Can High-Precision Methods of Seismic Monitoring for Earthquakes and Explosions find Application for Broad Areas?

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26 June 2019

Objective

Background

Progress

Prospects

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radical improvement in the quality of seismicity bulletins

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Prospects

?? Mongolia...

2006001-2013253: 10236 LEB events

50°N
45°N
40°N
35°N
30°N
25°N
95°E
100°E
105°E
110°E
115°E
120°E
125°E
130°E
HIA
ULN
MDJ
BJT
INCN
LZH
XAN
SSE
ENH
MATB
KMI
KMI

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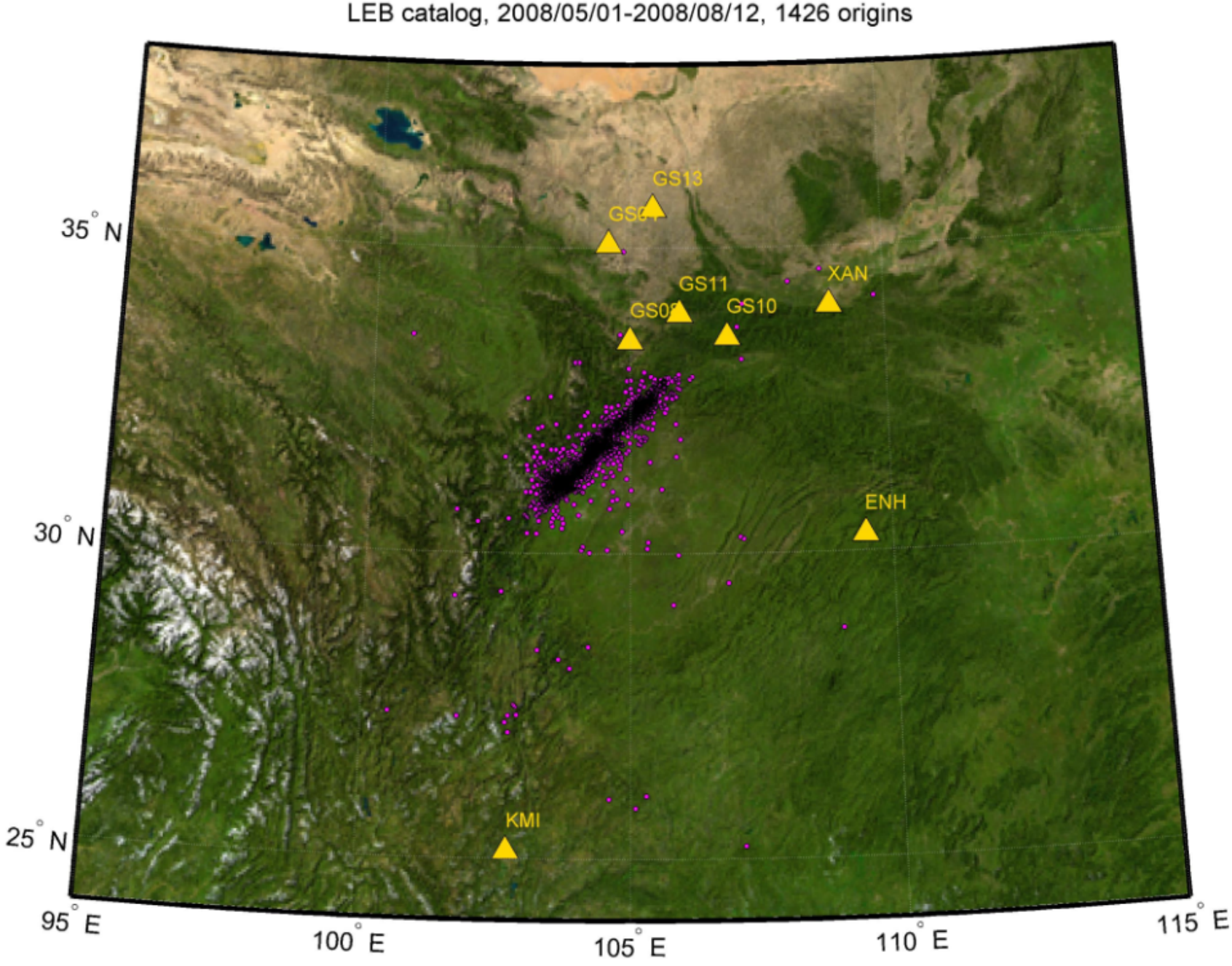
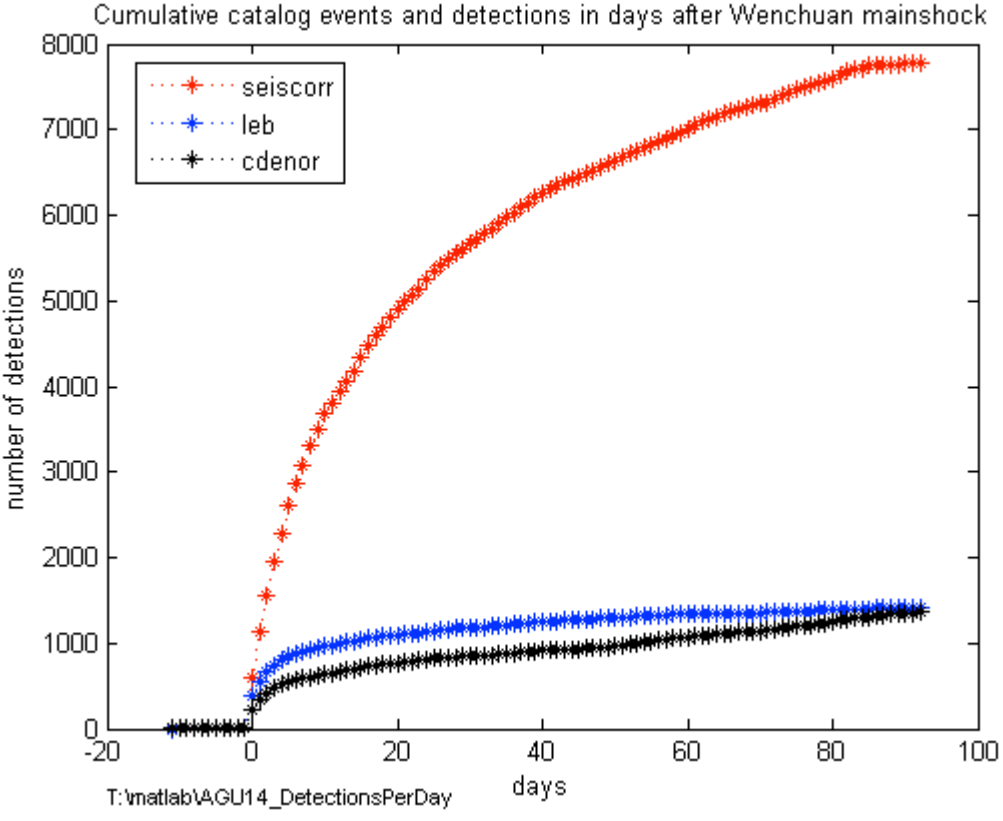
But precision at the level of a few hundred meters, or better, can be achieved in areas of dense seismicity when all events are located with reference to each other
(many investigators).

