REPORT
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# The propagation of seismic waves, misinformation, and disinformation from the 2024-10-05 M 4.5 Iran earthquake

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**Abstract** The 2024-10-05 Iran M 4.5 earthquake took place at a time of heightened tensions in the Middle East. We perform a discrimination and moment tensor analysis and identify a shallow-dipping, reverse fault source commensurate with the compressional setting of the Iranian interior. Nonetheless, the event's aftermath saw widespread dissemination of misinformation, and potentially active disinformation, concluding that it was in fact a test of an Iranian nuclear weapon. The 'evidence' for many of these claims was based on inaccurate interpretation of seismic data. In this paper, we analyse how geophysical 'fake news' propagated through social media (mainly Twitter/X) following this event, eventually gaining traction in mainstream, earned media. This event is an illustrative warning of how seismic data can be misinterpreted and/or manipulated in public discourse.

**Persian** زمین لرزه ای که به بزرگی ۴.۵ در تاریخ پنجم اکتبر سال ۲۰۲۴ در ایران رخ داد، در زمان بالاگرفتن تنش ها در خاورمیانه اتفاق افتاد. ما تحلیل تانسوری گشتاور انجام داده، گسل معکوس کم عمقی را به عنوان منبع این رویداد معین کردیم که با ساختار فشاری و تراکمی داخل ایران مطابقت دارد. با این وجود، در پی این حادثه اطلاعات نادرست (غیر عامدانه) و اطلاعات غلط (عامدانه) به صورت گسترده ای پخش شد با این نتیجه گیری که این حادثه مربوط به آزمایش سلاح هسته ای در ایران است. شواهد ارایه شده در بسیاری از این ادعاها بر اساس تفسیر نادرست داده های لرزه ای مربوط به این حادثه بود. ما در این مقاله و در تحلیلهایمان نشان میدهیم که چگونه اخبار جعلی ژئوفیزیکی مربوط به این حادثه درشبکه های اجتماعی پخش شد (علی الخصوص در توییتر/اکس)، چطور مورد توجه قرار گرفت و در نهایت چطور به مطبوعات و رسانه ها رسید. این حادثه میتواند به مانند هشداری باشد که چگونه داده های لرزه ای میتواند به طور اشتباه و یا عامدانه دستکاری شده و وارد گفتمگان عمومی جامعه شود.

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## 1 Introduction

Actively challenging and correcting false information is a key part of public engagement and hazard communication in seismology (Dryhurst et al., 2022). Within public discourse, false narratives may take the form of misinformation (the unintentional or mistaken sharing of false knowledge) or disinformation (the deliberate and deceptive sharing of false knowledge).

Common false narratives in seismology include the belief that earthquakes are deterministically predictable, strongly influenced by the weather, or triggered by the Moon or other planetary alignments (e.g. as desribed by Fallou et al., 2022; Romanet, 2023). Occasionally, claims are made which may cross the line into deliberate disinformation (e.g. as described by Gori, 1993; Kwanda and Lin, 2020). Definitively ascribing a false narrative to disinformation rather than misinformation is challenging. However, if material which is designed to be shared widely, despite the author possessing evidence that it is not true, this could reasonably be considered to constitute disinformation.

Although 'fake news' about seismic events has existed for decades, it is clear that its spread has been strongly exacerbated by social media, in particular Twitter/X (Murayama et al., 2021; Erokhin and Komendantova, 2023). False narratives are also observed to propagate faster than real news (Langin, 2018).

The impacts of spreading false information in the aftermath of earthquakes can be significant, for example hampering authorities' responsivness (Gori, 1993) and negatively influencing the wellbeing of affected populations (Mărcău et al., 2023). However, impacts are generally localised to the affected populations.

The 2024-10-05 Iran M 4.5 earthquake (seismically analysed in Sec. 3.1) was unusual in that the spread of misinformation and disinformation had potentially serious and widespread geopolitical consequences. What began as speculation on social media that this event was

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in fact a clandestine nuclear weapons test eventually acquired traction as misinformation in mainstream media, launching likely active disinformation campaigns. Because the seismic data were crucial 'evidence' in the spread of false narratives, we consider that this event warrants further attention from the seismology community. Given that communication is as much a part of the modern nuclear monitoring pipeline as classical source discrimination (e.g. Murphy, 1996) and modelling (e.g. Fisk, 2006), this event may serve as a potential learning experience.

In this fast report, we will briefly summarise this event, present a source inversion, and analyse the spread of 'seismic fake news' published on social and in earned media. Combined with existing literature on how to combat false information on seismic topics (e.g. Fallou et al., 2022; Dallo et al., 2022), we will also suggest key messages to emphasise when discussing the origin of this and similar events.

## 2 Data and Methods

### 2.1 Tectonic setting

The event in question occurred on 2024-10-05 and is reported by the USGS to have an origin time of 19:15 UTC (22:45 local time/UTC + 03:30) and a magnitude M of 4.5 (US Geological Survey, 2017). It appears in the International Seismological Centre catalogue (Bondár and Storchak, 2011) as event 642134423. Although it is below the magnitude for which the Global Centroid Moment Tensor (GCMT) project (Ekström et al., 2012) usually computes moment tensors, an inversion under this methodology was undertaken for this paper.

