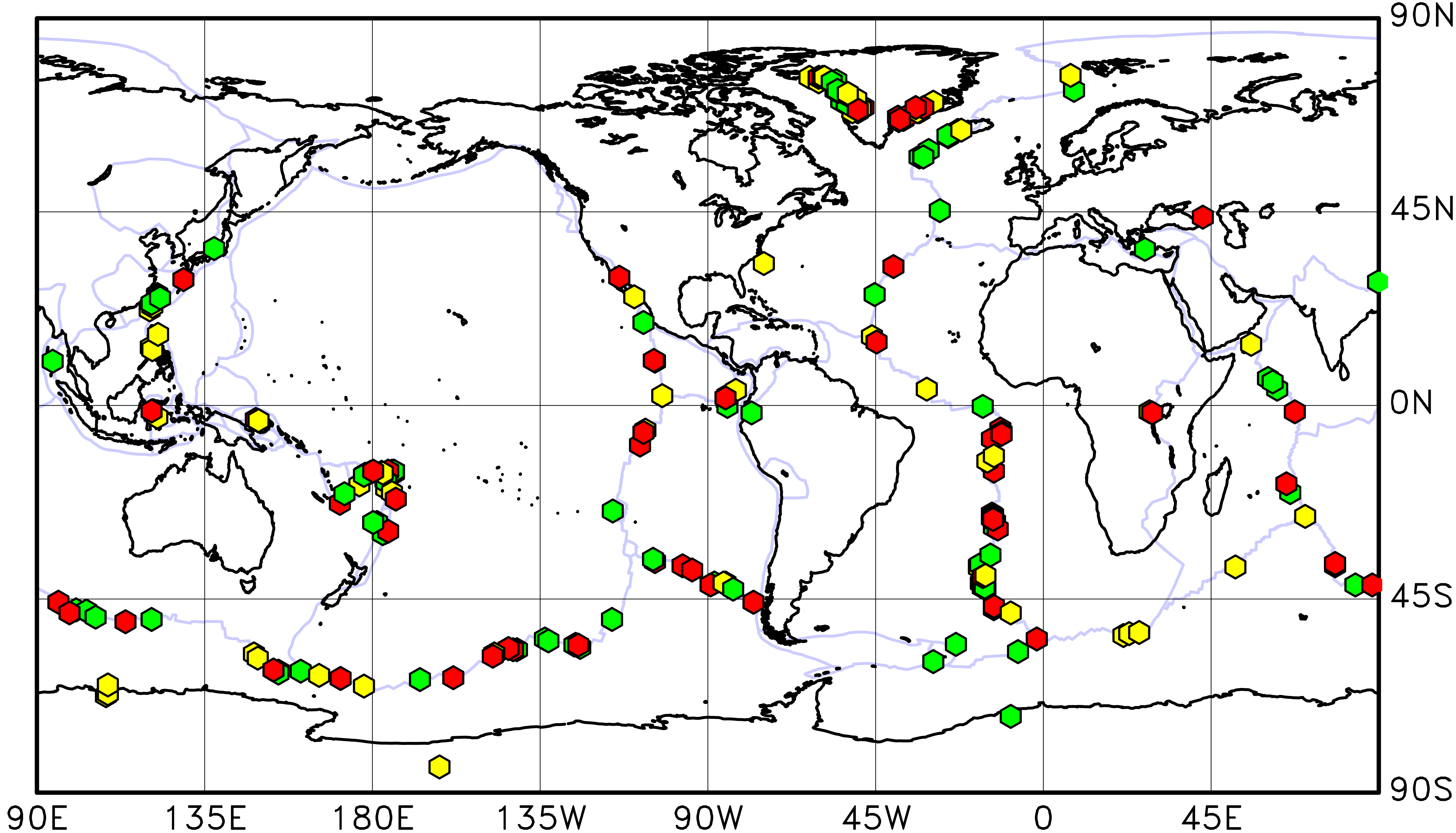


(Ekström, 2006)

In 2021 we detected and located 3377 earthquakes using surface waves



In 2021, 302 of the earthquakes were not in other catalogs



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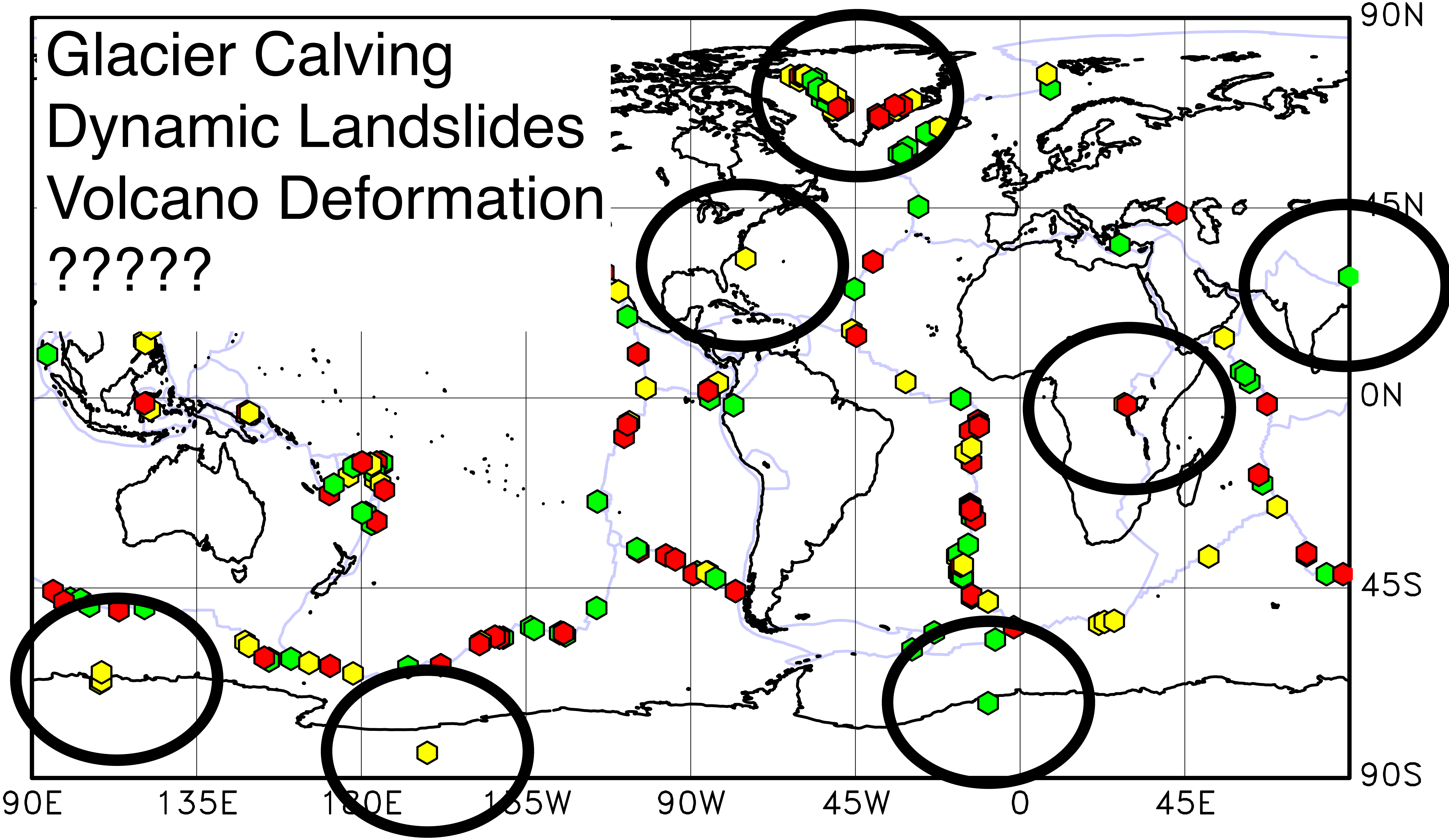
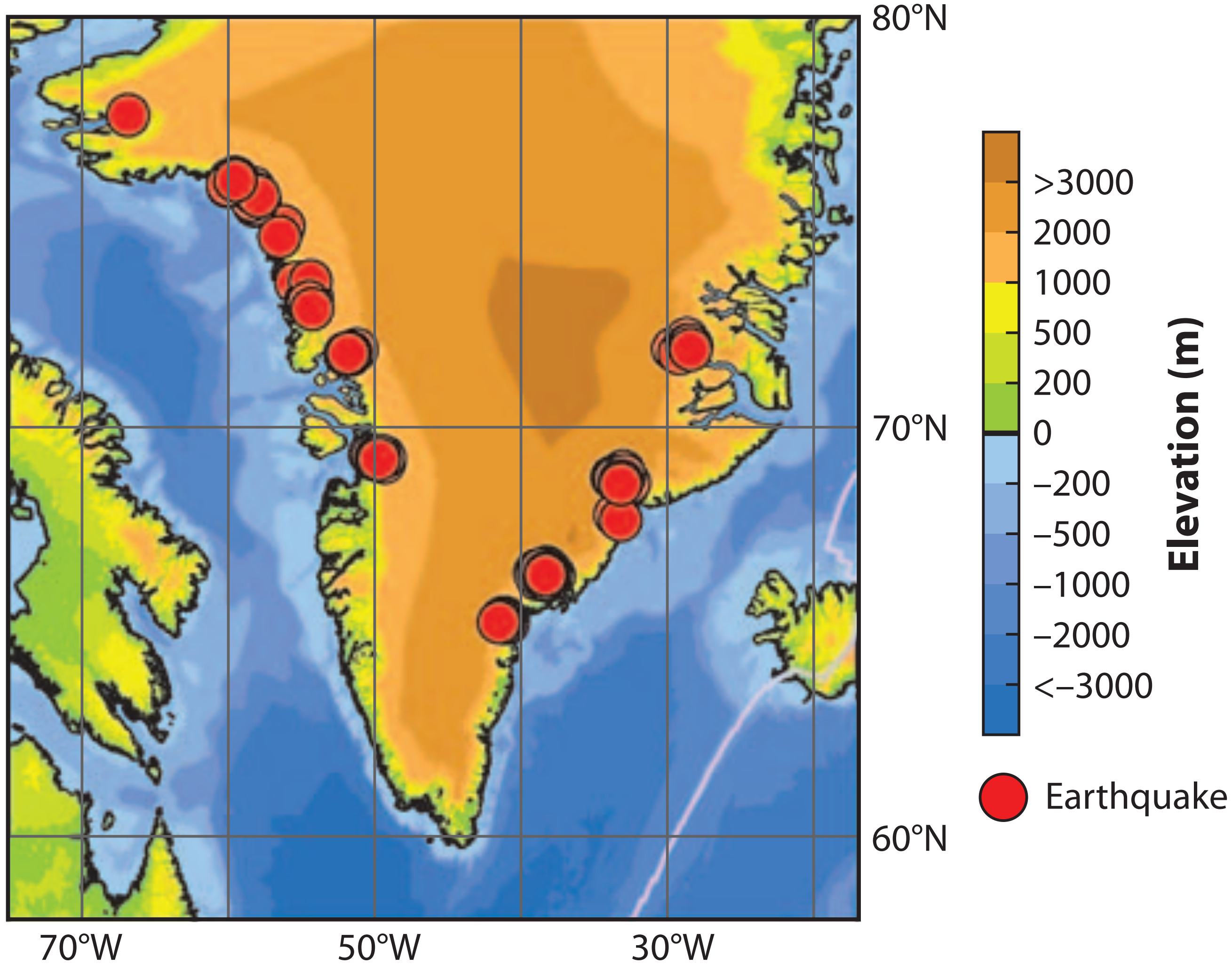