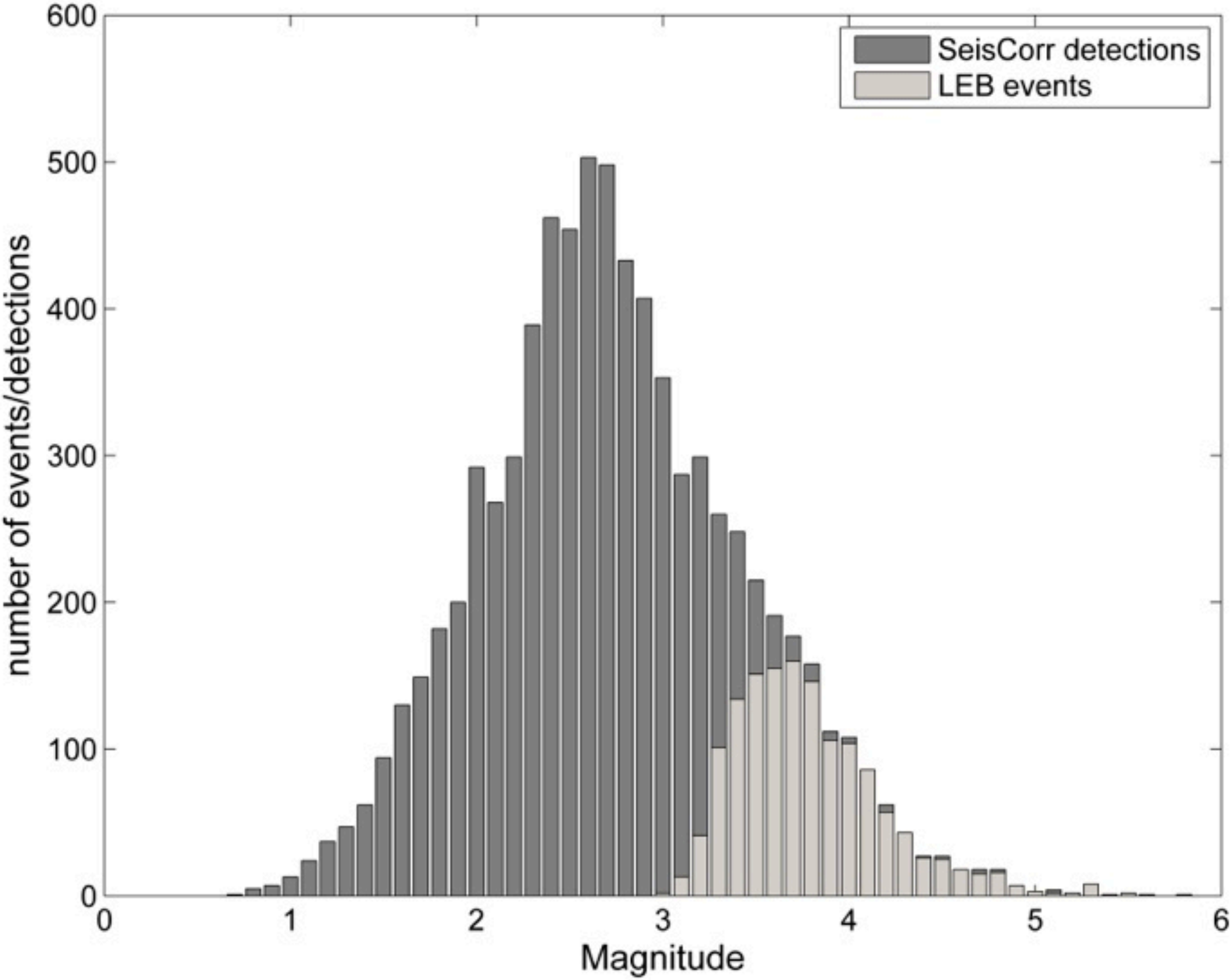
As an example of improved event detection, using waveforms, let's look at

aftershocks of the Wenchuan earthquake of May 2008

(work done in collaboration
between Lamont/Columbia University
and Sandia National Laboratories:
Heck, Richards, Schaff
Slinkard, Young):


LEB catalog, 2008/05/01-2008/08/12, 1426 origins
GS13
GS11
GS10
XAN
ENH
KMI
35° N
30° N
25° N
95° E
100° E
105° E
110° E
115° E
T:\matlab\Mapping Toolbox\China_map_wenchuan_sequence_LEB


Cumulative catalog events and detections in days after Wenchuan mainshock
seiscorr
leb
cdenor
number of detections
days
8000
7000
6000
5000
4000
3000
2000
1000
0
-20
0
20
40
60
80
100
T:\matlab\AGU14_DetectionsPerDay


SeisCorr detections
LEB events
number of events/detections
Magnitude
0
100
200
300
400
500
600
0
1
2
3
4
5
6

