New contributions to understanding Earthquake Light, from the 2023 Turkish earthquakes

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Abstract. Earthquake light is flashes of light from the ground which occur during earthquakes at night and is now well established as real from numerous video records, but data are still being gathered for explanation of those records. The Kahramanmaraş earthquakes (Turkey, 6 February 2023, M7.8 and M7.6), approximately doubled the international video records available with at least 127 new videos, and recording some new phenomena. 700 flashes were examined and the median length was 0.3 s. The largest flash was on a limestone hilltop, Mt. Ahir, height 2301 m which is to the north above Kahramanmaraş City, and the 10 km light spread on the ground is about ten times larger than others recorded internationally. There were a large number of videos actually recorded within blue and white light occurrences. A few videos showing "speckles" in the sky probably showing local condensation of water vapour due to seismic waves within the atmosphere.

In spite of the catastrophe the Turkish earthquake light was an important contribution to the scientific research. It was found that ***i***. The predominatnt colours were white and blue as for previous videos from other countries. ***ii.*** there were far more examples of pink colours than usual. ***iii.*** Earthquake lights did not physically harm people inside the lights. ***iv.*** There was not evidence for light being produced from large-scale electrical grid problems. ***v.*** The light did not seem useful for predicting earthquake at least for now. ***vi.*** The median length was 0.3 s. ***vii.*** A unique example was found in daylight. ***viii*** Snow does not seem to prevent the light.

Keywords: Earthquake light, Turkey, Kahramanmaraş, Mt. Ahır, limestone.

1. Introduction

There are now several review papers about earthquake light which is blue-white light from the ground at night [1, 2, 3, 4, 5] but in spite of video verification, earthquake light is still the subject of much discussion and there are few detailed surveys. A detailed survey of occurrences [3] showed that the most common are on the ground, blue-white, dome shaped, about 0.5 s long, co-seismic, with no lasting light from fires, and could occur both on igneous rocks, and greywacke. If there is smoke or the crackling noise of electrical discharge, light may be electric grid malfunction/fire and should be excluded. That is how the present study chose its sample.

The exact mechanism has been much debated. There are two main theories of origin. First is triboluminescence [6] in which friction between minerals in moving cracks creates both the light and a simultaneous electric disturbance. Second is the Freund mechanism [7] in which seismic pressures cause accumulation of negative charge in quartz (or perhaps silicates, more generally), and rapid expulsion of positive charge to the surface, when it interacts with the air to give white light. Blue colours in the air are the result of Rayleigh Scattering of the white light by the molecules of the atmosphere.

Earthquake light has been caught mostly on security cameras. Even when earthquakes are frequent in a country only about 0.5% of earthquakes produce light, i.e. mainly the higher magnitude shocks.

Earlier theories about earthquake light [8], suggested the origin would mainly be in volcanic rocks, but for New Zealand earthquakes [2] the rock was not volcanic but called greywacke, which is sedimentary, and a kind of mud-stone.

Up until the present study about 100 videos showing earthquake light were available online, and the present study has added another 127 from the M7.8 and M7.6 Turkish earthquakes in 2023 in the south-east of the country, The seismic features creating these earthquakes are discussed at length in the current volume.

The collection of videos contains an unusual complicating factor. The province of Hatay contains a natural gas pipeline, which broke in two places during the M7.8 earthquake, and the escaping gas caught fire and produced a yellow-orange flare [9]. This colour was quite different from that of the earthquake light.

2. Methods

Many videos were readily retrieved from the internet, because there are web-pages which collect earthquake-videos. ~~These include: [10, 11, 12]~~. Further search captured further videos. We captured the most important parts of the videos using Windows 10 features, and examined them frame-by frame using Adobe Premiere Elements 10. Some videos were monochrome but the vast majority was colour. Any subsequent rare changes to frames by photo-editing are noted in the figure captions of this paper.