The USGS estimated epicentre at 35.377°N 52.891°E places this event in a tectonically active region of Iran, within a compressional setting associated with convergence of the Arabian and Eurasian plates (Tavakoli et al., 1999; Robert Engdahl et al., 2006). Two earthquakes of very similar location and size to this event are an M 4.6 event on 2015-08-25 and another M 4.4 event on 2018-01-15. The moment tensors of these events were inverted for using the same GCMT methodology as described in Sec. 3.1; though a robust and stable solution was not possible for the 2018-01-15 event due to poor-signal-to-noise ratios. These two events are by no means the largest experienced in the area, with many in excess of M 6 in the last century (Khodaverdian et al., 2016). An illustrative map of this region is shown in Fig. 1.

### 2.2 Seismic data

Seismic data from this event are shown in Fig. 2; Fig. 2A shows body waves between 0.05 and 0.5 s while Fig. 2B highlights surface waves between 15 and 30 s . All traces in Fig. 2A show a clear P-wave arrival (dashed blue line). S-wave arrivals (dashed orange line) are present, but they are more variable in amplitude between stations. This is more likely a consequence of regional geology rather than radiation pattern, given that these stations are located in a very narrow azimuth range.

Data from distances closer than than 5° are not available, and as per Fig. 1 stations are almost all to the north-east of the event. Limited azimuthal and epicentral coverage almost certainly affects source inversions, but for this event a robust (meaning a well-converged and stable solution during the moment tensor inversion) analysis of the source location and mechanism is nonetheless possible.

### 2.3 Social media methods

Irrespective of the actual source of this event, speculation, misinformation, and likely disinformation about its origin abounded in its aftermath. We attempt to trace the sharing of misinformation and disinformation related to this event on social media, with a focus on Twitter/X, which had the highest density of relevant posts of the various sites searched.

This study focused on tweets in English, Persian, Arabic, and Hebrew, as these comprised the largest share of posts. A member of the authorial team fluent in each respective language then analysed the tweets. Details of the search methodology, including terms used and acknowledged limitations is given in supplement Sec. S2.

#### 2.3.1 Categorisation

We found that tweets about this event generally fell into one of four categories. These are:

- **Informational posts** - those sharing demonstrably accurate and factual information about the earthquake only,
- **Speculative posts** - those raising questions about the origin of the earthquake, including hypothesising that it could have possibly been a nuclear test without definitively claiming it to be one,
- **Misinformation posts** - those presenting or sharing false information or 'evidence' that this was a nuclear test, either mistakenly or where evidence of intent cannot be surmised, and
- **Disinformation posts** - those presenting or sharing false information or 'evidence' that this was a nuclear test, where likely intent to mislead or deceive is present.

It is also important to note that concretely determining whether a post constitutes deliberate disinformation rather than accidental misinformation is very challenging. Therefore, we have been very conservative about doing so. However, we note that some accounts display multiple hallmarks of a likely higher risk of spreading deliberate disinformation. These include a lack of verifiable biographical information, high volumes of tweets that generate little interaction from (identifiably) human users, and limited reactivity (e.g. Hindman and Barash, 2018). In this particular study, we also identified a number of accounts that imitated or falsely implied they were sharing content from legitimate news outlets, which we consider to be strong evidence of disinformation.