As an example of improved event location, using waveforms, let's also look at

small earthquakes in a swarm, west of Beijing

(work done in collaboration
between Lamont/Columbia University
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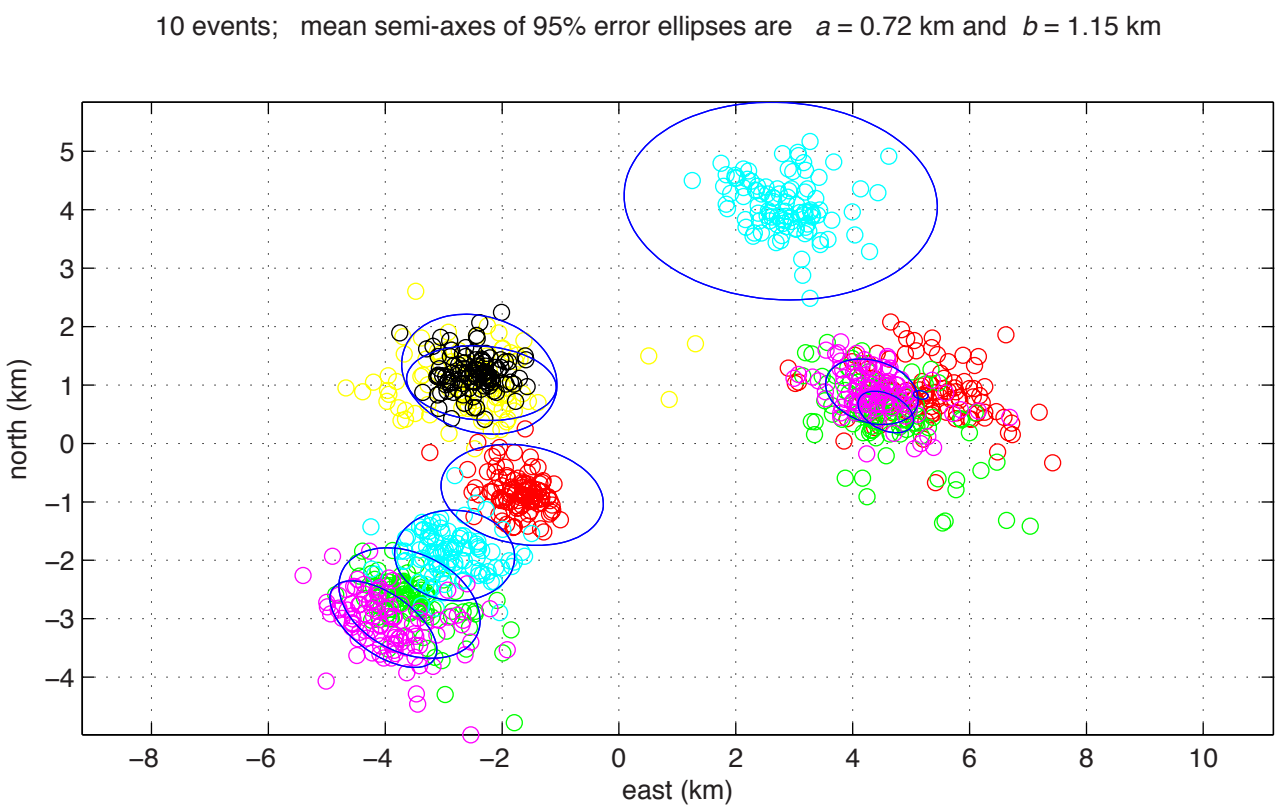
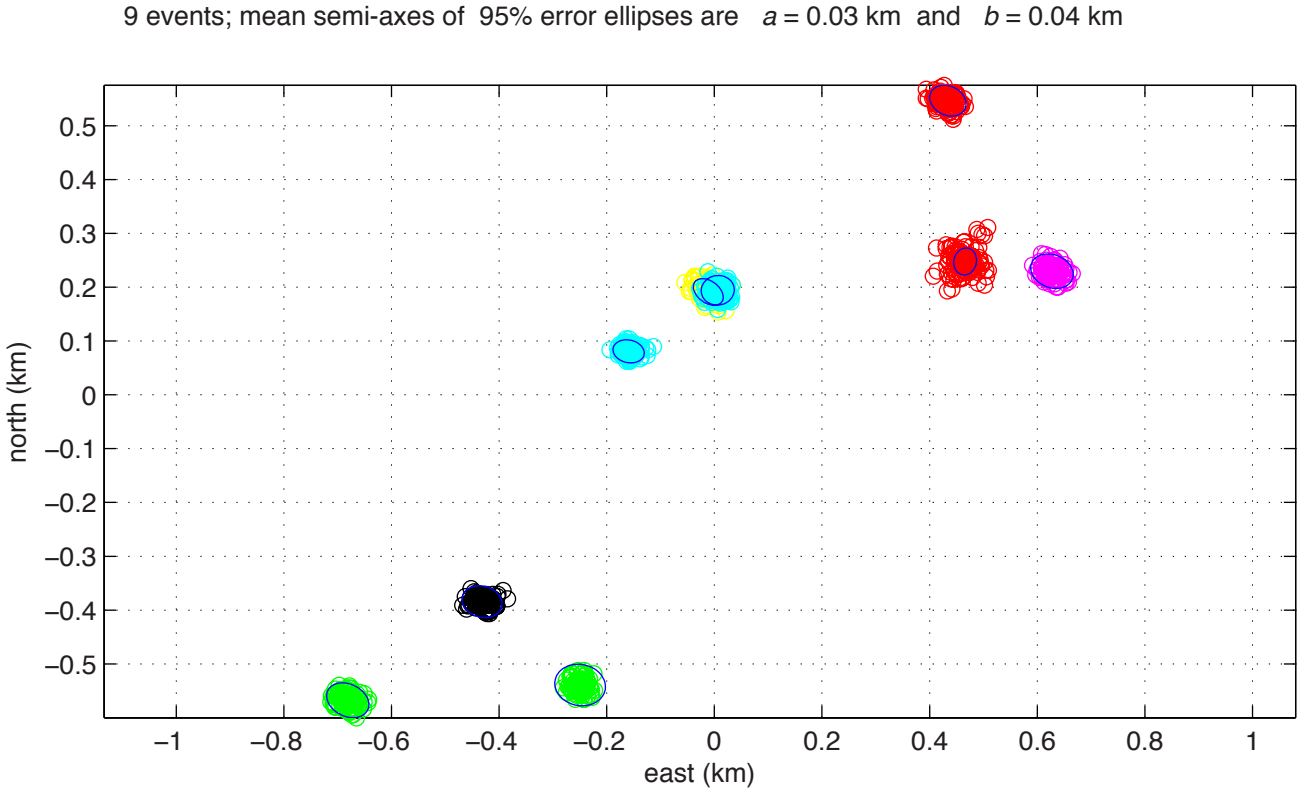
Slinkard, Young):

2006001-2013253: 10236 LEB events

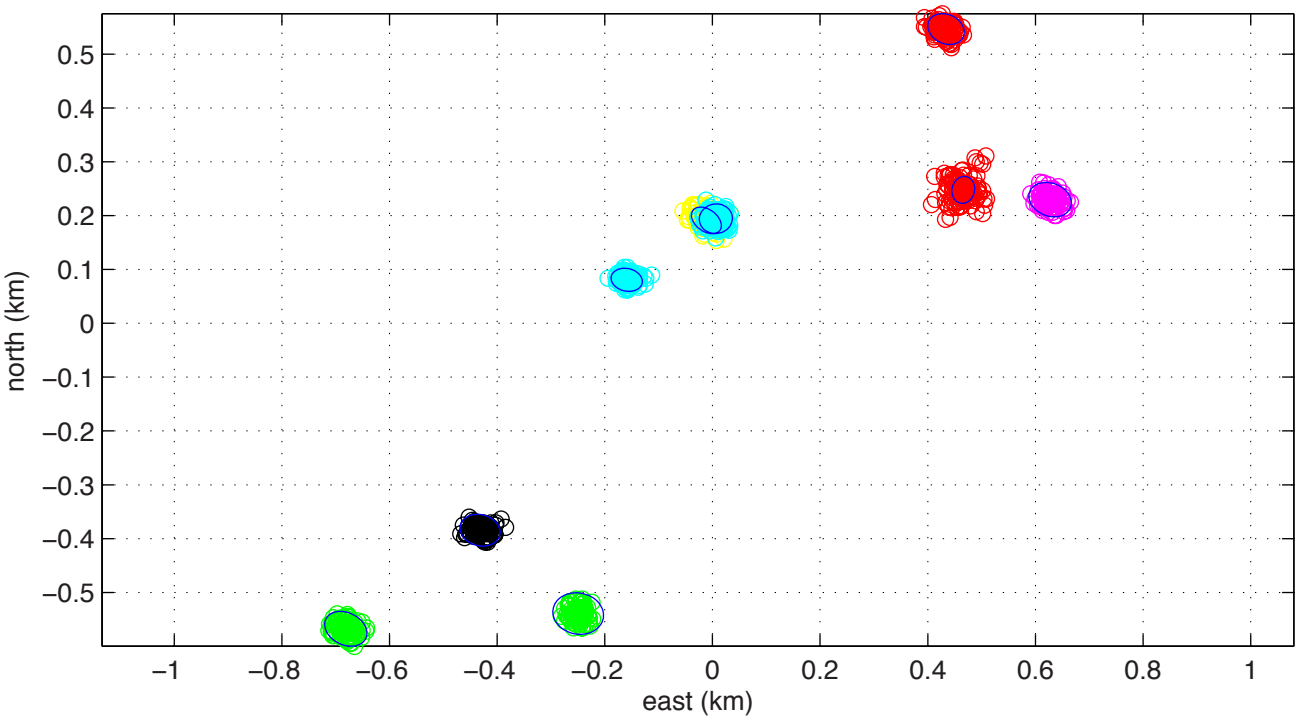
50°N
45°N
40°N
35°N
30°N
25°N
95°E
100°E
105°E
110°E
115°E
120°E
125°E
130°E
HIA
ULN
MDJ
BJT
INCN
LZH
XAN
SSE
ENH
MATB
KMI
KMI

