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On a report that the 2012 *M* = 6.0 earthquake in Italy was predicted after seeing an unusual cloud formation

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Abstract

Several recently published reports have suggested that semi-stationary linear-cloud formations might be causally precursory to earthquakes. We examine the report of Guangmeng and Jie (2013), who claim to have predicted the 2012 M = 6.0 earthquake in the Po Valley of northern Italy after seeing a satellite image showing a linear-cloud formation over the eastern Apennine Mountains of central Italy. From inspection of four years of satellite images we find numerous examples of linear-cloud formations over Italy. A simple test shows no obvious statistical relationship between the occurrence of these cloud formations and earthquakes that occurred in and around Italy. All of the linear-cloud formations we have identified in satellite images, including that which Guangmeng and Jie (2013) claim to have used to predict the 2012 earthquake, appear to be orographic – formed by the interaction of moisture-laden wind flowing over mountains. Guangmeng and Jie (2013) have not clearly stated how linear-cloud formations can be used to predict the size, location, and time of an earthquake, and they have not published an account of all of their predictions (including any unsuccessful predictions). We are skeptical of the validity of the claim by Guangmeng and Jie (2013) that they have managed to predict any earthquakes

1 Introduction

The old notion that earthquakes might be preceded by noticeably peculiar weather has recently been seemingly supported by several reports that unusual cloud formations might be causally precursory to earthquakes. Many of these reports have identified linear arrangements of clouds which seem to persist for several hours in a more or less stationary location near earthquake epicenters. For example, Shou (1999) reported linear-cloud formations 32 days prior to the 17 August 1997 M = 7.4 Izmit, Turkey earthquake and 30 days prior to the 4 February 1998 M = 5.9 Afghanistan earthquake. Shou (2006) reported linear-cloud formations 5 days prior to the 26 December 2003

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M = 6.6 Bam, Iran earthquake. Guo and Wang (2008) reported linear-cloud formations 69 days prior to the 22 February 2005 M = 6.4 Zarand, Iran earthquake and 64 days prior to the 28 February 2006 M = 6.0 Tiab, Iran earthquake. Wu et al. (2009) reported-linear cloud formations prior to the 12 May 2008 M = 7.9 Wenchuan, China earthquake.

More recently, from examination of linear-cloud formations seen in infrared satellite images, Guangmeng and Jie (2013) predicted three earthquakes before their occurrence, and they communicated their predictions with colleagues prior to the occurrence of each earthquake event. Similar to reports by other investigators, Guangmeng and Jie described the clouds as being linearly arranged near geological faults, and unmoving or stationary relative to these formations for hours – that is, they are not advected away by wind. In the case of an Italy earthquake, Guangmeng and Jie observed seemingly linear cloud formations on 22–23 April 2012. On the basis of this observation, they predicted that an earthquake would occur somewhere in Italy: either M = 5.5–6.0 within "about" ten days or if M = 6.0 in 30 days. They did not give any specific bounds on epicenter or hypocenter location, and they did not give any expression of statistical confidence for their prediction. What is interesting, however, is that 30 days later there was an M = 6.0 earthquake on 20 May 2012 (epicenter 44.80° N, 11.19° E). For two Iran earthquakes, they observed clouds on 19–20 February 2012, a week prior to an M = 5.1 earthquake on 27 February, and they observed clouds on 1 March 2012, a week prior to an M = 5.1 earthquake on 8 March.

Reports of precursory cloud formations have, in turn, motivated the development of physical theories (e.g., Freund et al., 2009; Harrison et al. 2014). And, indeed, if cloud formations could be reliably correlated with impending seismic activity, this would, as Guangmeng and Jie assert (2013, p. 95), certainly be an important development for the science of earthquake prediction. Our concern, however, is that the evidence for precursory cloud formations appears to be vague and anecdotal. We are, therefore, motivated to examine the claim that earthquakes are sometimes preceded by unusual cloud formations.