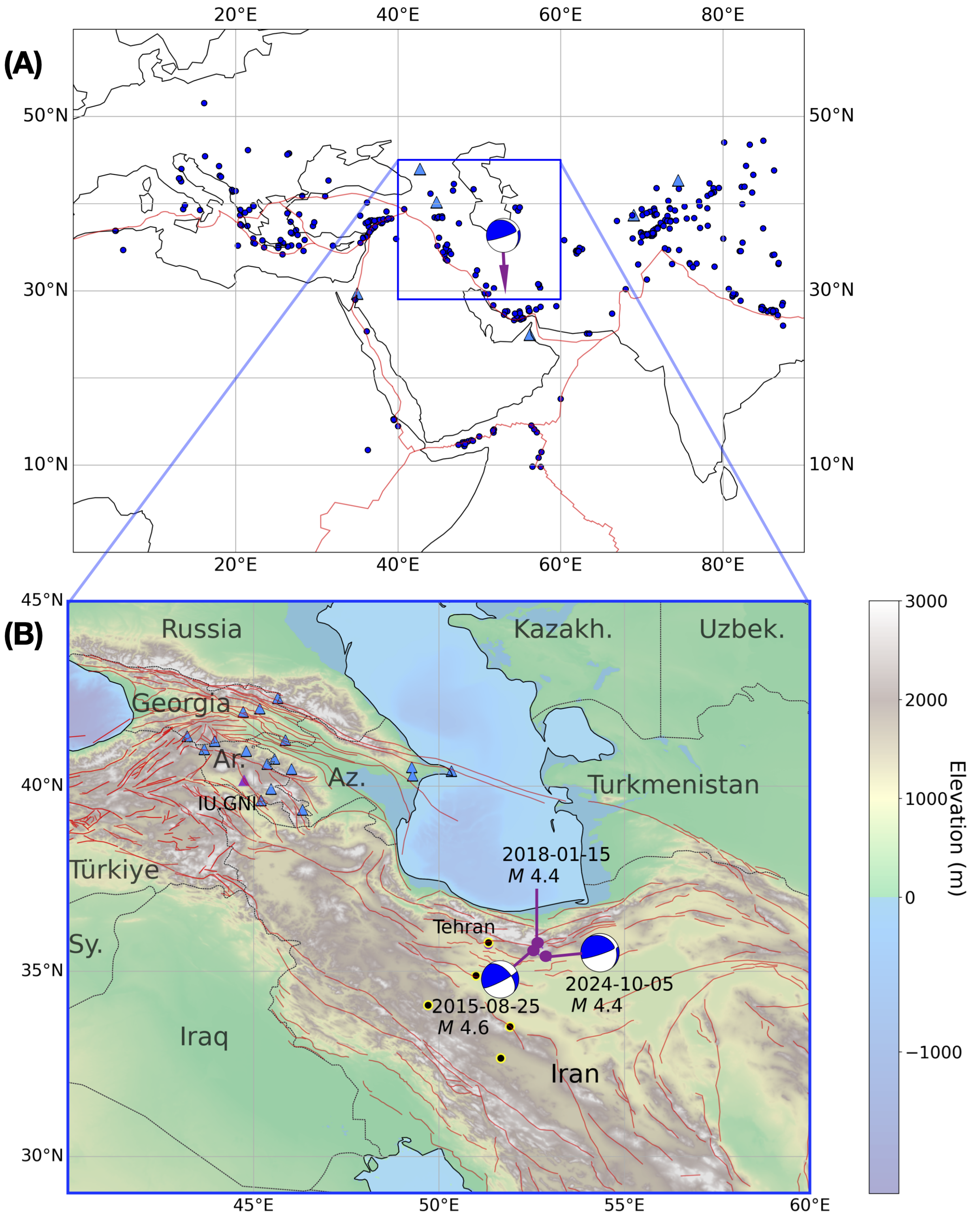


**Figure 1** Geography of the region of interest. **A)** The 2024-10-05 event is located at the position of the illustrated moment tensor and the inferred plate velocity (around 22 mm/year) at this position is indicated with a purple arrow, as calculated from the GAGE Plate Motion Calculator. Plate boundaries are in red, earthquakes with magnitude M > 6 between 2014 and 2024 are shown as blue dots, and seismic stations within 20° used in the surface wave inversion for the 2024 event are represented by blue triangles. **B)** Seismometers used in derivation of P/S ratios are marked as blue triangles. This includes IU.GNI, in purple, outside Yerevan, Armenia, the significance of which is discussed in Sec. 3.2.3. The 2024-10-05 event, as well as two events highlighted as being similar by the CTBTO, are also displayed. In all three cases, moment tensor inversions were undertaken using the GCMT method. For the 2018-01-15 event, a stable solution could not be derived, whilst the 2015-08-25 event has a very similar focal mechanism to the 2024-10-05 event. Selected Iranian nuclear facilities, with locations derived from the Nuclear Threat Initiative Database, are shown as yellow/black dots. The Iranian capital, Tehran, is labelled next to the co-located Tehran Research Reactor. Topography from NOAA (2022) and fault lines (red) from Styron and Pagani (2020).