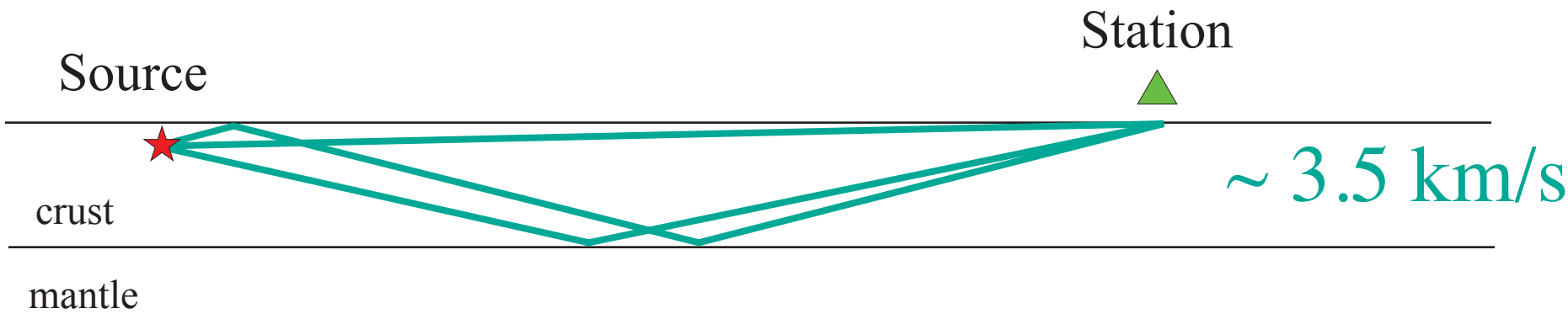

10 events; mean semi-axes of 95% error ellipses are a = 0.72 km and b = 1.15 km
north (km)
east (km)
5
4
3
2
1
0
−1
−2
−3
−4
−8
−6
−4
−2
0
2
4
6
8
10


9 events; mean semi-axes of 95% error ellipses are a = 0.03 km and b = 0.04 km
north (km)
east (km)
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
−1
−0.8
−0.6
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1

tens of meters!

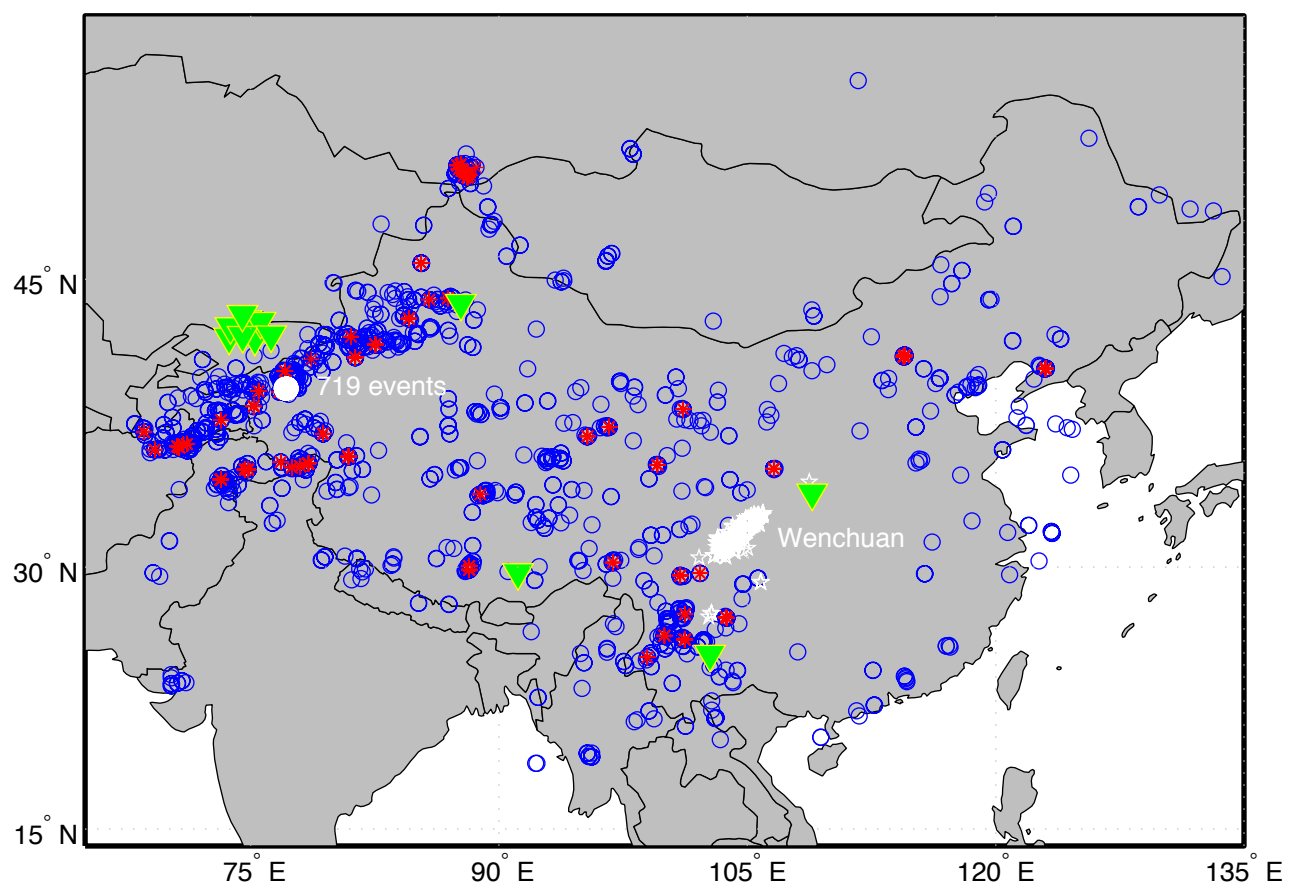
9 events; mean semi-axes of 95% error ellipses are a = 0.03 km and b = 0.04 km