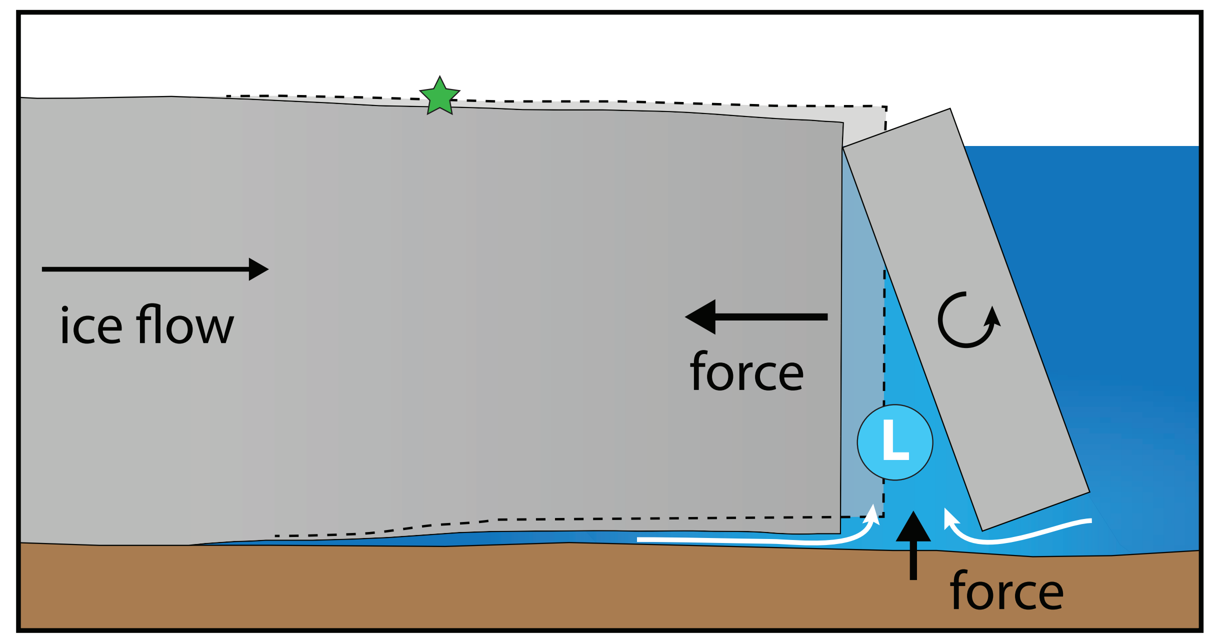
Greenland Glacial Earthquakes



Nettles and Ekström, 2010

Basic calving source model:

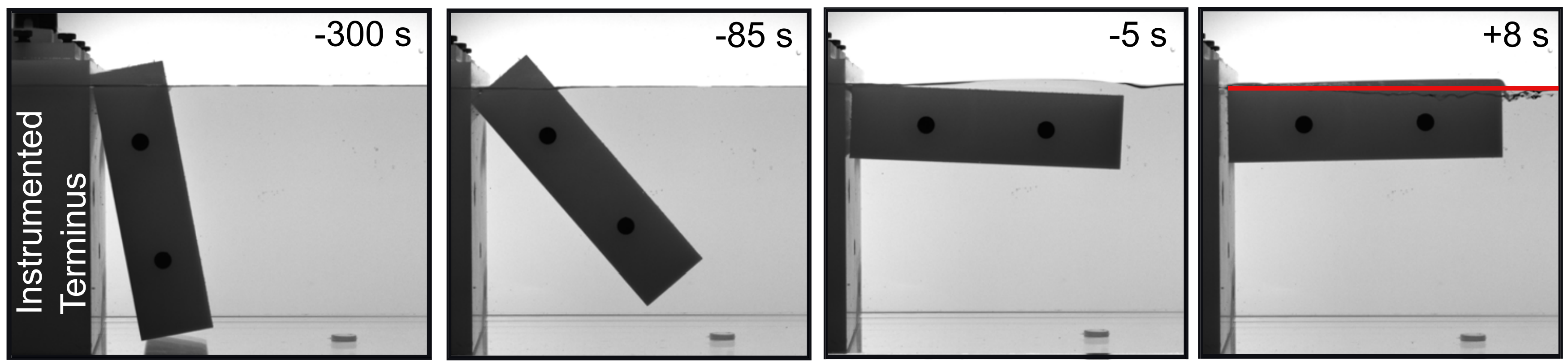
Contact forces and hydraulic pressure generate seismic waves at glacier terminus