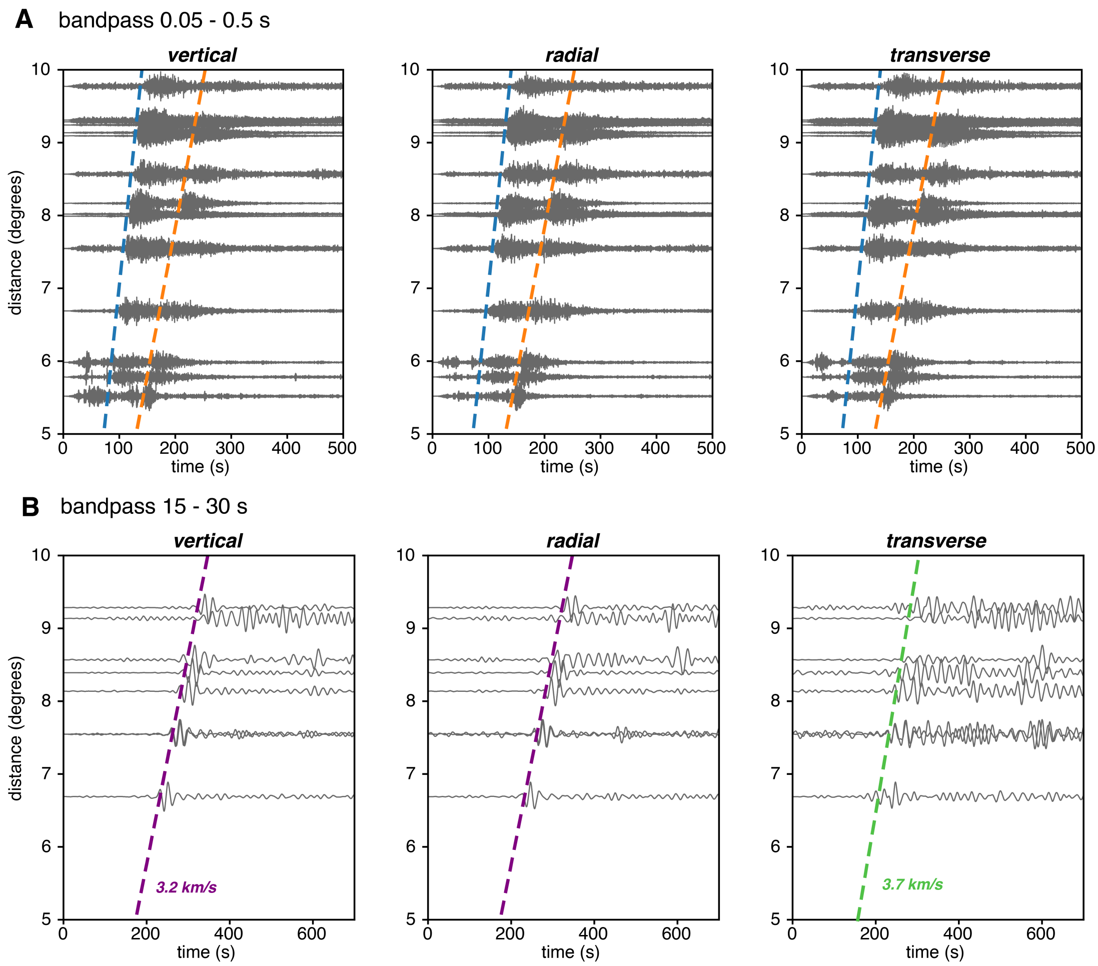


**Figure 2** Vertical, radial, and transverse record sections from this event. These data are from regional seismometers (Fig. 1B) that are not used in the GCMT surface wave inversion but are instead shown to illustrate body phase presence and variation. Data in **(A)** are filtered between 0.5 - 0.05 s (2 - 20 Hz). P and S wave theoretical arrival times, as calculated using TauP (Crotwell et al., 1999) are shown as blue and orange dashed lines respectively. **(B)** shows stations for which surface waves are apparent; data here are filtered between 15 - 30 s. The dashed purple and green lines show calculated surface-wave moveouts with velocities of 3.2 km/s (Rayleigh) and 3.7 km/s (Love), respectively. Data presented are visually selected based on the clear presence of body or surface wave phases.

# 3 Results and Discussion

## 3.1 Source inversion

A moment-tensor inversion for this earthquake was carried out using the GCMT methodology of Ekström et al. (2012) in order to determine the source mechanism. This inversion used 38 individual components from 22 unique seismic stations at global distances and was based on surface waves with periods longer than 40 s. The period band used was selected to optimise the inversion, given the lower magnitude of the source as compared to the one adopted in normal GCMT inversions.

The inversion yields the following source properties: Latitude: 35.40±0.04°, Longitude: 52.84±0.05°, and origin time (UTC): 19:15:38.2 ±0.6. Here, depth is fixed at 12.0 km , the standard GCMT value where an actual estimate cannot be made as per Ekström et al. (2012). The results of the inversion for the moment-tensor structure itself are shown in Table 1.

This moment tensor is indicative of a shallow-dipping reverse-fault event, commensurate with the compressional setting of the Iranian interior (e.g. Tavakoli et al., 1999). Such a source is very different from the monopolar-dominated moment tensors of nuclear test events (e.g. Ford et al., 2009; Alvizuri and Tape, 2018).

| Component | Value (x$10^{22}$ Dy-cm) | Error (x$10^{22}$ Dy-cm) |
|---|---|---|
| $M_{RR}$ | 1.14 | 0.27 |
| $M_{TT}$ | -1.92 | 0.21 |
| $M_{PP}$ | 0.79 | 0.21 |
| $M_{RT}$ | 4.38 | 0.48 |
| $M_{RP}$ | 1.68 | 0.55 |
| $M_{TP}$ | 0.90 | 0.17 |

**Table 1** Derived moment tensor parameters for this event.

Following the method of Wang et al. (2020), we also computed the 3-component P-to-S amplitude ratio for this event, which yields a median value of 1.17 for stations plotted in Fig. 1A. Although this value is on the high end of uncorrected P/S ratios for natural seismic events recorded at local to regional distances, it is not inconsistent with measured P/S ratios of known tectonic events (see Wang et al., 2021). Figs. S1.2-1.4 in the supplement highlight potentially higher-than-expected and significantly variable in P/S ratios for three more events in this area. This suggests that the observed ratios are a consequence of the region and its characteristic seismicity rather than something particularly unusual about the October 2024 event.