3. Results

Evidence of rain occurred in 55 of 127 videos, and 25 showed snow on the ground, which is a much higher percentage than for videos from other countries. The rain or snow did not seem to prevent the earthquake light compared with occurrences in international videos. The light was co-seismic or at most a few seconds before video evidence of shaking, so is not useful for prediction. We could not verify a web claim of light 17 s before one earthquake.

3.1 Geographical distribution

The 127 videos showed earthquake light occurring in 8 provinces, Elazığ, Şanlıurfa, Adıyaman, Kahramanmaraş, Diyarbakır, Osmaniye, Kayseri, Hatay (Fig. 1) and the geographical extent was about 400 km. Most were near the East Anatolian fault. Copies of the 127 videos are available from the authors.

Fig. 1. Provinces of Turkey. Light yellow colour indicates where videos of earthquake light were recorded. The two lakes, Tuz and Van are shown in a darker blue, but no earthquake light was recorded there.

The 23 videos labelled as from Kahramanmaraş were more than double the number from other individual provinces. Some provinces had no videos, probably because of fewer security cameras. Another factor might be fewer urban areas.

3.2 Forms

The basic shape of uninterrupted earthquake light is a white hemisphere, on the surface of the ground. Radially out from this, the colour is progressively bluer. International examples follow in figures 2 to 6. Best resolutions are used, but are limited by the properties of the original videos.

Fig. 2. Earthquake light in Pisco, Peru, 2007, M8.0 [13].

Fig. 3. Earthquake light, Taita, New Zealand, 2016, M7.8 [14].

Fig. 4. Earthquake light in Romania 2016, M5.6 [15].

Fig. 5. Peoria, Arizona, 2017, M7.1 (Puebla earthquake, Mexico) [16].

Fig. 6. Hatay, Turkey, 2023, M7.8 [17].

Because there is white light and blue light, the averaged light for earthquake light is pale blue. If an observation is very near the white light, there will be little blue light visible. If the white light on the ground is hidden (for example, in a city where there are buildings), the colour in the sky is mostly blue.

The following previously unpublished example from Sendai, Japan [18] shows sequential frames of the video (figures 7a to 7e), in which earthquake light appears in the centre of a road, illuminates buildings, then rapidly disappears. The light is closer to turquoise than sky blue. Turquoise is much less common in earthquake light videos than the latter.

Fig. 7. Sendai, Japan, M7.3 earthquake, 2022. **(a)** before earthquake light; black horizontal bar is a video artefact.

(a) Pre-earthquake light. Black horizontal video artefact.

(b) 0.03 s later. Patch of light on the road.

(c) 0.03 seconds later. Patch enlarges

(d) . 0.03 s later. Patch intensifies, pale turquoise seen on buildings. A blue video artefact is in the sky.

(e) 0.03 s later. Light disappears.

Neither in the literature nor the present study have people reported significant injury from the earthquake light.

3.3 Geology

The largest flash was recorded at Mt. Ahır immediately to the north of Kahramanmaraş, and had a diameter of approximately 10 km with an estimated error of 2 km. More usual is a diameter of about 50 m.

Fig. 8. (a) Kahramanmaraş city before earthquake flash on Mt. Ahır, top of frame.

(b) Peak flash at Kahramanmaraş on Mt. Ahır at top of frame. Several seconds after Fig. 8a. Flash length 1.13 s. [19].

4. Discussion

4.1 Mt. Ahır

The size of the earthquake light on Mt. Ahır is an order-of magnitude larger than any other published result. It is also unusual because its production of earthquake light is mostly within limestone [20].

Actual land rupture did not happen through Mt. Ahır but was felt strongly about 15 km south of the city and well north, with connection to the East Anatolian Fault as seen in Figure 9 [21].