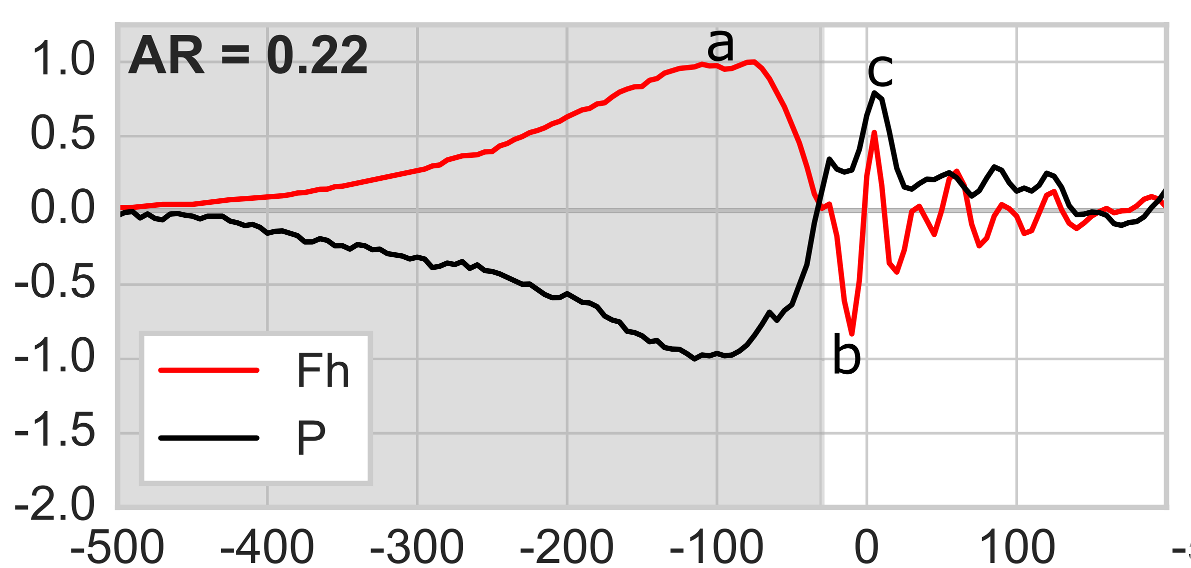
Murray, Nettles, et al., 2015

Greenland Glacial Earthquakes

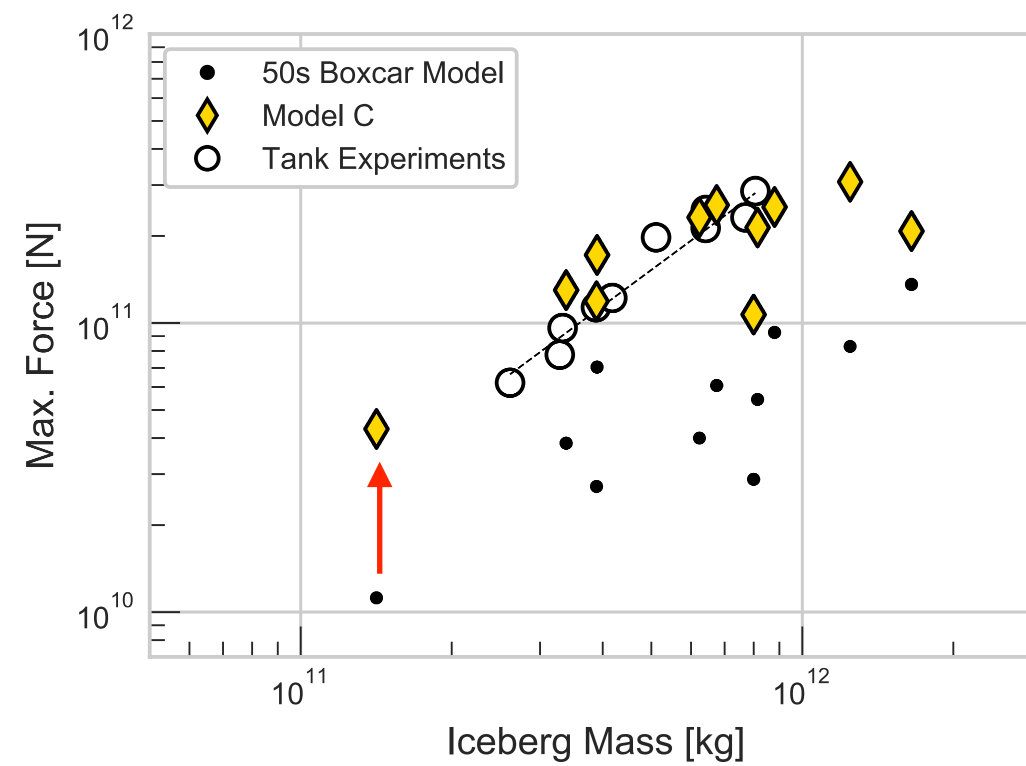
Tank experiment



Force and pressure history

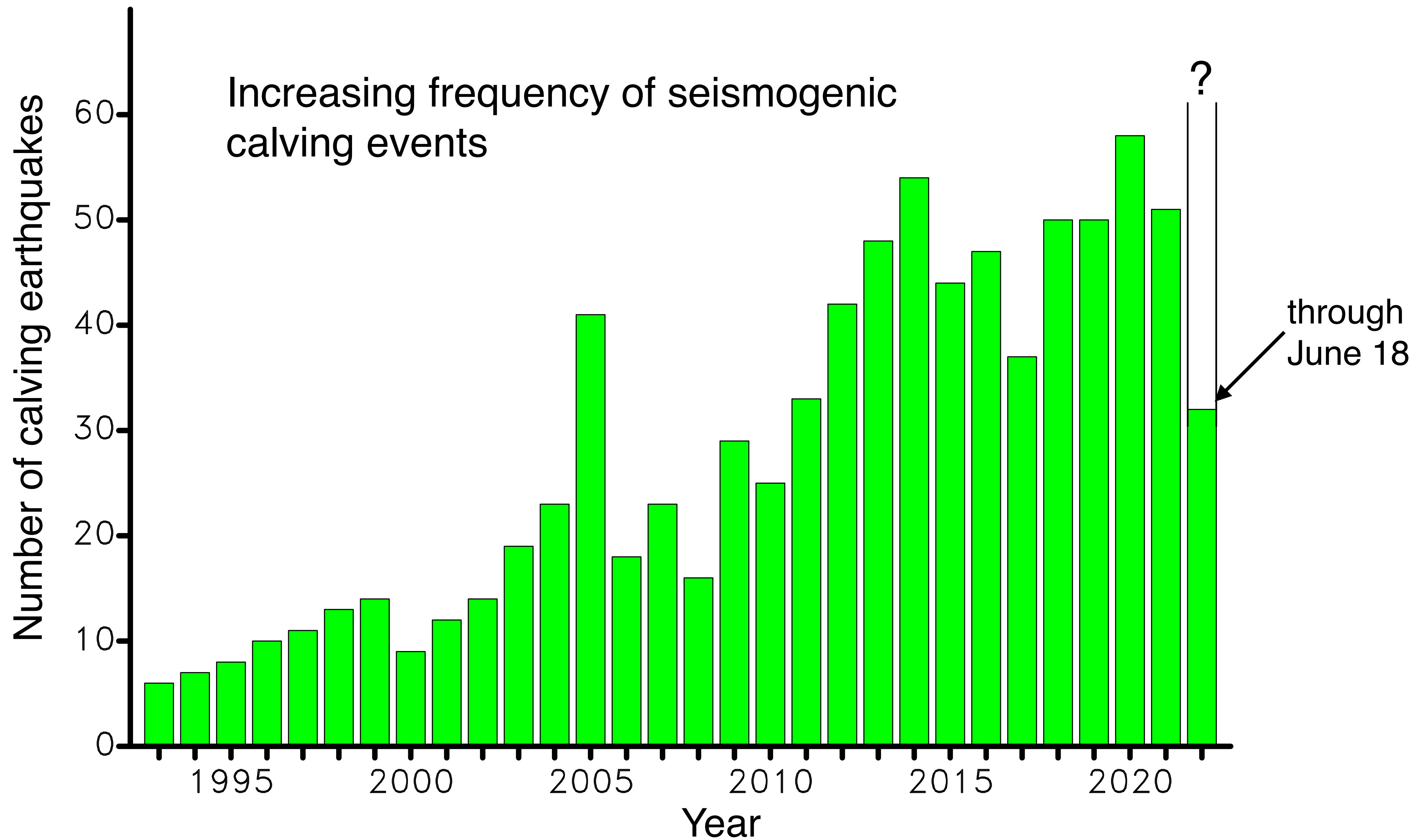


Improved force-mass calibration



Olsen, Nettles, et al., 2021

Greenland Glacial Earthquakes



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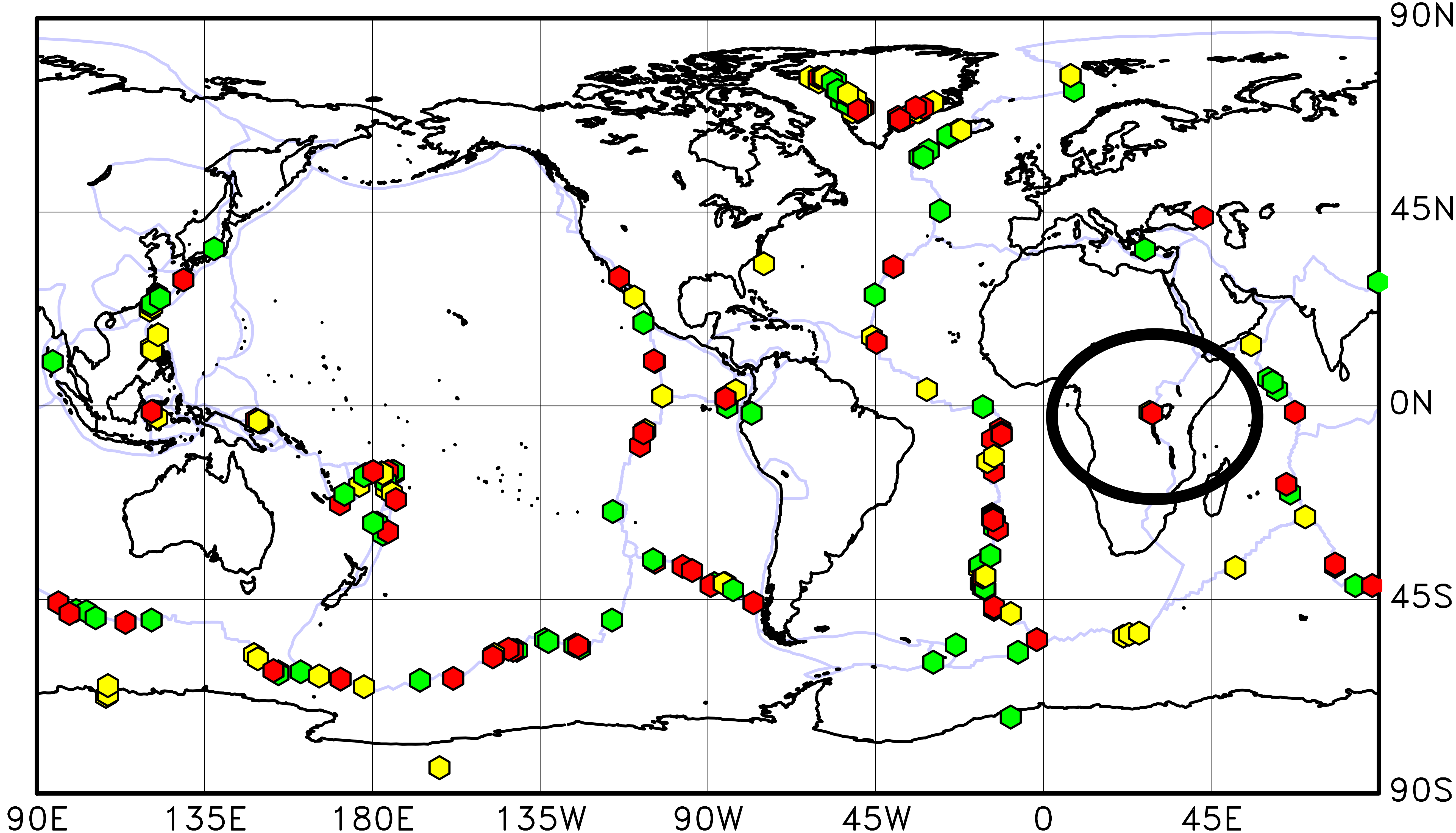
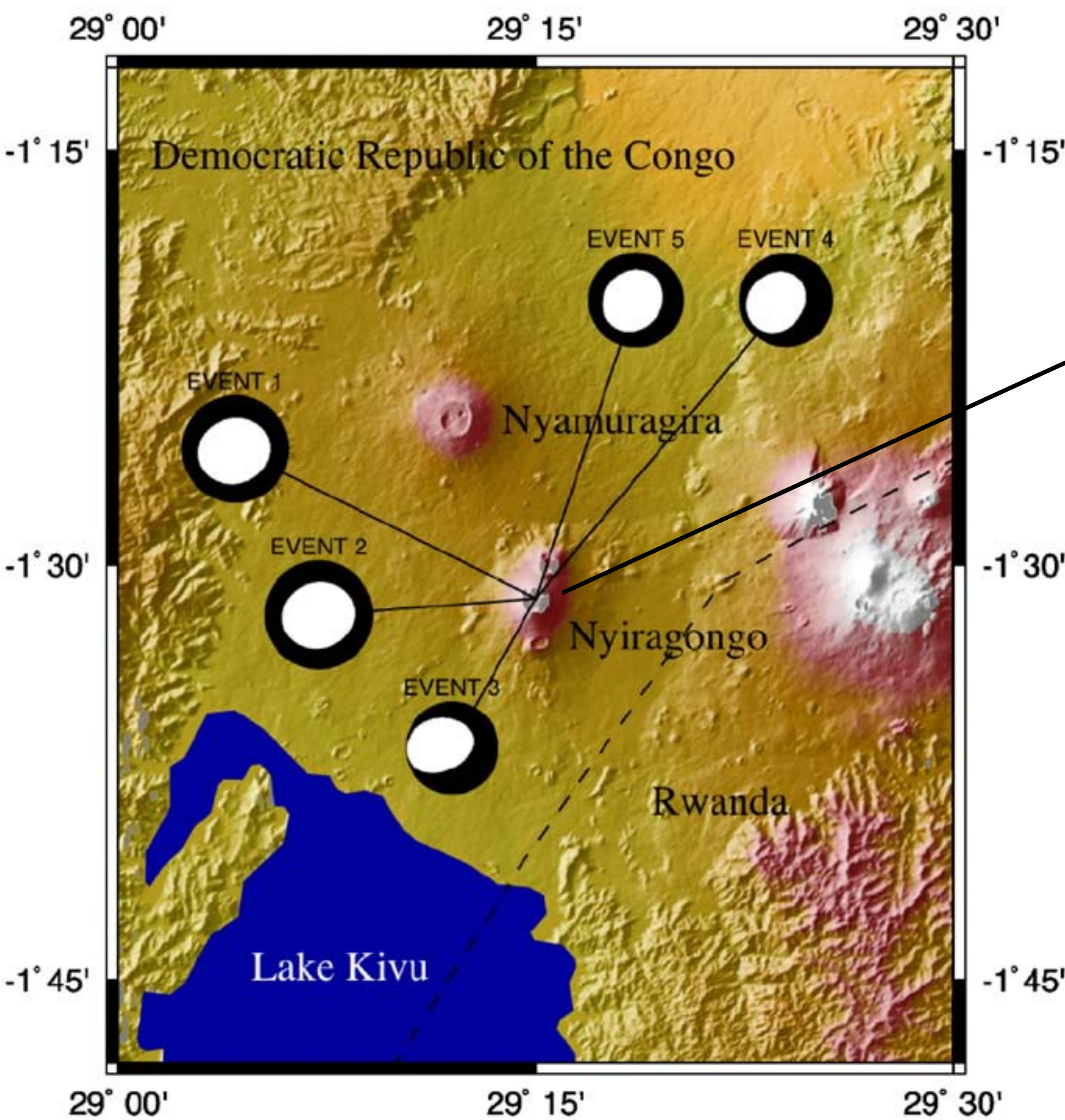