Finally, we note that the conclusion of this being a tectonic, rather than nuclear, event has been communicated through various monitoring agencies, most notably the Comprehensive Test Ban Treaty Organisation (CTBTO), who reported that 'earthquakes with similar characteristics occurred in the region on 25 August 2015 (Fig. S1.2) and 15 January 2018 (Fig. S1.3), both of similar magnitude.' [1]

### 3.2 Social media analysis

As English-language posts made up the greatest fraction of online content, discussion in this section is focussed on said posts. The corresponding section in the supplement is Sec. S3, and further analysis of posts in other languages and on platforms other than Twitter/X can also be found in supplement Secs. S3-6.

#### 3.2.1 Initial informational tweets

We identify the first publicly available post on Twitter/X referring to an 'earthquake in Tehran, the capital of Iran' at 19:26 UTC, approximately 11 minutes after the earthquake (Fig. S3.1, bottom panel). This originated from a self-identified 'aggregator' account and was limited to accurate factual content; we therefore classify it as 'informational,' though the original source of the 'aggregated' information cannot be identified.

The initial tweet was followed by a preponderance of numerous identical (down to the character) tweets in the next few minutes, presumably from automated/'bot' accounts (Fig. S3.1, middle and top panels).

#### 3.2.2 Speculation and misinformation

A response to a tweet from one of these bot accounts is the first suggestion that we can identify on social media of any kind that this was not an earthquake (Fig. S3.2, top panel). This was posted at 19:32 UTC, only 17 minutes after the earthquake's origin, and suggested that the event represented an Israeli weapons strike on Iran. Such a strike was widely expected in the first week of October. Some of these posts also commented on the supposed proximity of the epicentre to Iranian nuclear sites (Fig. S3.2, bottom panel).

In the same thread are suggestions from other users that the earthquake was linked to HAARP (the High Altitude Active Auroral Research Program; 19:39 UTC, Fig. S3.3, bottom panel), weather machines (19:57 UTC, Fig. S3.3, top panel). These suggestions refer to various conspiracy theories regarding the supposed deliberate triggering of seismic events by governments and other supposedly nefarious organisations (e.g. Arce-García and Díaz-Campo, 2024; Erokhin and Komendantova, 2024). While some of these conspiratorial tweets may be more satirical than earnest in nature (e.g., referencing 'Jewish space lasers,' Fig. S3.4), that tone may not be explicitly communicated, furthering the propagation of misinformation. It should also be noted that while some tweets may have had humorous intent, many more furthered similar harmful narratives using an unambiguously serious tone.

The first suggestion we identified that this event was a nuclear test—made in response to one of the likely bot tweets—was posted at 19:38 UTC, around 27 minutes after the event (Fig. S3.5, bottom panel). Over the next few hours, we observe repeated instances of unsupported misinformation circulating online, claiming that this event was a nuclear test linked to the ongoing conflict in the Middle East (Fig. S3.6-7).

During this period, numerous other posts commented on the high seismicity levels in northern Iran or shared data from earthquake monitoring agencies, such as the United States Geological Survey, the Iranian Seismological Center, and the European-Mediterranean Seismological Center. While none of these organisations raised concerns about a potential nuclear origin for this event, speculation and misinformation persisted despite the availability of reliable seismic data and experts to interpret it.

#### 3.2.3 Misleading seismograms

Within twenty-four hours of the event, we find seismic data being posted to support the conclusion that this was a nuclear test (Fig. S3.8). Many of these posts shared uncorrected, unfiltered data from station IU.GNI (Garni, Armenia); supported by a plot copied (uncredited) from Walter et al. (2007) illustrating the anomalously high P-to-S ratios of other nuclear explosions.

However, the posted data for IU.GNI are for the wrong earthquake, instead showing a seismic event, close to the IU.GNI station, some seven hours earlier (around 12:37 UTC). We have re-plotted data from this event in the Supplement (Fig. S3.9).

The signal at around 12:37 UTC does not correspond to an earthquake in the International Seismological Centre (Bondár and Storchak, 2011) catalogue. Coupled with the short separation between phases and the high ground amplitudes at this station alone, this indicates that it is a local event. Conversely, the signal recorded at IU.GNI from around 19:18 UTC onward is a much closer match to other stations in the area, as shown in Fig. 2.

We were not able to identify the original source of this image using reverse graphic searches due to the inability of image lookup tools to differentiate between this seismogram and other similar waveforms from other stations and events.

Interestingly, one of the first posters of this seismogram appears to have had some knowledge of seismology. For example, they responded to other users commenting on the event depth, pointing out that it was fixed (at 10 km) and hence not reliable, i.e., that a nuclear test could not be ruled out on the basis that no tunnels exist and no one could set off an explosion that deep. As ever, concluding that this represents deliberate disinformation, rather than a substantial oversight

[1] https://www.ctbto.org/news-and-events/news/ctbto-detects-two-earthquakes-northern-iran-5-october

in posting the wrong seismogram, is challenging. However, this pattern of substantial and sustained engagement with other users, and a knowledge of seismology, does potentially imply a human author with some specialist knowledge of this material.

