

Table 9  
Regional Results

Region	Count	LEB			NET-VISA		
		Precision	Recall	Error	Precision	Recall	Error
Japan	1565	100.0	1.9	38	83.3	2.2	104
U.S.	132	100.0	3.0	33	90.5	14.4	93
Italy	96	50.0	1.0	49	66.7	2.1	55
Kazakhstan	65	73.3	16.9	57	70.4	29.2	63

Precision, recall, and average error (km) of the LEB and NET-VISA measured against various regional bulletins.

in the table suggest that NET-VISA has slightly poorer results for events at depth more than 400 km, although there are too few deep events in this dataset to support a definite finding.

### Comparison with Regional Bulletins

Returning to Figure 23, the gap between the SEL3 extrapolation and NET-VISA on the lower right end of the figure suggests that NET-VISA is predicting spurious events with extremely high confidence. In reality, many of these events are indeed real events that are missed by the human analysts and hence absent from the LEB. To understand the true scope of the LEB, we have compared it against various regional bulletins, which are based on data from many more stations than in the IMS. In Table 9 we consider both the LEB and NET-VISA bulletins restricted to specific regions of the earth and evaluate them against the corresponding regional bulletins. This table shows that in all regions NET-VISA finds new events not appearing in the LEB, most notably in the United States and Kazakhstan. The results in the continental United States are further subdivided by the local magnitude ( $M_L$ ) in Table 10. These results indicate that NET-VISA is able to find roughly half of the events with  $M_L$  between 3 and 4.5, as well as some weaker events, while the LEB finds only 7% of events with  $M_L$  between 3 and 4.5 and none below this.

The exact demarcations of these regions and the bulletins used are described in Table 11. The NEIC bulletin was used as the ground truth for the continental United States. This bulletin was downloaded from the Incorporated Research Institutions for Seismology (IRIS). For the other regions we relied upon the raw bulletins from the International Seismological Center (ISC; see [Data and Resources](#)). The relevant agency codes are displayed in the table.

*ISC Event 13437052.* As a concrete example we display the waveforms of one of the events in central Asia that is absent in the SEL3 and the LEB, but is found by NET-VISA and confirmed by a regional bulletin. This event has been given the event identifier 13437052 by ISC. (See Table 12 for the event location.) NET-VISA forms the events using regional phases ( $P_n$ ,  $P_g$ ,  $S_n$ ,  $L_g$ ) at three IMS stations (MKAR, AAK, and KURK). The waveforms for the three stations are displayed

Table 10  
Continental U.S. Results ( $M_L$ )

$M_L$	Count	LEB		NET-VISA	
		Recall	Error	Recall	Error
Unknown	13	23.1	35	23.1	60
1.0–2.0	23	0.0	–	0	–
2.0–2.5	48	0.0	–	4.2	112
2.5–3.0	35	0.0	–	20.0	118
3.0–4.5	13	7.1	28	53.8	78
All	132	3.0	33	14.4	93

Recall and average error (km) subdivided by event magnitude ( $M_L$ ) in the continental United States.

Table 11  
Regional Boundaries

Region	Longitude (°)	Latitude (°)	Ground Truth
Japan	130 to 145	30 to 45	JMA bulletin (ISC)
U.S.	–125 to –70	25 to 50	NEIC bulletin (IRIS)
Italy	6 to 19	36 to 48	ROM bulletin (ISC)
Kazakhstan	46 to 86	40 to 55	NNC bulletin (ISC)

The definition of the various regions used for the regional evaluation and the corresponding ground-truth bulletin.

in Figures 27, 28, and 29, respectively. In all three figures the first arrival comes in around 12 s into the waveform. The figures show the raw waveforms, two filtered versions, and the STA/LTA for the higher frequency filtered waveform. The automatic arrivals are marked with the STA/LTA as dotted vertical lines. Of these three, MKAR is a primary IMS seismic station, while the other two are auxiliary seismic stations. While the event satisfies the criteria for inclusion in the LEB, it lacks the three primary stations required for inclusion in the Reviewed Event Bulletin (REB); had the event been found by NET-VISA and presented to an analyst, it is possible that further primary arrivals could have been added manually.

### IDC Evaluation

Finally, we present results of an independent evaluation of NET-VISA by the IDC. The results were broadly similar to