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2 Many clouds and many earthquakes

We focus our examination on the report by Guangmeng and Jie (2013) that precursory linear-cloud formations were realized over an earthquake fault in Italy prior to the occurrence of an earthquake. We access the same infrared satellite images that Guangmeng and Jie acquired from the Meteo Company SAT24, but instead of simply focusing on a short duration of time before the 20 May 2012 M = 6.0 earthquake, as Guangmeng and Jie did, we examine four years of satellite images (January 2010 to December 2013). In Fig. 1, we present 24 separate instances of linear-cloud formations over Italy, each of which was selected independent of any seismic activity. These show linear-cloud formations along different regions of the Apennine Mountain range in Italy. The linear-cloud formation identified by Guangmeng and Jie as possibly precursory to the 20 May 2012 Italian earthquake, 22 April 2012, is just one of the 24 examples shown in Fig. 1. To show how these clouds were formed and their stationary nature over the eastern Apennine Mountain range, in the Supplement we include movies for many of the examples shown in Fig. 1.

Using the online catalog of the National Earthquake Information Center of the U.S. Geological Survey (www.earthquake.usgs.gov), in Table 1 we list the 14 $M \geq 5.0$ earthquakes that occurred in and near Italy, that is, within the geographic square of 35–48° N latitude and 6–20° E longitude, and within the time interval 01 January 2010 to 31 December 2013. The locations of the earthquakes are shown in the map in Fig. 2. A lower magnitude threshold leads to the counting of a larger number of events; in the same geographic square for the same duration of time there were 68 earthquake events with $M \geq 4.5$. Such a low threshold was not discussed by Guangmeng and Jie (2013), and so we do not consider it either.

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3 Discussion and conclusions

To be practically useful for predicting an earthquake, a possible precursory phenomenon must be clearly identifiably associated with an impending earthquake. We note, however, that linear-cloud formations, similar to those that Guangmeng and Jie (2013) claim to have used to predict an earthquake, are frequently seen in Italy. In Fig. 1 we show 24 instances of linear-cloud formations in a 4 year period of time, but there were others as well. Yet outside of the M = 6.0 earthquake event on 20 May 2012, and its subsequent aftershocks, it is difficult to imagine how the smaller earthquakes might be identified as being associated with a particular "linear"-cloud formation. Indeed, Guangmeng and Jie did not provide any specific criteria for classifying cloud formations as possible earthquake precursors, and there were many instances when it would be difficult to say whether or not a particular cloud formation was "linear", "semi-linear", "temporarily linear", etc. How, specifically, do they manage to predict, even if only vaguely, the magnitude, location, and timing of an earthquake from their examination of cloud formations? We do not know.

Independent of the occurrence of earthquakes, and contrary to what is stated by Guangmeng and Jie (2013, p. 91), there is a simple meteorological explanation for the cause of linear-cloud formations in Italy. It is a mountainous country; most prominently, the Apennine Mountains runs along the length of the Italian peninsula. It is well-known that winds flowing towards mountains are lifted causing adiabatic cooling of air masses, and, if the relative humidity reaches 100 %, then "orographic" clouds form on the lee side of the range (e.g., Whiteman, 2000). Since mountain ranges are often aligned with mountain-bounding faults, orographic cloud formations can sometimes appear to be aligned with faults. And, since mountains are, for this discussion, unmoving and stationary, these orographic clouds are not advected away by the winds that are involved with their formation.

We note that the clouds in Fig. 1 are always located on the lee (eastern) side of the Apennine range when the wind flows from the southwest. With respect to the prediction

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of Guangmeng and Jie (2013), the linear-cloud formation for 22 April 2012 runs parallel to the NW–SE Apennine mountains, a tectonic region characterized by NE–SW extension and normal faulting. But the M = 6.0 earthquake on 20 May 2012 that they claim to have predicted occurred in the Po Valley in northern Italy, a tectonic region characterized N–S compression which produces E–W reverse faulting. While, ultimately, the Apennine Mountains and the Po valley are related to each other through large-scale regional plate tectonics, Guangmeng and Jie (2013) do not explain how a precursory linear-cloud formation that they identify over one part of Italy could, in practical terms, be related to an earthquake in a distinctively different part of Italy. We believe that the linear-cloud formation identified by Guangmeng and Jie (2013) and the other linear-cloud formations seen in Fig. 1 are simply orographic clouds, and, thus, unrelated to the earthquakes. That we have not been able to identify distinctive linear-cloud formations during January 2010 to May 2011 in Fig. 1 is possibly just the result of variable atmospheric conditions that happened not to be conducive to orographic cloud formation during this time, even though there were actually two earthquakes during this time in the list given in Table 1.