A number of posts contained text accompanying these misleading seismograms which repeatedly claimed that this event was likely to be a nuclear test on account of the 'lack of compressional wave'. This is of course inaccurate on multiple counts: there is clear evidence of a P-phase in the 12:37 UTC event data, and explosions tend to produce strong compressional waves (e.g. Massé, 1981) with anomalously high P-to-S ratios as compared to other events in the same tectonic region (Walter et al., 2007).

Many posts attributed the comments about this event's purported unusual source parameters to unnamed and uncited 'Armenian scientists.' We are unable to find any public comment from Armenian research organisations or researchers about this event and speculate that this attribution may be entirely fictional.

Finally, a more limited number of posts on Twitter/X suggested that the 'lack of an aftershock' following this event made it more likely to represent a nuclear test. Whilst we did not identify a specific fault for this event, and hence did not search for more aftershocks specifically on it, there are numerous events of similar and smaller magnitudes that have occurred within this region of Iran in the weeks following it, as expected. The largest nearby event occurred on 2024-11-06 and was an M 4.6 event with an epicentre around 50 km from the 2024-10-05 event. It is also pertinent to note that aftershocks can follow some nuclear tests, corresponding to cavity collapse or failure of a partly unlocked fault, for example (Hamilton and Healy, 1969; Gross, 1996; Schaff et al., 2018).

#### 3.2.4 Potential deliberate disinformation

As noted previously, it is challenging to determine whether misinformation has crossed the line into deliberate disinformation. One particularly interesting set of tweets that may construe disinformation involves 'Breaking News' posts, as purported breaking news stories have been shown to lend themselves to propagation of disinformation (e.g. Alkhodair et al., 2020; Kwanda and Lin, 2020).

We identify a number of 'Breaking News' tweets which include logos and graphics extremely similar to reputable mainstream news organisations (e.g., the BBC) stating that Iran has undertaken a nuclear test (Fig. S3.10). Impersonation of legitimate sources has been noted as a route to sharing fake news (e.g. Wardle, 2018), and may reasonably be taken as evidence of deliberate intent to deceive. Examples of said logos are shown in the supplement to this report.

Similarly, the day after the earthquake (2024-10-06), we note a number of purported 'news' organisations (claiming this status in their usernames or biographical information) sharing amalgamated misinformation about this event and the conclusion that it was a nuclear test. Many of them post entirely identical content to similar accounts on a regular basis and are therefore likely to be automated. Given the scale of this sharing of false information, we consider that it could reasonably amount to deliberate disinformation.

Finally, we note that one of the most widely shared posts containing the misleading seismic interpretation from IU.GNI originated from an account that has been linked to Russian state-supporting disinformation campaigns (Fig. S3.11, Millward, 2023).

### 3.3 Crowdsourced detections create a fake earthquake in Israel?

A number of posts on Twitter/X drew comparisons between this event and a supposed earthquake felt in Israel the same evening. The first post on social media about the supposed Israel event came from the European-Mediterranean-Seismological Centre (EMSC) at 19:36 UTC (21 minutes after the Iran event)[2]. This post included a graphic of an estimated epicentre centered on northern Tel Aviv (Fig. S3.12).

Intriguingly, this announcement came only 2-3 minutes after the first earthquake monitoring accounts (My Earthquake Alerts, Earthquake Monitor, and the EMSC itself) posted about the Iran event—with the EMSC post alone gaining in excess of 120,000 views to date.

The post about the Israel event at 19:36 UTC was marked as 'Automatic crowdsourced detection, not seismically verified yet' and received over 140,000 views. Crowdsourced detections are made by EMSC on the basis of online traffic searches (Bossu et al., 2015) and include 'Twitter Earthquake Detection' tools that identify spikes in social media posts about earthquakes in close to real time (S. et al., 2012). They are widely recognised as valuable and useful tools in earthquake early warning and real-time characterisation (Sakaki et al., 2010). Although the EMSC promptly followed its post about the Israel event 15 minutes later with a comment stating 'We have no data confirming this crowdsourced detection. It likely was a false detection,' this secondary tweet received fewer than 20,000 views.

Remarkably, we conclude that upon news of the event in Iran (at 19:15 UTC) reaching Israel (around 19:33 UTC), online searches for more information about earthquakes spiked, presumably driven by fear that the Iran event was actually a nuclear test. Less than three minutes later, at 19:36 UTC, the volume of searches was sufficient to trigger a false alert for an event in Israel.

This false alert was believed to be real by Twitter/X users, fueling narratives that linked both events to ongoing geopolitical tensions, potential reciprocal attacks, or even nuclear detonations. This likely reinforced a causal loop, prompting a greater number of searches for recent earthquakes by individuals and organisations in Israel. By the time the loop was broken—15 minutes after the initial EMSC tweet, when no actual seismic data indicating a quake were received—the story had spread too widely to be effectively countered by the 'false detection' announcement.