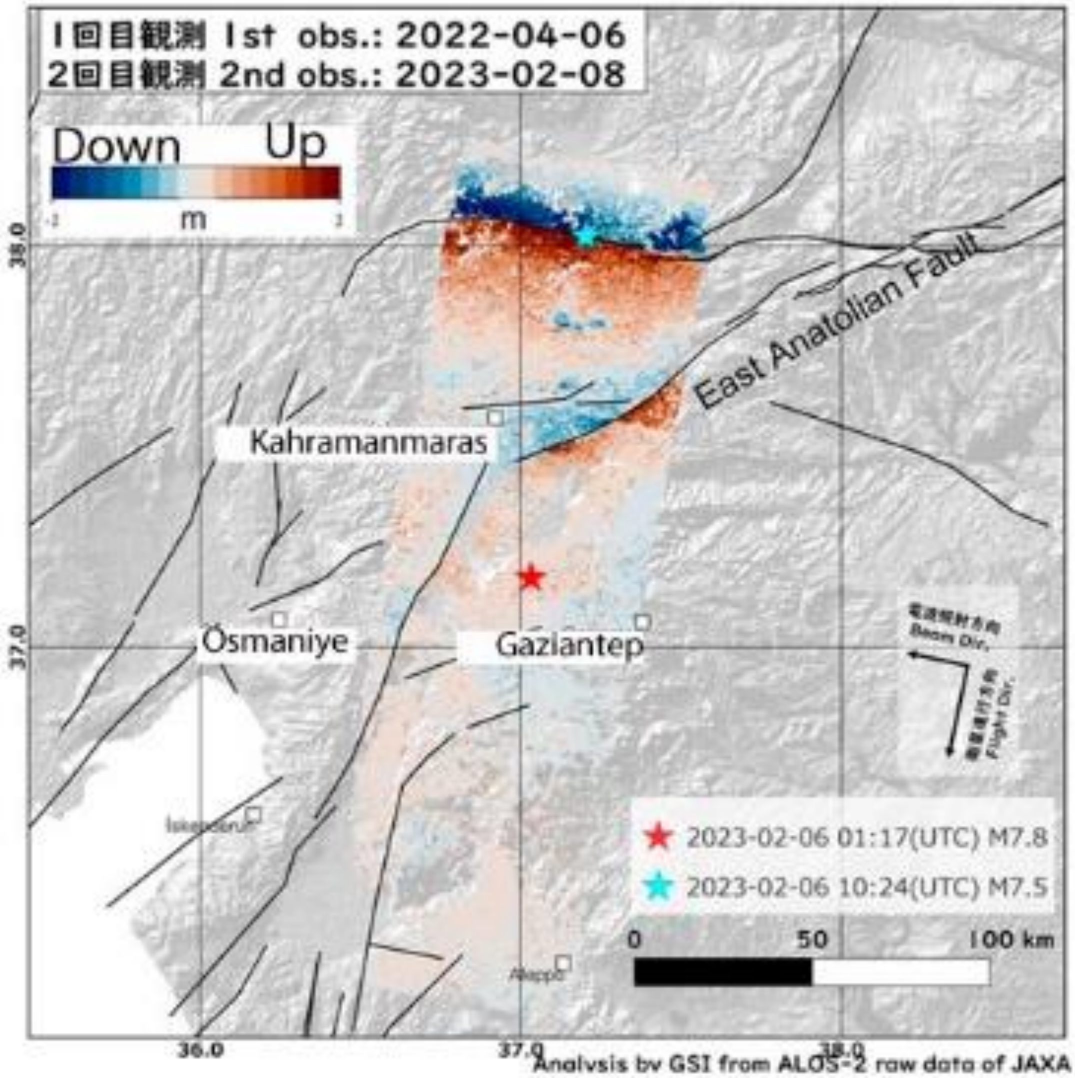


Fig. 9. Location of ground ruptured near Kahramanmaraş.

The following data from satellite interferometry shows ground movement but not rupture [22]. Figure 10 shows maximum land movement near Kahramanmaraş though without surface rupture. This means land rupture is not important for the production of earthquake light from these earthquakes, but strong land movement certainly seems important.