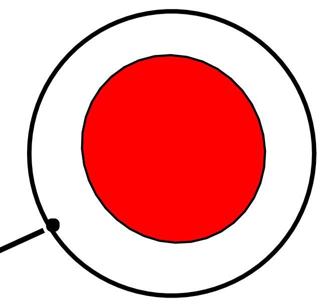
Slow earthquake at start of Nyiragongo eruption, 22 May 2021

Slow events in 2002-2005 following 2002 eruption

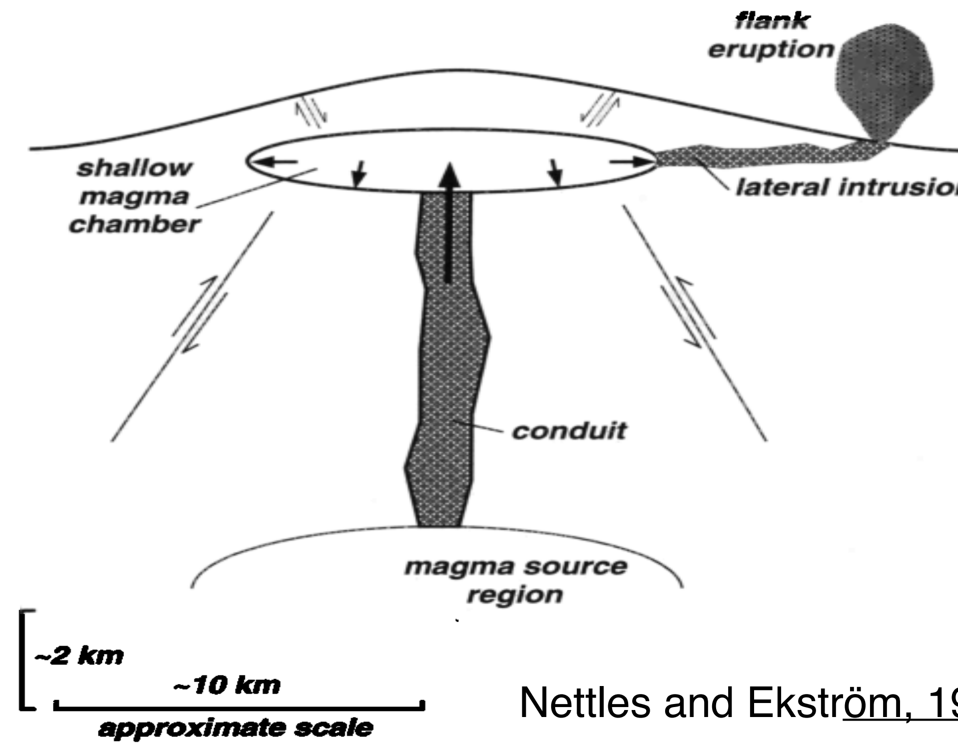


(Shuler and Ekström, 2009)

2021-05-22
M5.1

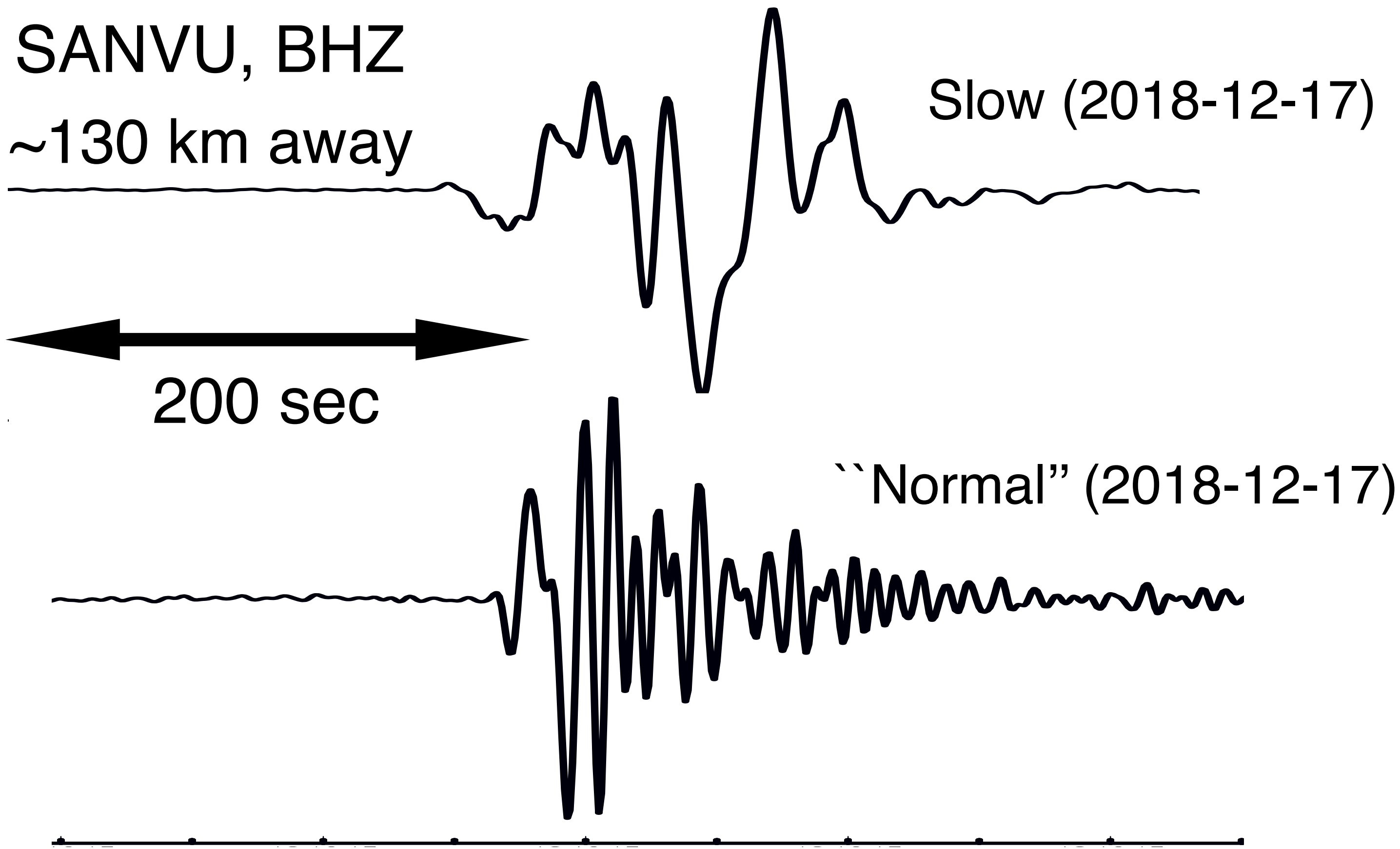


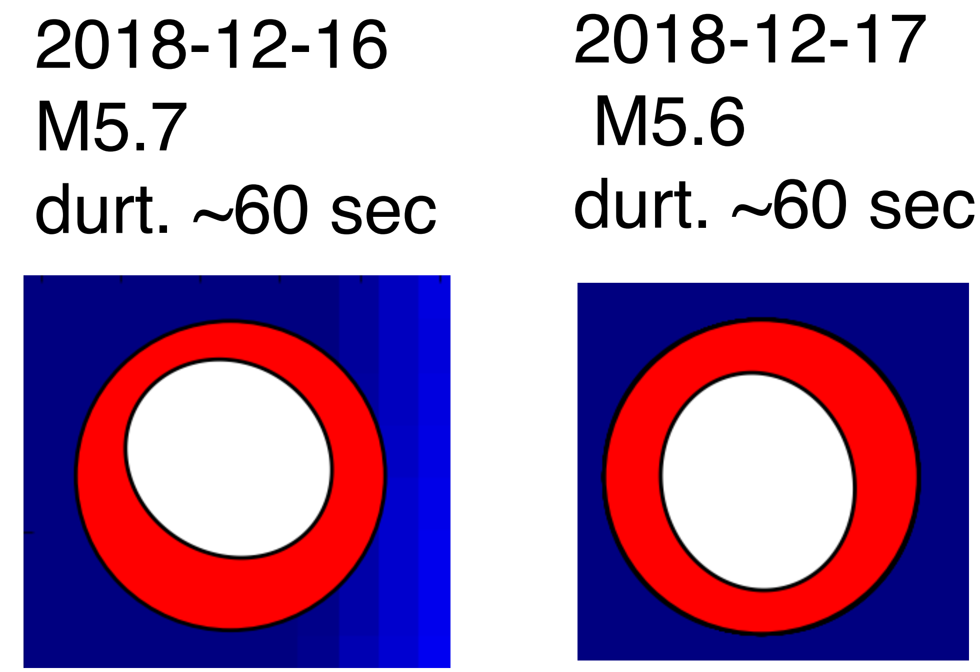
Reverse mechanism like this are more common during inflation. This event is peculiar.