[2] https://x.com/LastQuake/status/1842650048393330758

### 3.4 Earned Media Analysis

Although speculation about the nature of seismic events in Iran is commonplace, this event was unusual in that it acquired traction in earned media outlets. This is significant in that many of these have enormous reach, amplifying misinformation and potential disinformation associated with this event to a far larger audience (with some organisations having in excess of a million followers on a single social media platform).

We find that the vast majority of coverage in earned/-mainstream media is in English and Persian, and hence we focus on these in this section. News articles about this event were sourced through online news aggregators, again using broad search terms such as 'Iran earthquake' and 'Iran nuclear test' across the days and weeks following the event. Dates are reported as the relevant UTC day where a determination of posting time can be made.

#### 3.4.1 Results - English

Within earned/mainstream media outlets, published news articles almost exclusively speculated (or otherwise entertained the idea) that this event may have been a nuclear test. These articles could be seen as indirectly supporting the propagation of misinformation by giving credence and visibility to misinformed interpretations of complex seismic data and by failing to seek independent, expert verification. A summary of identified articles, dates, and countries of origin are given in supplement Tab. S3.1.

The largest concentration of articles came from Indian media outlets. Many are very similar in content, suggesting that they are based on one another, and include links to incorrect seismograms and other evidence as described in Sec. 3.2.3. The conclusions of these articles are varied, though one (FirstPost) goes as far as to suggest that this event has 'some characteristics that suggest the possibility of a nuclear test,' which is demonstrably untrue.

Beyond India, we also identified stories in Zimbabwean, American, Pakistani, Bangladeshi, French, and British news outlets. Again, these sources vary between speculation and actively platforming misinterpreted seismograms. Even where conclusions are more circumspect, there remain significant scientific errors.

As an example, the Daily Mirror article states, 'Fortunately, the earthquake's shallow depth and magnitude do not indicate a nuclear test as trying to contain an underground explosion without surface damage is particularly hard.' Whilst it is indeed true that minimising surface deformation from nuclear testing is challenging, the fixed depth (10 km) is far too deep to indicate an artificial origin, rather than too shallow, and the magnitude is actually entirely within a plausible range for a nuclear test (Zhang and Wen, 2013).

Interestingly, one English-language news outlet that we find dismissing the suggestion that this was a nuclear test is the Iranian state-run Tehran Times (October 8).[3] Despite pre-dating many of the articles listed in Tab. S3.1 and being locally based, this piece does not appear to have been referenced by them.

#### 3.4.2 Fact-checking responses

Finally, we note that there are a number of English-language 'fact checks' which were carried out on the speculation that this was a nuclear test, including by LogicallyFact (October 9)[4] and FullFact (November 19).[5] These were in addition to official 'fact check' communications from organisations such as the CTBTO[1] (October 9).

Many of these 'fact checks' appear to have considerably less reach than the original misinformation posts or subsequent news articles. For example, the CTBTO's Twitter/X post about this event[6] has fewer than 5,000 reported views whilst the most widespread misinformation-spreading post from 'Russia News' has more than 30,000.

#### 3.4.3 Results - Persian

In contrast to English-language earned media, articles published in Persian tended to describe the event in an accurate manner. Much of the content in these articles appeared to be based on official communications from the Iranian Seismological Centre.

Expert opinions were also far more widespread in Persian-language outlets, including interviews with local experts who were more familiar with the regional seismicity. Whilst some later articles did comment on or speculate about the nuclear hypothesis, they uniformly concluded that the event fit the profile of a natural earthquake based on expert opinions and official reports. This pattern was common across outlets regardless of political standpoint, in contrast to posts on Twitter/X, where pro- or anti-government users expressed differing sentiments regarding this event.

### 3.5 Suggested communication strategies

We note that general strategies for addressing earthquake-related misinformation and disinformation have been extensively discussed in published literature (e.g. Fallou et al., 2022; Dallo et al., 2022; Dryhurst et al., 2022). Many of the suggestions made in this literature are clearly relevant to this work, especially with regard to increased seismic education or 'prebunking.' We make the following additional suggestions specifically relevant to events of this type:

- **Fixing depth** In studying this event, we observed the canonical fixed depth of 10.0 km being widely misinterpreted. This spanned those claiming it was too shallow to be an earthquake, those claiming it was so deep that it must have been part of a highly sophisticated weapons program, and others who (correctly) surmised that the depth was unreliable and then (incorrectly) speculated that it could have

[3] https://www.tehrantimes.com/news/504740/Rising-call-for-nukes

[4] https://www.logicallyfacts.com/en/article/earthquake-seismograph-or-nuclear-test-in-iran-amid-israel-war-experts-weigh-in

[5] https://fullfact.org/online/video-earthquake-iran-nuclear-testing/

[6] https://x.com/CTBTO/status/1844042091619381620

been a weapons test closer to the surface. One suggestion to address this issue would be to revise how fixed depths are reported publicly—for example 'Depth: unconstrained (fixed at 10 km)' rather than 'Depth: 10 km (fixed).'