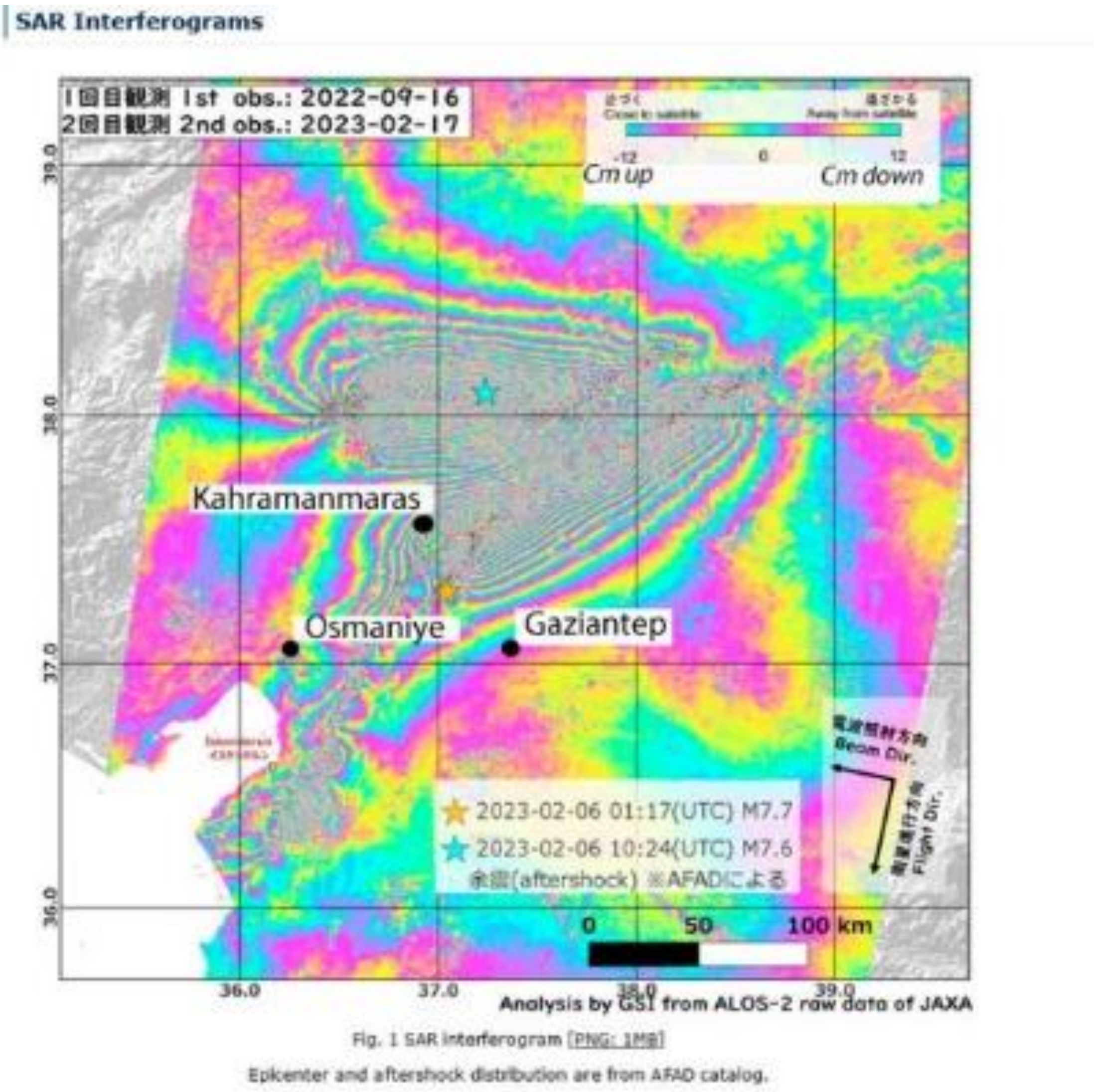


Fig. 10. Land movement near Kahramanmaraş. Closest lines show the most local movement. Data from Geospatial Information Authority of Japan; reproduction allowed by them with attribution [22].