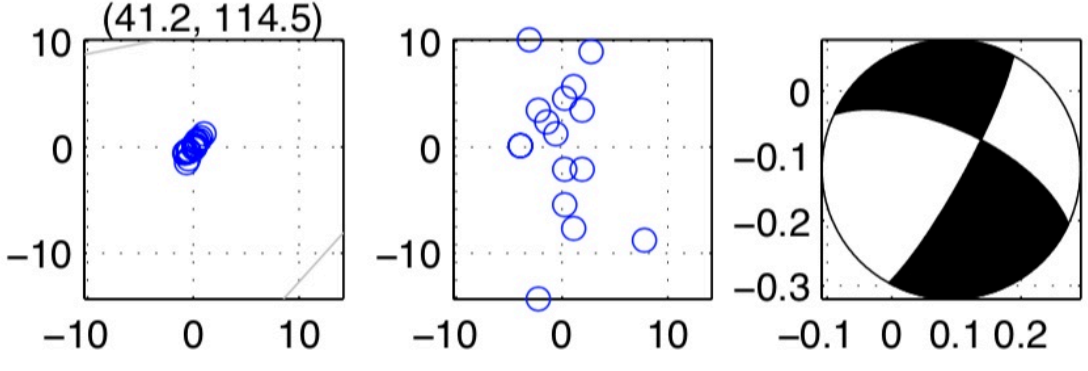


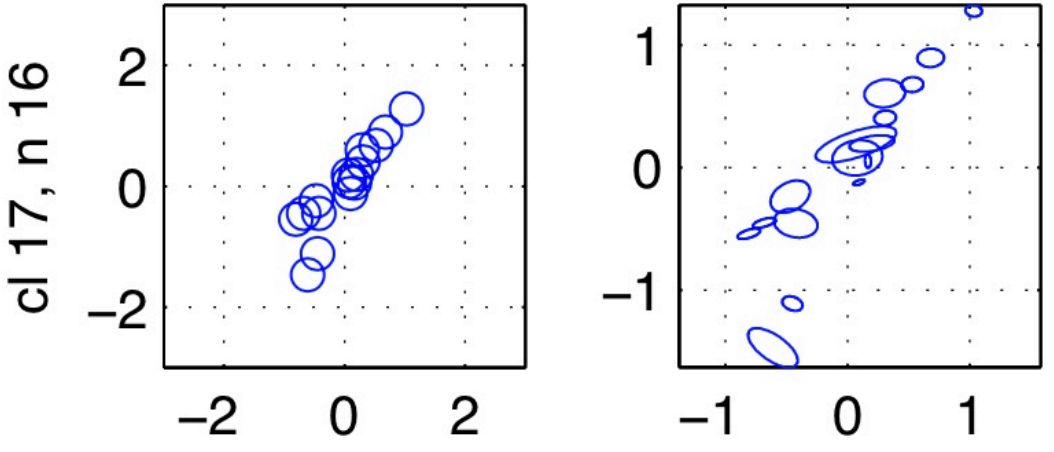


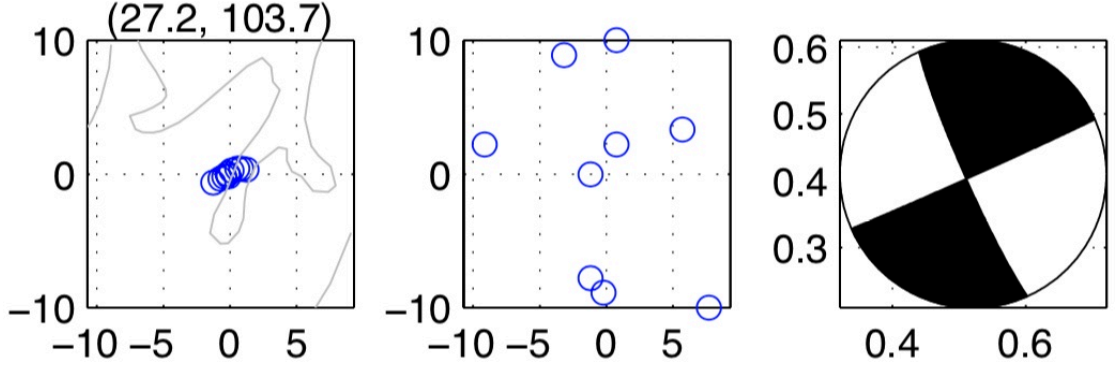
The *Lg*-wave is transverse-wave (*S*-wave) energy, trapped in the crust, having amplitudes that decay exponentially with depth below the crust-mantle interface (the "Moho").

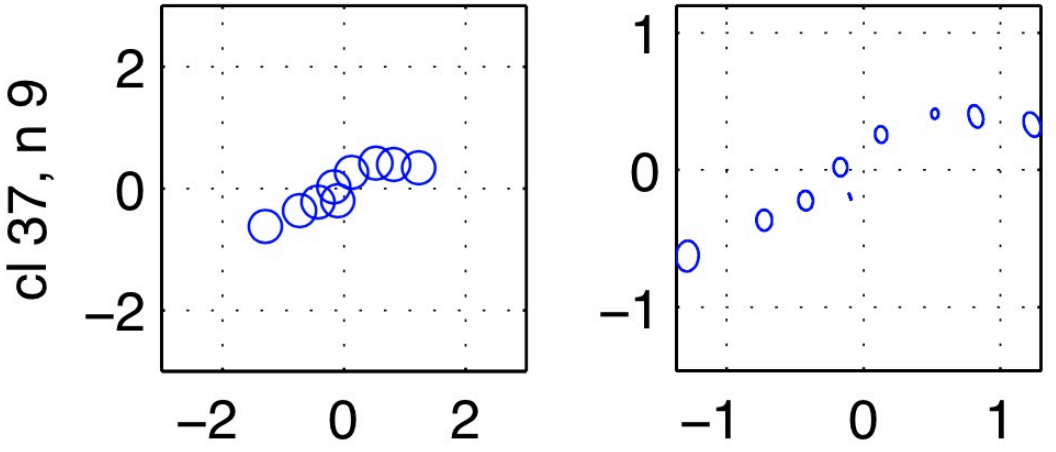
The crust thus becomes an efficient waveguide (just like the way an optical fiber carries light efficiently). But *Lg* is blocked if the crust becomes thin (just as an optical fiber fails, if the fiber thins).


719 events
Wenchuan
45° N
30° N
15° N
75° E
90° E
105° E
120° E
135° E


(41.2, 114.5)
10
0
−10
−10
0
10
10
0
−10
−10
0
10
0
−0.1
−0.2
−0.3
−0.1
0
0.1
0.2