- **Rapid moment tensor solutions** Similar to the point made above, we recognise that the reason that a preliminary moment tensor was not released and shared on social media soon after this event was that it was relatively minor. The USGS computes moment tensor solutions for all seismic events worldwide with magnitudes of M 5.0 or greater, but robust results can also be achieved for events with magnitudes as small as M 4.5, provided a regional network of high-quality broadband seismic stations is available[7]. While rapid and authoritative moment tensor solutions are not possible for all seismic events, lowering the magnitude threshold for moment tensor analysis of global events—where possible—could help stem the spread of misinformation. However, this approach has potential drawbacks, including the significant time investment required from trained analysts to review events and the risk of sharing poorly-constrained or inaccurate moment tensors if sufficient data coverage is not available. Any such release would need to include extensive guidance on how to interpret (and how not to misinterpret) these results, emphasising that expert source discrimination cannot be reduced to a simple visual inspection of initial beachballs.

- **Crowdsourced earthquake alerts** We surmise that the crowdsourced earthquake alert for the Israel event was likely due to a spike in searches related to the event in Iran, and unfortunately led to increased attention and further propagation of misinformation about said Iran event. It may be possible to build in extra control logic to automated alerts to reduce the likelihood of this. For example, this could involve excluding searches where the name of a non-adjacent region (e.g. 'Iran' from a user in Israel) is contained within the query term.

- **Official communications** As this earthquake was relatively minor, it is unsurprising that it was not initially the subject of official announcements or communications from international agencies such as the CTBTO. However, it did receive standard automatic entries from the USGS, European-Mediterranean Seismological Centre, and Iranian Seismological Centre. There is potential for more proactive monitoring of ongoing discussions on social media for events of interest and attempting to debunk misinformation within hours rather than days after it emerges. Naturally, this would require significant resources, and one potential drawback could be the risk of an organization's failure to comment on a particular earthquake being misinterpreted.

- **Community fact checking** Expert opinions on the origin of this event were shared much more slowly than misinformation, often becoming prevalent in fact-checking reports days to weeks later—by which point speculation on social media had significantly diminished. Although some misinformation posts on Twitter/X about this event did receive 'community notes' debunking false narratives, this was by no means universally true. There may be scope for marshalling responses to misinformation on social media from within the seismological community in closer to real-time; however, this would require significant resources and could potentially expose individual researchers to online harassment. We also speculate that the ongoing exodus of many academics from Twitter/X (Bisbee and Munger, 2024) may have reduced the likelihood of expert community responses to this event on that platform.

# 4 Conclusions

In this paper, we studied the propagation of seismic waves, misinformation, and disinformation following the 2024-10-05 M 4.5 Iran earthquake. Analysis of regional-distance seismograms from this event indicates a shallow-dipping reverse fault source in central Iran. Combined with observed P-to-S ratios, this analysis is clearly indicative of a tectonic, rather than nuclear, source.

We also observed the propagation of information about this earthquake on social media, predominantly Twitter/X. In the first few minutes after the earthquake, we observed initial, informational posts about the event which quickly gave way to speculation that this was a nuclear test, followed by clear misinformation and spreading of conspiracy theories (e.g. a HAARP origin for the event). In the hours after the earthquake, we observed misleading and misinterpreted seismograms being shared on social media as 'evidence' that this was definitively a nuclear test coupled with erroneous interpretation of the presented seismic signals, or linking the event to an earthquake which supposedly happened in Israel on the same day. Some of the posts we identified on Twitter/X could reasonably be considered to cross the line into active disinformation, in that they imitated or purported to be from reputable news organisations when in fact they were not. In the days after the earthquake, we observed these social media stories gaining traction in earned media. This appeared to be mostly confined to English- and Persian-language media, which is perhaps unsurprising given that the articles appeared to be largely based on unsubstantiated social media posts, and the greatest number by far of these earned media articles were written in English.

Whilst mainstream media coverage was less forthright in its conclusions, we consider that many of these stories nonetheless gave a platform to clear seismic misinformation, including the sharing of misleading seismograms without the consultation of experts. Whilst a number of organisations followed up with 'fact checks' that did include expert input, these appear to have been more limited in reach than the

[7] https://www.usgs.gov/programs/earthquake-hazards/magnitude-types

original misinformation. This is commensurate with social research which finds that that fake news spreads faster than real news on Twitter/X (e.g. Langin, 2018). We hope that our proposed communication strategies may help to address this.

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## Data and code availability

Seismic data were downloaded from IRIS/Earthscope https://www.earthscope.org/about/earthscope/. Source locations and magnitudes were taken from the USGS catalogue https://earthquake.usgs.gov. The map locations of Iranian nuclear facilities were based on those provided by the nuclear threat initiative https://www.nti.org/education-center/facilities/. The topographic basemap is based upon the ETOPO products of NOAA/NCEI https://www.ncei.noaa.gov/products/etopo-global-relief-model (NOAA, 2022). The GAGE Plate Model is available here https://www.unavco.org/software/geodetic-utilities/plate-motion-calculator/plate-motion-calculator.html. Details of the GCMT methodology can be found at https://www.globalcmt.org.

## Competing interests

The authors declare no competing interests.

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