Another significant observation of earthquake light was production from an unusually small earthquake. This was the M4.8 earthquake at Kayseri (200 km NW of Kahramanmaraş) which was in the lowest 20% of earthquakes intensities recorded internationally as producing earthquake light [23].

4.2 Electrical grid problems?

The main electrical substation for Kahramanmaraş is not on Mt. Ahır but within the city, so the large light on Mt. Ahır is not due to substation explosion. Most earthquake light does not come from electrical grid problems.

4.3 Pink colours

The pinkish colour has been seen before, in a video from Peru of an M8.0 earthquake in 2007 [24]. Pink earthquake light colours are unusual but here are two from the current Turkish collection of 9.

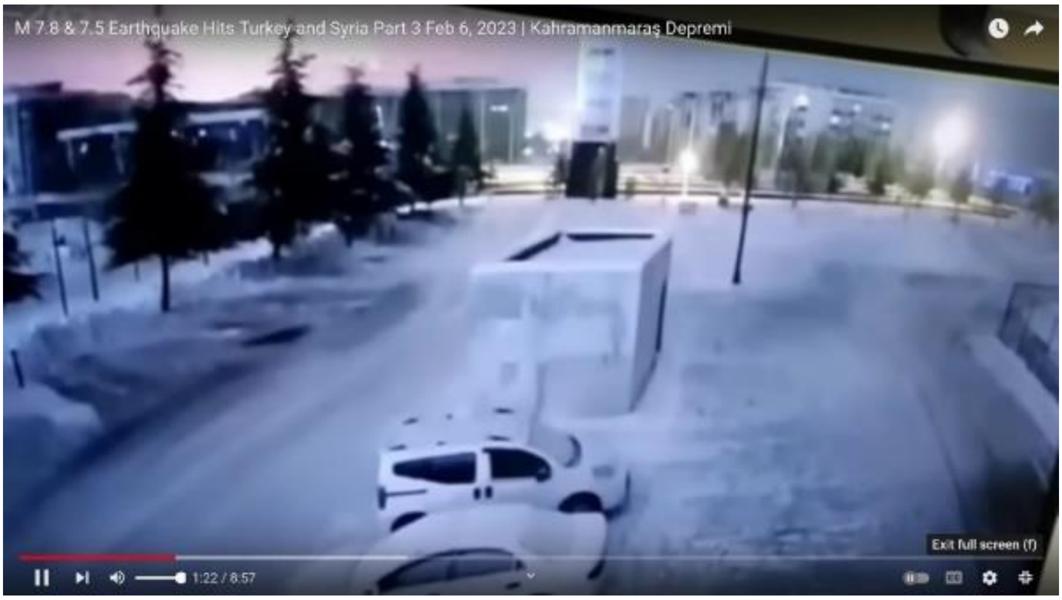


Fig. 11. This video is of a TV screen. The pink colour is to the left of the frame, around its central white section [25].

A second is:

Fig. 12. Pink light on snow [26].

Figure 13. (a) Blackout conditions [27] (b)Pink light

This shows the flash centre which would normally be white, but is pink, and the normal exterior sky-blue colour which is replaced with turquoise. The pink is probably due to raindrops or ice crystals of unusually uniform size.

4.4 Speckles

In a small minority of cases, the gradation between the earthquake light colour near the ground and further out is not smooth, as in Figures 2 to 6, but seems to be speckled.

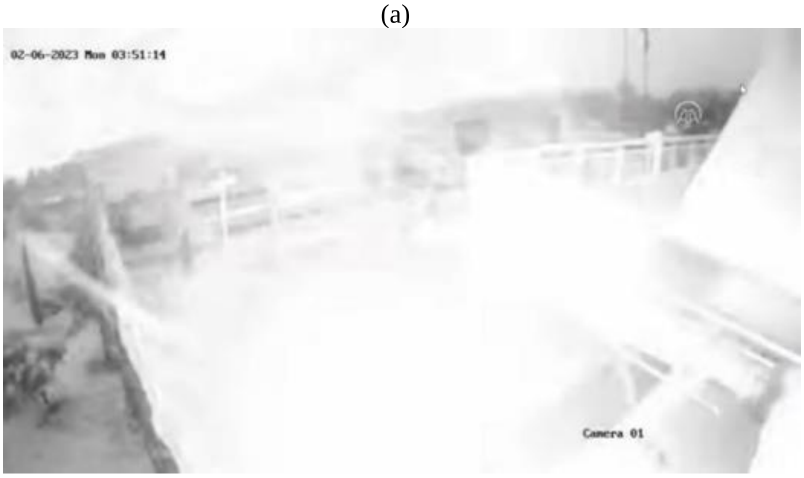
(a) (b)