cl 17, n 16
2
0
−2
−2
0
2
1
0
−1
−1
0
1


(27.2, 103.7)
10
0
−10
−10 −5 0 5
10
0
−10
−10 −5 0 5
0.6
0.5
0.4
0.3
0.4
0.6


cl 37, n 9
2
0
−2
−2
0
2
1
0
−1
−1
0
1

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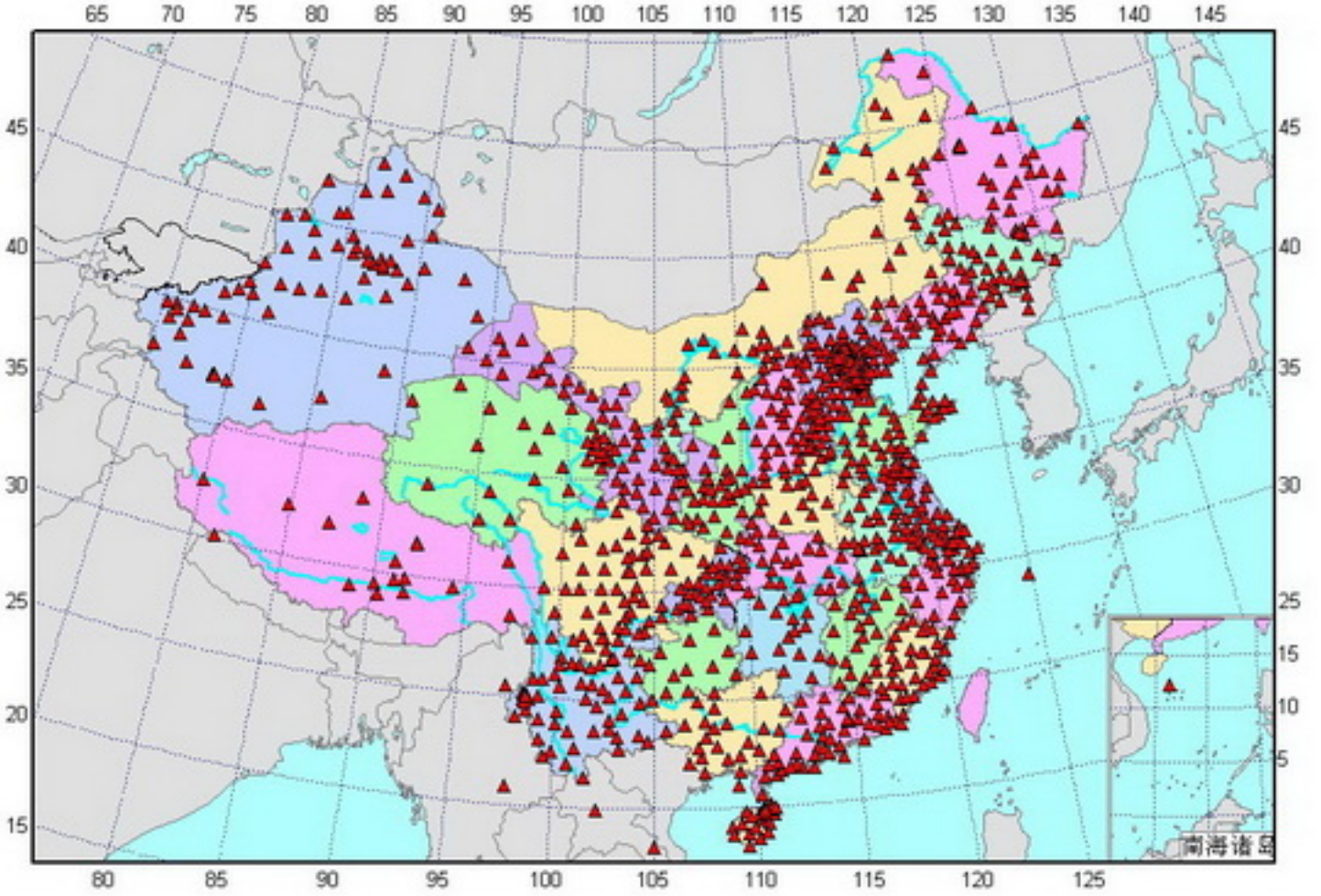
- Our final locations explain travel-time residuals (that is, the difference between observed and calculated times) which are 89 times better than those for the catalog locations (0.042 s versus 3.730 s).

- The average of semi-major axes for the 3689 relocated events, is 420 meters.

To apply modern methods of event location in a particular region of space and time, six separate steps can be identified:

1. identify seismic events likely to be well recorded, using, for example, a regional bulletin or detailed global bulletin;
2. pull out waveforms to serve as templates (our work to date has identified a few tens of seconds of the *Lg* wave as being particularly suitable);
3. cross correlate the template for each channel against the continuous archive for that channel, and note detections (e.g., via CC values greater than a value identified via a predetermined false alarm rate, as discussed in Slinkard *et al.*, 2014);
4. validate such detections (via an association approach or against a local bulletin); after a review of the quality of the detections
5. measure the relative arrival times (via cross correlation) of pairs of events that were not far apart from each other and were recorded at common stations; and
6. relocate as many events as possible using double-difference methods.


65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145
45 40 35 30 25 20 15
80 85 90 95 100 105 110 115 120 125
南海诸岛

MONGOLIA
RCAG

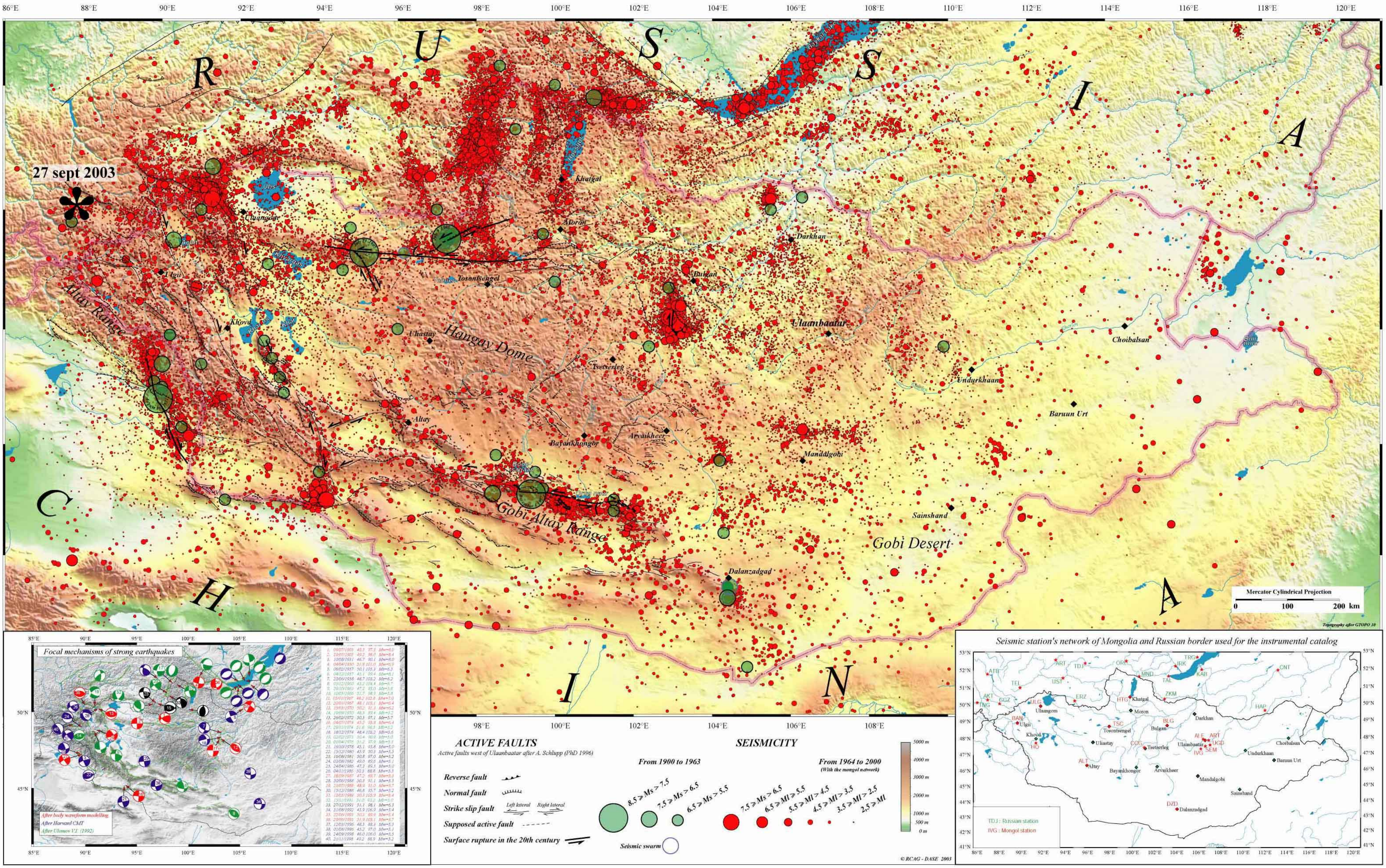
Research Center of Astronomy and Geophysics
Mongolian Academy of Sciences