Nettles and Ekström, 1998

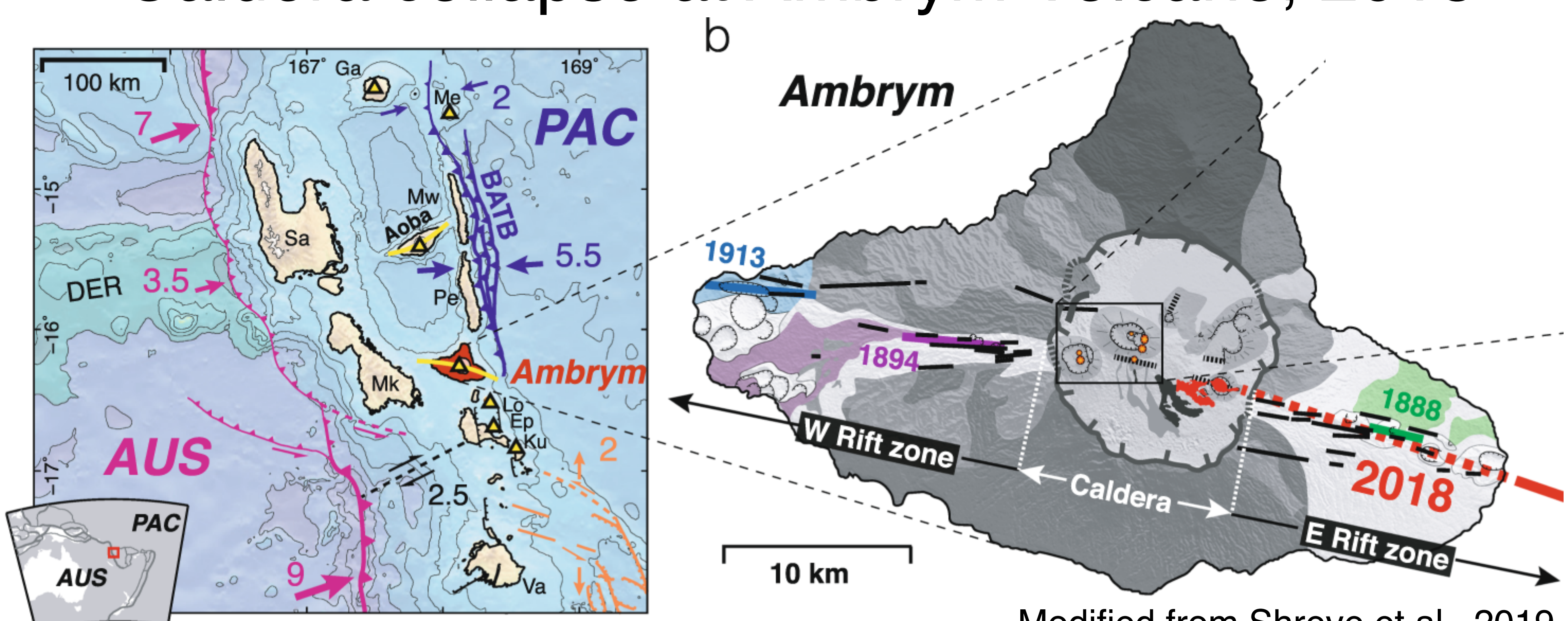
The two largest slow earthquakes we have detected over 30 years:





Wilding, Nettles, Ekström, 2019

Caldera collapse at Ambrym Volcano, 2018



Modified from Shreve et al., 2019

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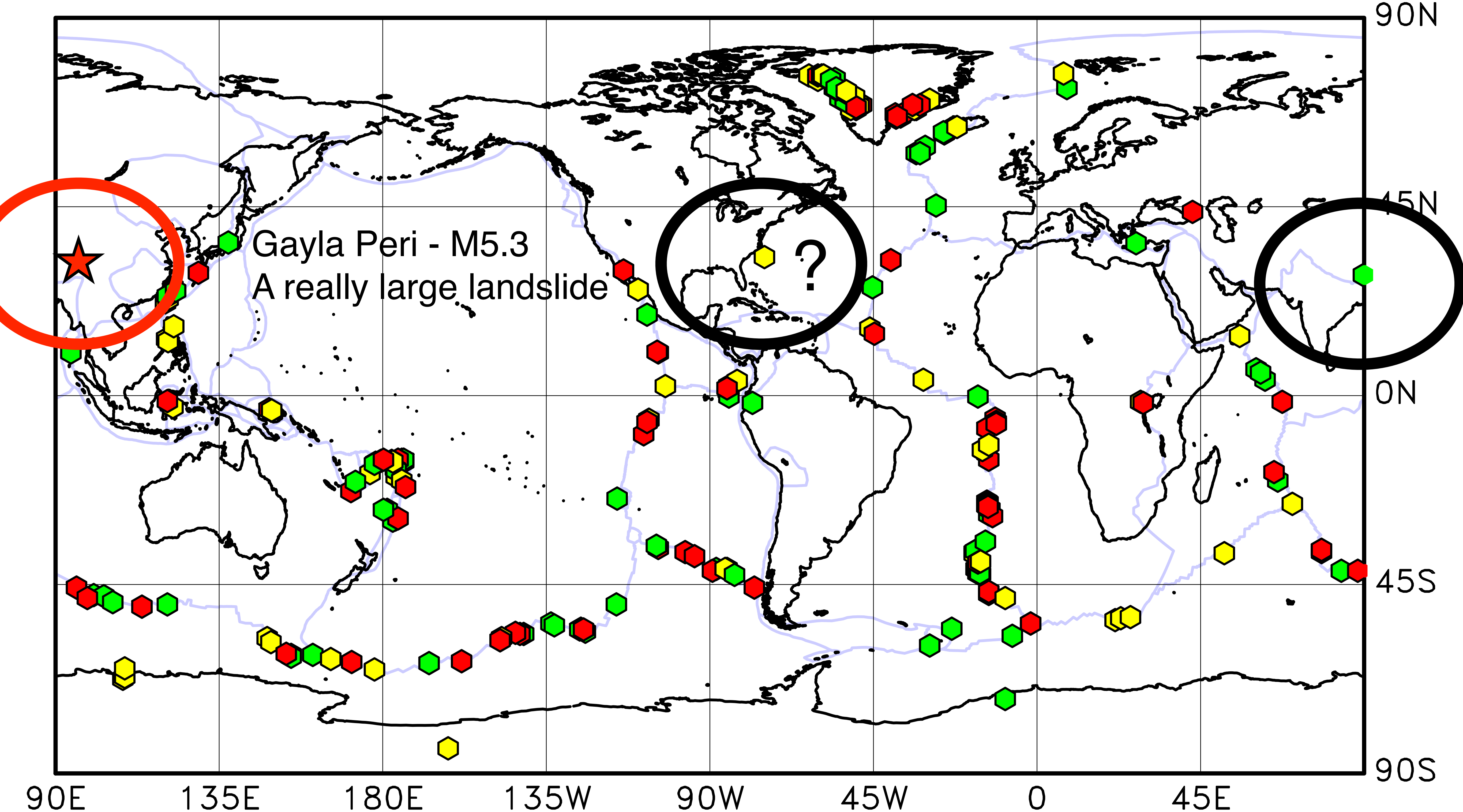
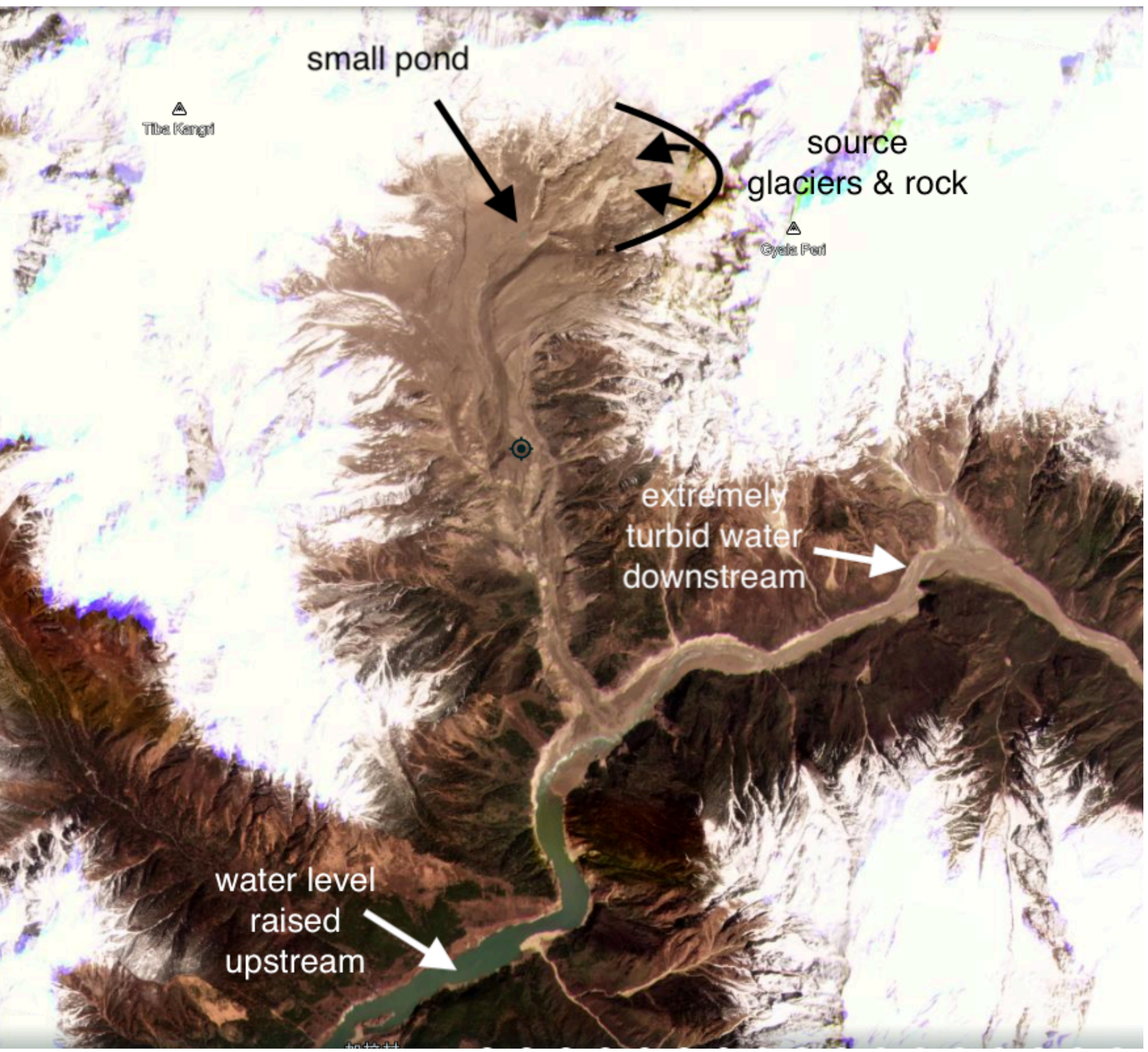
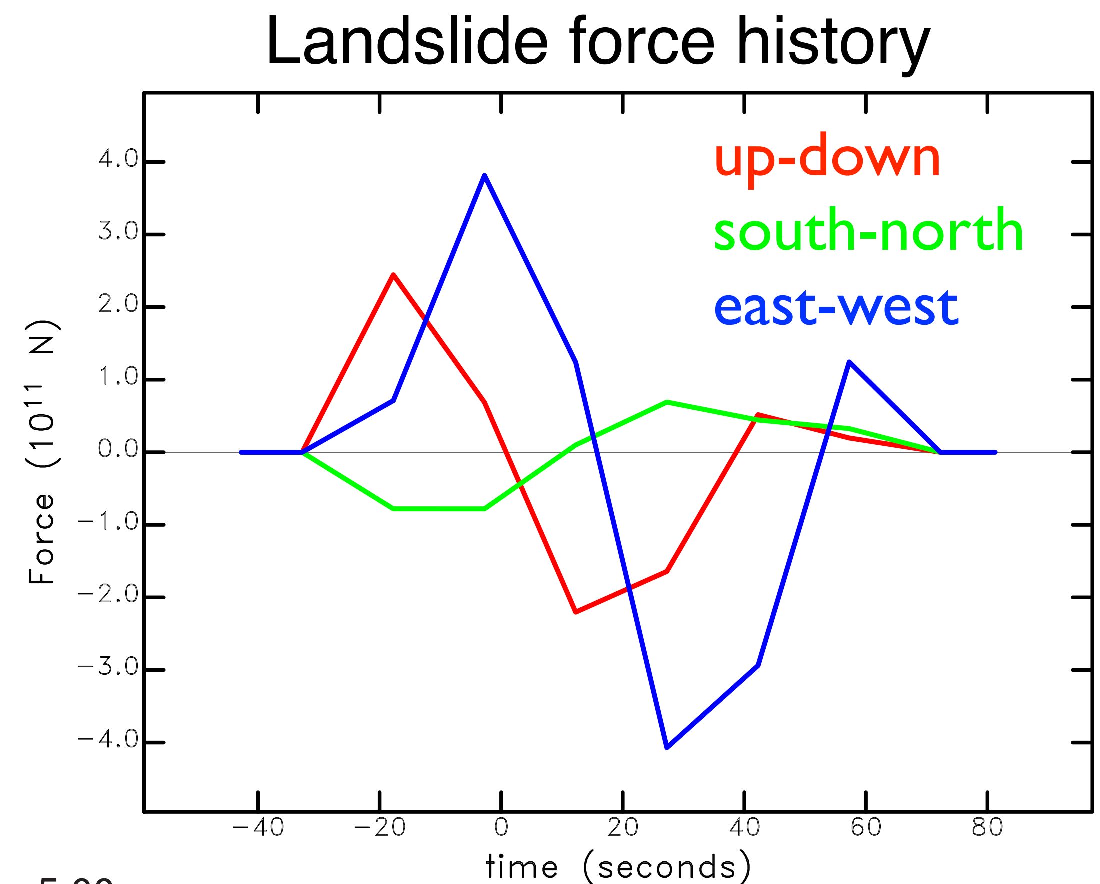
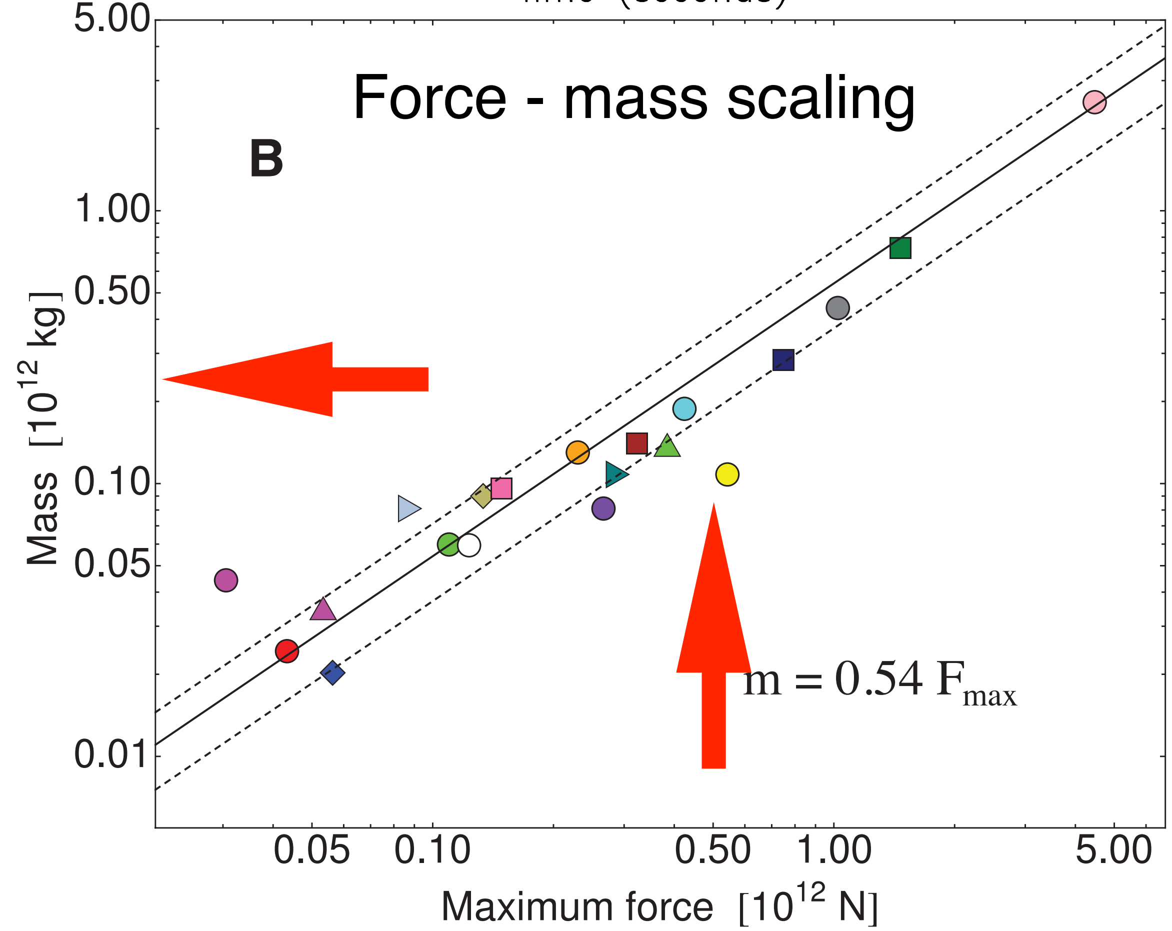


Gyala Peri landslide 2021-03-22
M 5.3, mass ~ 200 megatons
Blocked the Tsangpo river