Fig. 14. (a) Speckles behind the building. Extra lettering has been removed [12]. **(b)** Maximum extent of speckles. Frame is one frame later than Fig. 14a

4. 5 Videos from inside blue or white earthquake light

There are various videos which show what it is like to be in the middle of a white discharge or a blue one. Following are frames from half a dozen videos which show blue or white discharges, and for contrast the blackout appearance from electrical grid loss of power before the earthquake light. The first shows a mild version of the typical local white discharge on the ground.

(a)



(b)

Fig. 15. (a) Balcony with snow [28]. (**b)** White earthquake light on the ground.

The following sequence Figures 16 (a) to (d) shows the normal street lighting, the blackout appearance after power failure, the blue earthquake light and the white [11]. There appears to be a first obscured white source which has led to indirect blue light then there seems to be an independent very local white light. Both the latter are co-seismic.

(a)

(b)

(c)

(d)

Fig. 16. (a) Street with normal lighting, **(b)** blackout, **(c)** blue earthquake light, **(d)** white earthquake light. An independent event, 3 seconds later than (c) [11].

Fig. 17. "Blue fog". Green tubes at top are installed lighting not earthquake light [29].

Figure 17 is typical of several videos taken in a very humid atmosphere, and shows diffuse blue colours created by further scattering of light on rain.

(a) **(b)**

Fig. 18. (a) Gangway at a port. Blackout before flash. [30]. **(b)** Blue and white earthquake light. Several seconds later than Fig. 18a.

(a) **(b)**

Fig. 19. (a) Kahramanmaraş street before flash, **(b)** several seconds later. Much blue light and some turquoise. Illuminated from sky[31].

(a) **(b)**

(c)

Fig. 20. (a) Diyarbakır; street during backout. **(b)** blue earthquake light, **(c)** white earthquake light with some blue light. All the frames for Figs. 20 a-c have been flipped left to right by the video authors [32].

When the videos show diffuse blue light, it comes from above the viewer. No white light is usually visible above, and this is because those videos are in cities. The smaller dome of white light is obscured by buildings. The diffused appearance results from a large amount of scattered blue light reaching the scene from many angles in the sky.

(a) **(b)**

Fig. 21 (a) Co-seismic shock M7.5, 6 Feb. 2023, preseismic environment [10]. (**b**) Half a second later showing earthquake light in daylight as a blue flash.

The source of the blue light flash was high in the sky as shown by reflections on wet surfaces.

5. Conclusions

The Turkish examples besides paralleling international examples, contain half a dozen videos which are the best of their kind, particularly for white and blue flashes. Being inside one of the white domes of light does not show any light emerging from ground cracks, contrary to what would be expected from a triboluminescent origin and there was no evidence of origin from electrical grid problems. Blue colours on the ground seem to be usually illumination from the sky. One was even found in a daylight earthquake as illustrated above.

It is a new finding that earthquake light can occur on limestone. Another finding is that snow on the ground does not prevent earthquake light. We did not find light which was suitable for predicting earthquakes beecause it was almost always co-seismic, or at most one or two seconds before we detected shaking. Besides videos from the security cameras, there were some video sequences from individuals who used their smartphones, and this is a helpful example of resilience, and citizen-science.

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The references are often to videos or timing of segments within them. Authorship is given exactly as in the original sources where available but within compilations on the web, authorship and origin data has usually been suppressed and is not available

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