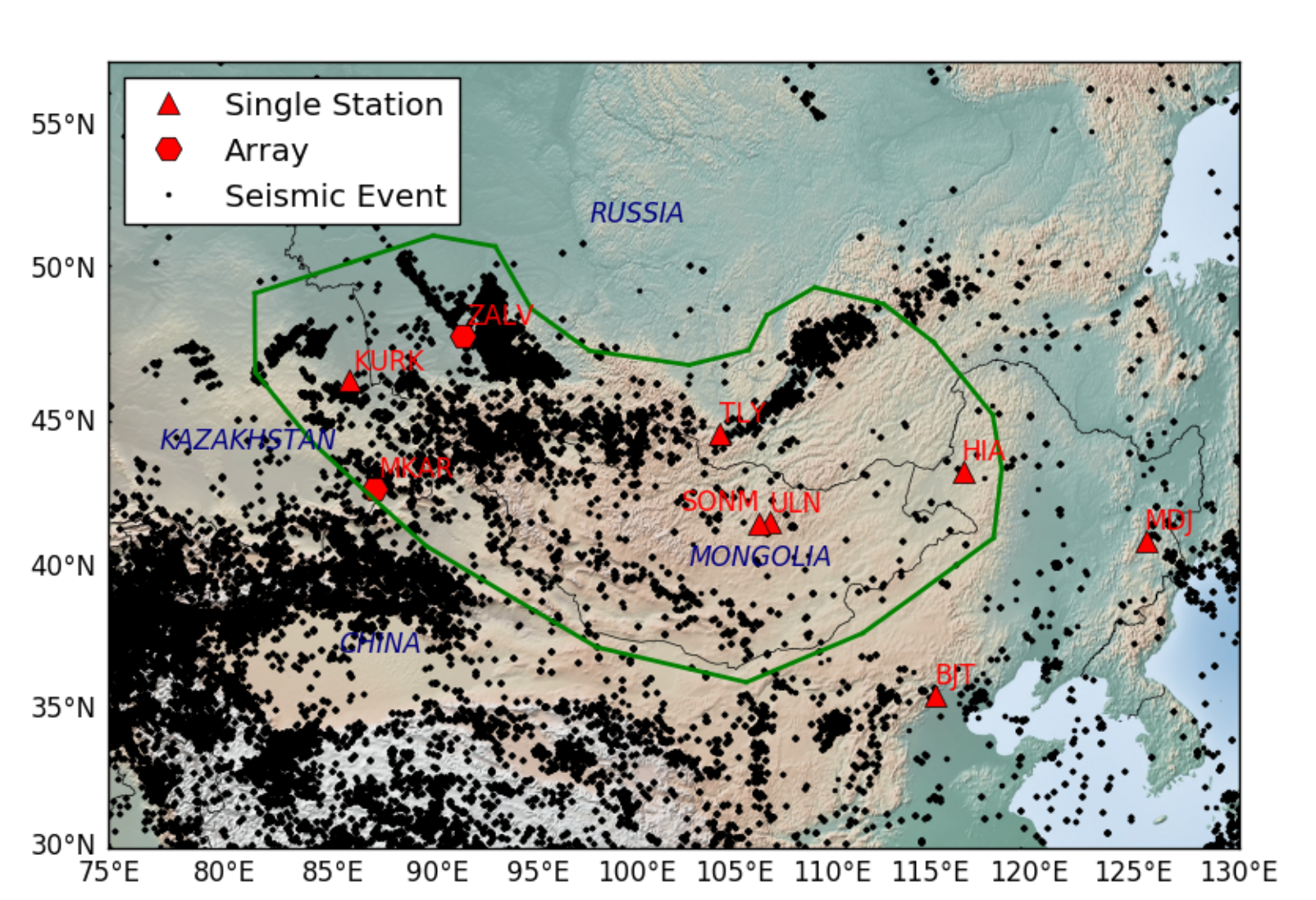
ONE CENTURY OF SEISMICITY IN MONGOLIA (1900 - 2000)