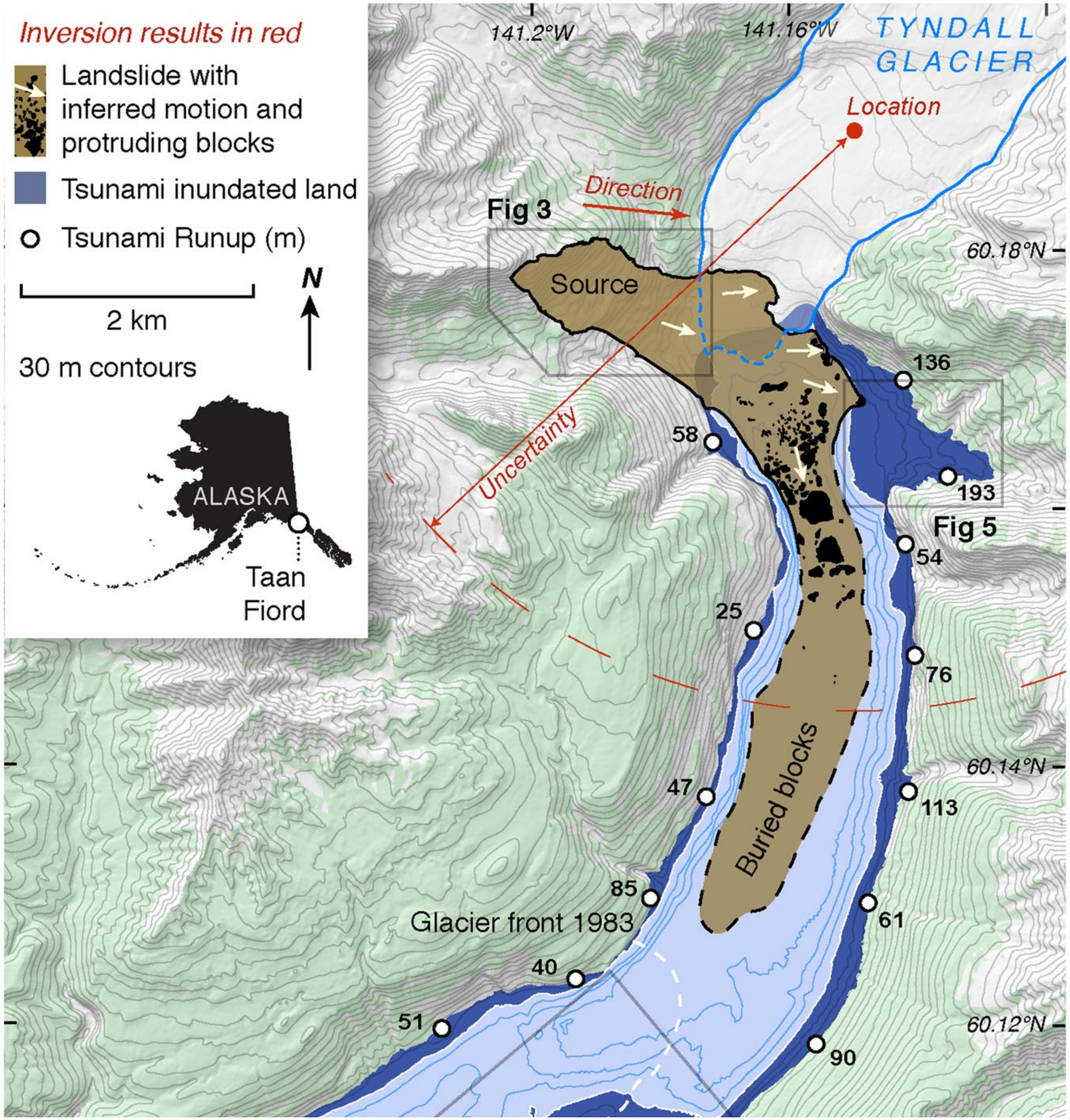




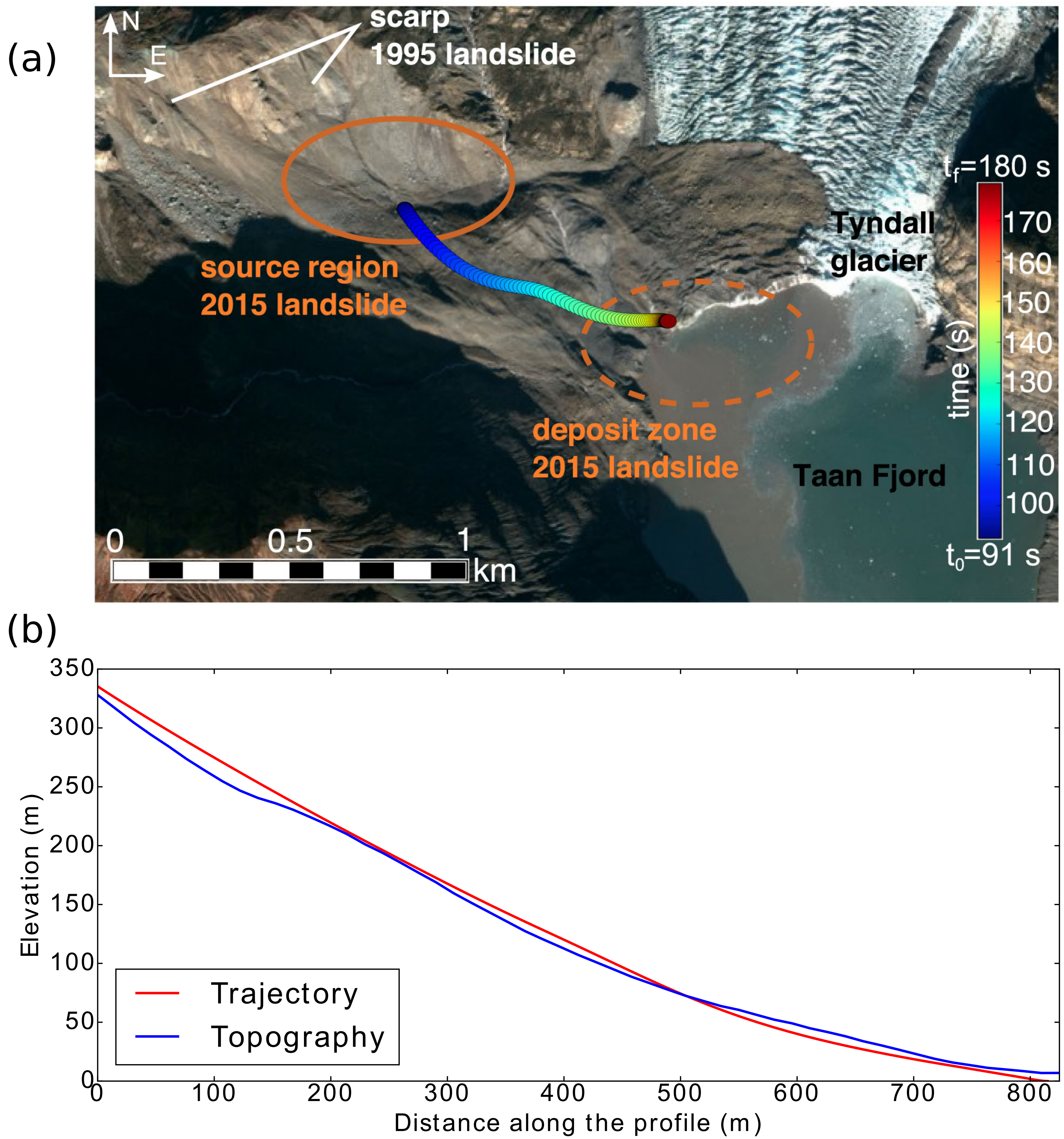


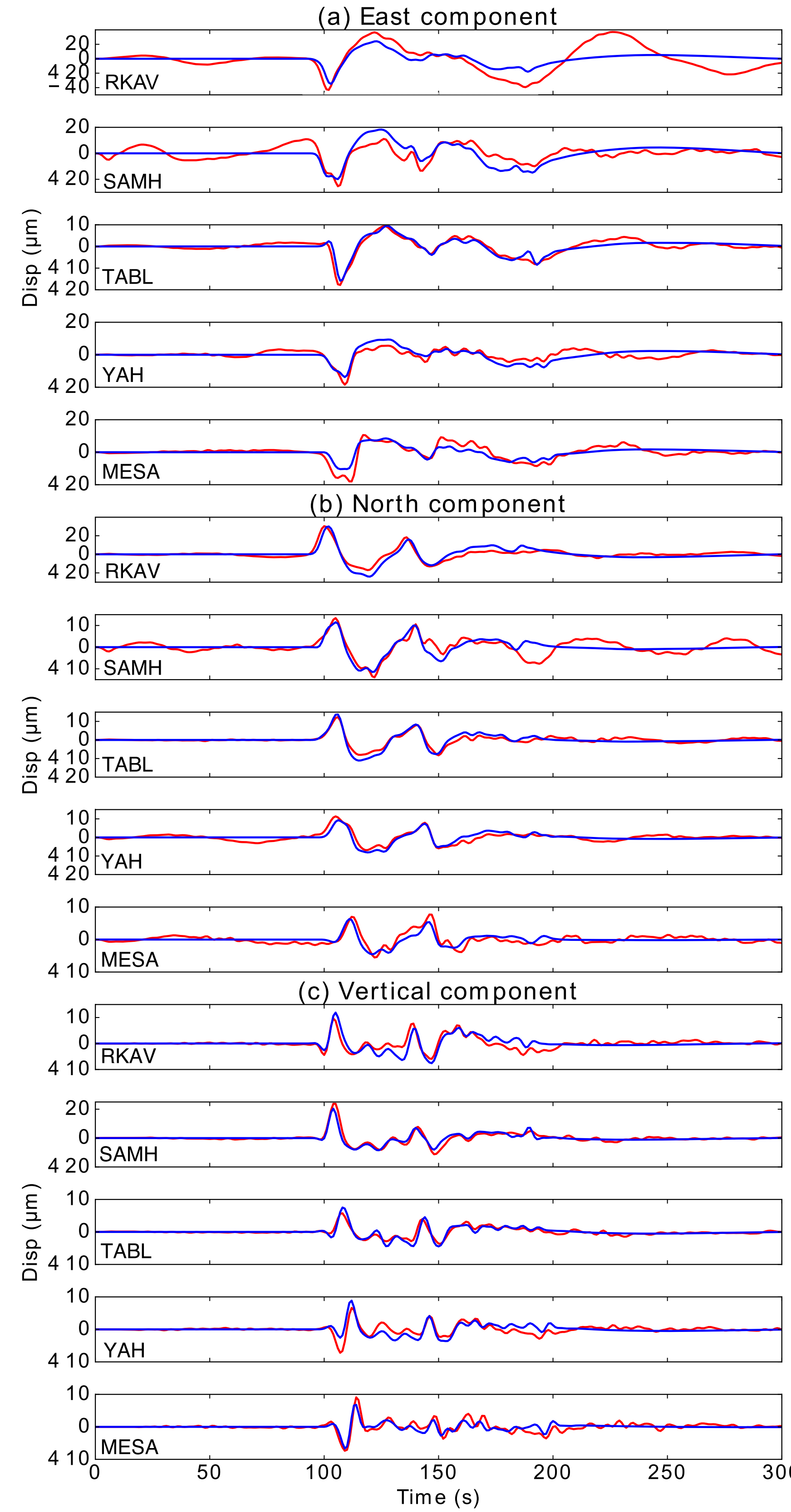
Ekström and Stark, 2013

Taan Fiord Landslide of 2015: identified and quantified by seismology



Seismograms give us the force history, which gives us the mass acceleration
Integrate twice and you have the center-of-mass trajectory





Gualtieri and Ekström, 2018

Congratulations GEOSCOPE!

Keep on observing!

There are discoveries out there, waiting for us!