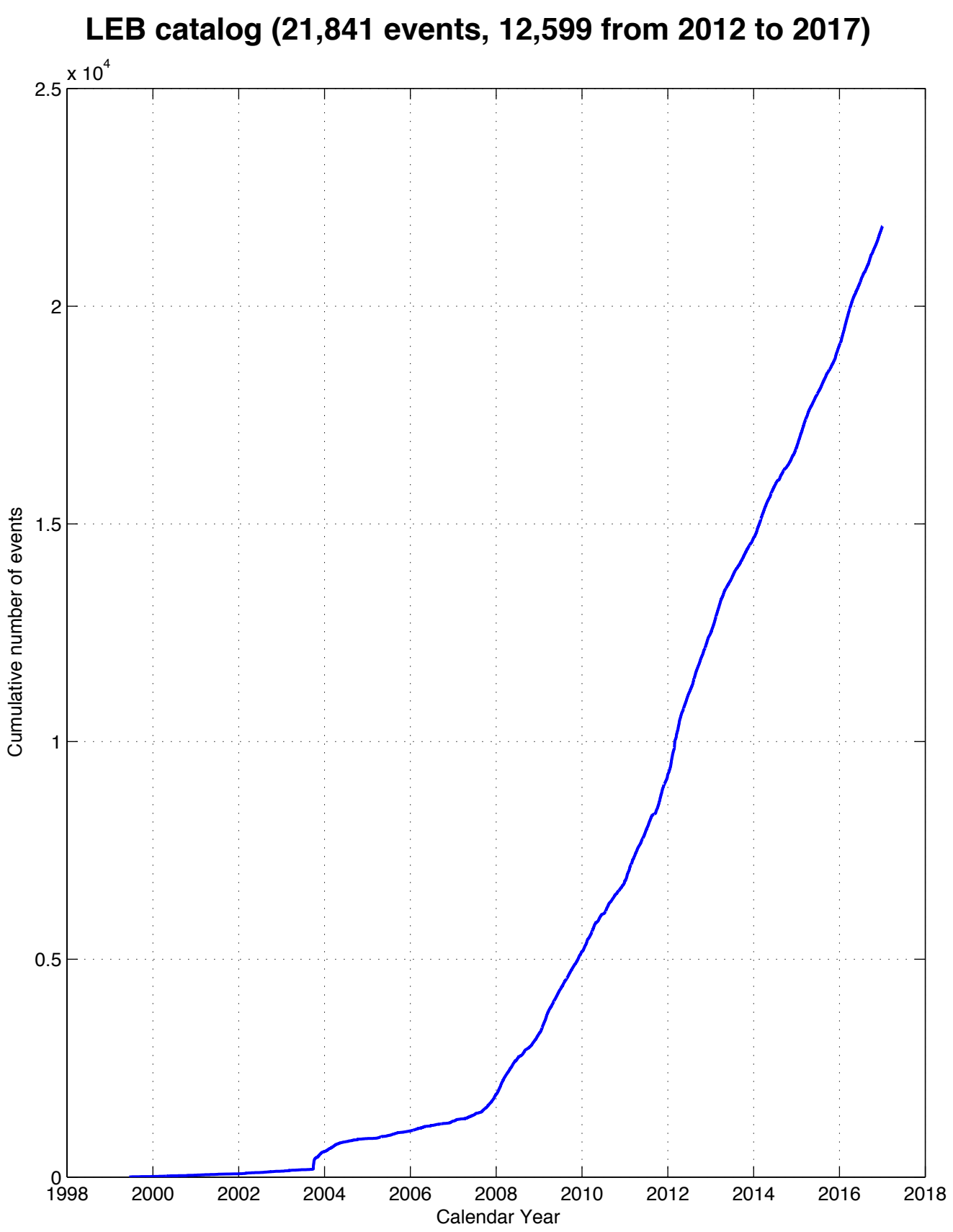
Coordinators: Dr. Dugarmaa T. (head of Department Seismology- RCAG) and Dr. Schlupp A. (Researcher - DASE)

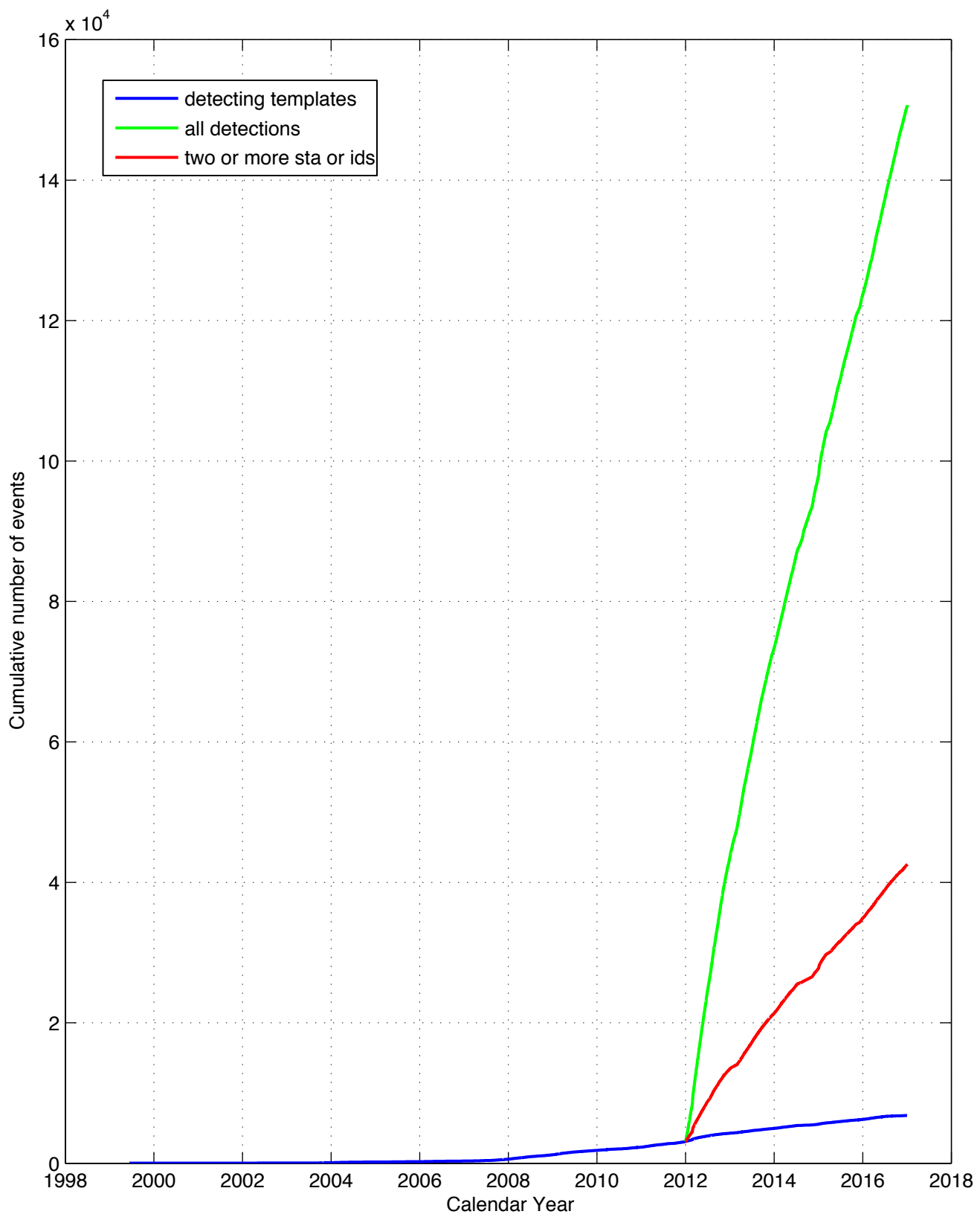
Authors : Adiya M., Ankhtsetseg D., Baasanbat Ts., Bayar G., Bayarsaikhan Ch., Erdenezul D., Mungunsuren D., Munkhsaikhan A., Munkhuu D., Narantsetseg R., Odonbaatar Ch., Selenge L., Dr. Tsembel B., Ulziibat M., Urtnasan Kh. and in collaboration with DASE since 1994 and its scientific (DASE/LDG) and technical (DASE/TMG) teams

Département Analyse
Surveillance Environnement
FRANCE




Single Station
Array
Seismic Event
RUSSIA
KAZAKHSTAN
MONGOLIA
CHINA
ZALV
KURK
MKAR
TLY
SONM
ULN
HIA
MDJ
BJT
55°N
50°N
45°N
40°N
35°N
30°N
75°E
80°E
85°E
90°E
95°E
100°E
105°E
110°E
115°E
120°E
125°E
130°E


LEB catalog (21,841 events, 12,599 from 2012 to 2017)
x 10^4
2.5
2
1.5
1
0.5
0
Cumulative number of events
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Calendar Year


x 10^4
16
14
12
10
8
6
4
2
0
detecting templates
all detections
two or more sta or ids
Cumulative number of events
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Calendar Year

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Big data methods, applied with insight!