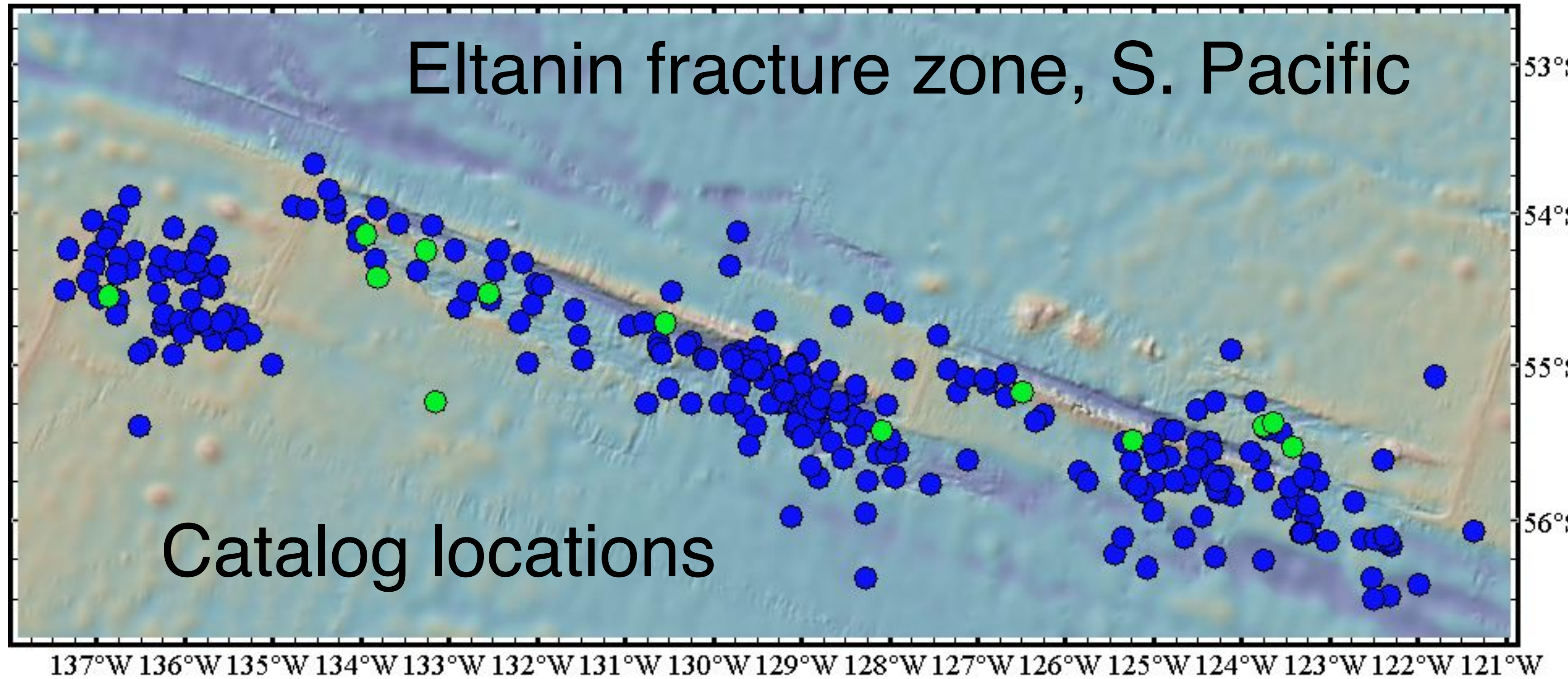
The information is in the wiggles!

Improve earthquake locations!

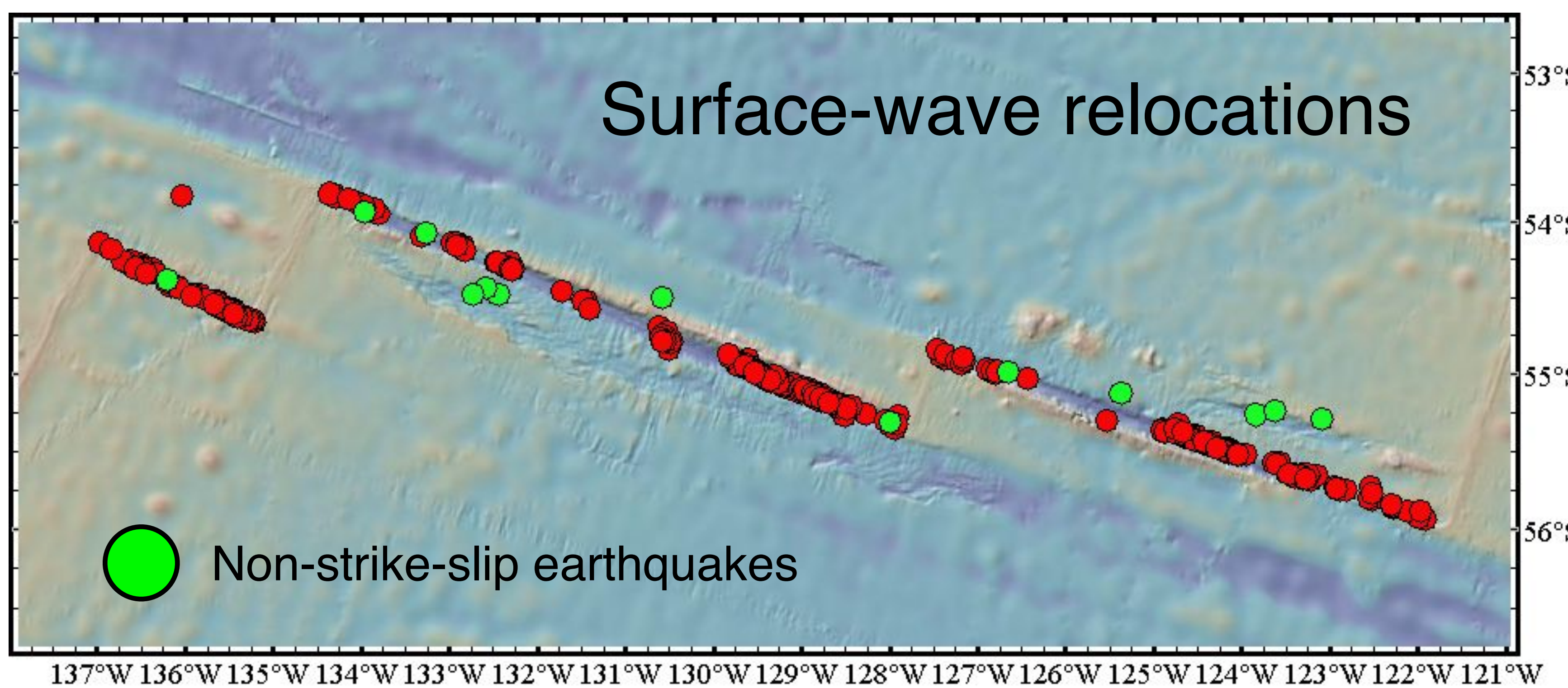
The information is in the wiggles!

La lutte continue!

It should be possible to located all M5 and larger earthquakes with to within 3 km using tele-seismic surface waves.

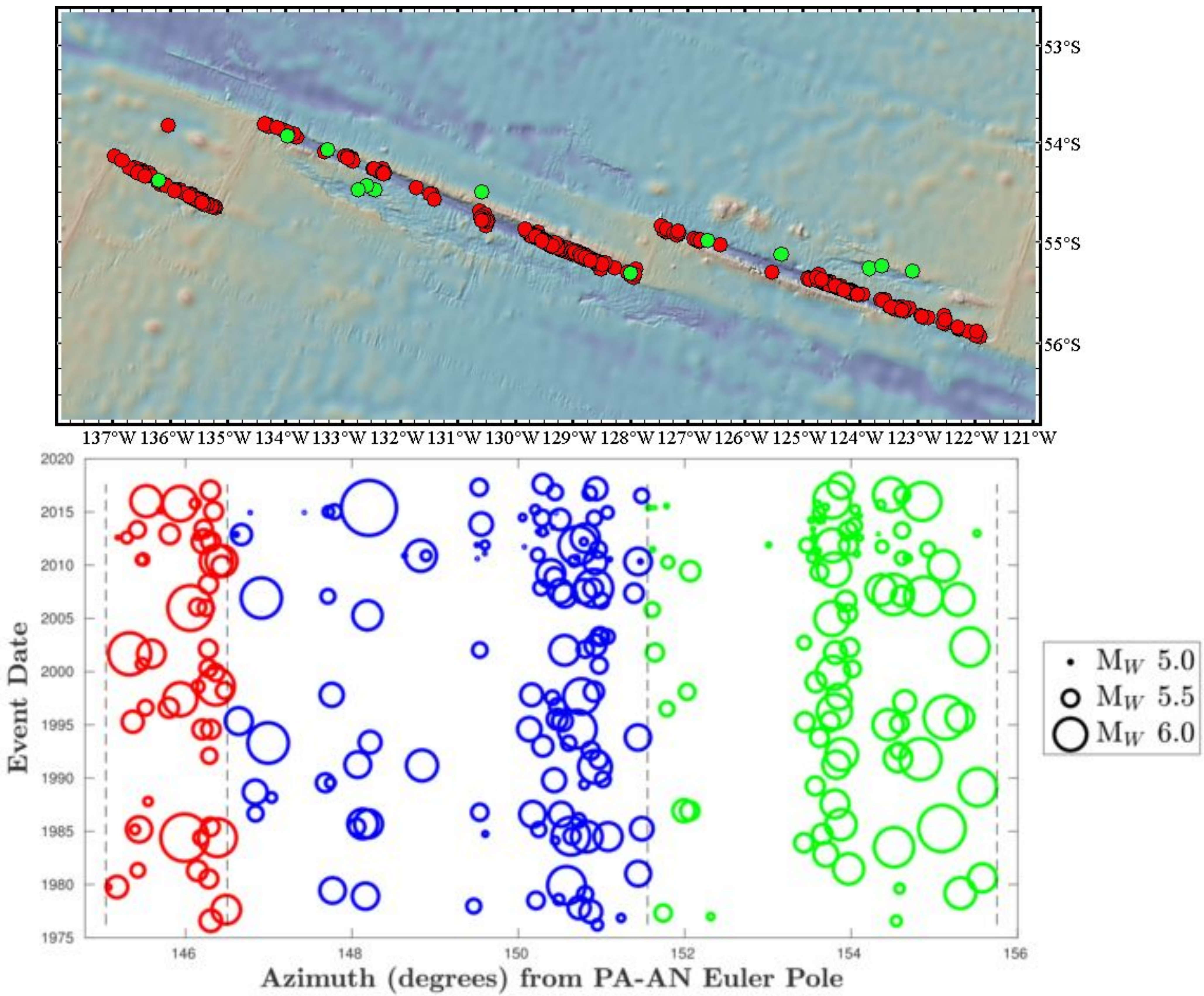


Relative-location methods (JHD, double-difference) need stable networks.



Howe, 2018; Howe, Ekström, Nettles, 2019

The reward: High-precision mapping of earthquake history, faults and coupling



Howe, 2018; Howe, Ekström, Nettles, 2019

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