To objectively evaluate an earthquake-prediction hypothesis, each individual prediction should be clearly stated in quantitative terms: (1) a magnitude which the predicted earthquake is expected to exceed, (2) a specified range of epicenter geographic coordinates and hypocenter depth, and (3) a specified time window in which the earthquake can be expected to occur. To obtain confidence in the statistical significance of a prediction hypothesis, one that is based on the observation of possible precursory phenomena, an alternative null hypothesis of a random relationship between the possible precursory phenomena and earthquake occurrence must first be dismissed. This must be done using compilations of predictions that have been made prospectively of future earthquake occurrences. On the other hand, a prediction hypothesis can be dismissed with retrospective analysis of observations we already have of possible precursory phenomena and earthquakes that have already occurred (e.g., Love and Thomas, 2013,

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Sect. 2). If the hypothesis cannot predict past earthquakes, then there is no reason to expect that it can predict them in the future.

With that understanding, then, we perform a simple retrospective examination of the time statistics of the occurrence of the earthquake listed in Table 1 and the linear-cloud formations shown in Fig. 1. As a null hypothesis we consider a uniform distribution in time. A simple Kuiper test (Press et al., 1992, Sect. 14.3) reveals that the earthquake list would not be a likely realization from a uniform distribution in time, $p = 0.0239$. However, if we "decluster" the list for aftershocks, removing those earthquake events occurring near and after the 20 May 2012 $M = 6.0$ event, then the Kuiper test reveals that the remaining events would have a high probability of being realized from a uniform distribution, $p = 0.8951$. In contrast, the occurrence list of linear-cloud formations would not be a likely realization from a uniform distribution, $p = 0.0015$. If we "decluster" this list by removing linear-cloud formations seen on consecutive days, the probability is still small, $p = 0.0054$. One might reasonably conclude from this simple and straightforward examination of the data that linear-cloud formation and the occurrence of earthquakes are not evidently related to each other in a statistical sense over the latitude-longitude region we have selected. We imagine that Guangmeng and Jie might feel differently. If they do, then they need to clearly state the statistical relationship that they expect to exist between linear-cloud formations and earthquake occurrence. They have not yet done that. And, until they do, the rest of the geophysical community cannot statistically test their hypothesis against future data.

Although Guangmeng and Jie (2013) report a few successful earthquake predictions, they do not mention any unsuccessful predictions. Have all of their predictions been a success? We do not know. Reporting only successful predictions (not reporting all unsuccessful predictions) leads to what is sometimes called "publication bias" in which unsuccessful predictions are simply not published, or "file drawer bias" in which unsuccessful predictions are simply "filed away" and not seen again (e.g., Boslaugh 2013, p. 462). Until Guangmeng and Jie report all their predictions, successful and unsuccessful, until each prediction is expressed in quantitatively specific terms, and until

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these predictions are objectively recorded before the predicted earthquake occurrence, then there is no way for the rest of the scientific community to evaluate the validity of their results. For now, we are skeptical of the validity of the claim by Guangmeng and Jie (2013) that they have managed to predict any earthquakes.

The Supplement related to this article is available online at doi:10.5194/nhessd-2-5889-2014-supplement.

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Table 1. $M > 5$ earthquakes that occurred in and near Italy (lat. 35–48° N; long. 6–20° E) during 2010 to 2013.

Date	Year	Time (UTC)	Lat (° N)	Long (° E)	Depth (km)	M
22 Aug	2010	10:22:58	37.24	19.95	24	5.5
3 Nov	2010	18:13:11	40.04	13.25	468	5.2
7 Jul	2011	19:21:46	41.95	7.70	11	5.3
19 Jul	2011	07:13:12	37.21	19.92	9	5.1
27 Jan	2012	14:53:13	44.48	10.03	60	5.0
20 May	2012	02:03:52	44.89	11.23	6	6.0
20 May	2012	13:18:02	44.83	11.49	5	5.0
29 May	2012	07:00:03	44.85	11.09	10	5.8
29 May	2012	10:55:57	44.89	11.01	7	5.5
29 May	2012	11:00:25	44.87	10.95	10	5.1
3 Jun	2012	19:20:43	44.90	10.94	9	5.1
25 Oct	2012	23:05:24	39.88	16.01	6	5.3
21 Jun	2013	10:33:59	44.22	10.11	10	5.2
29 Dec	2013	17:08:43	41.37	14.44	10	5.3

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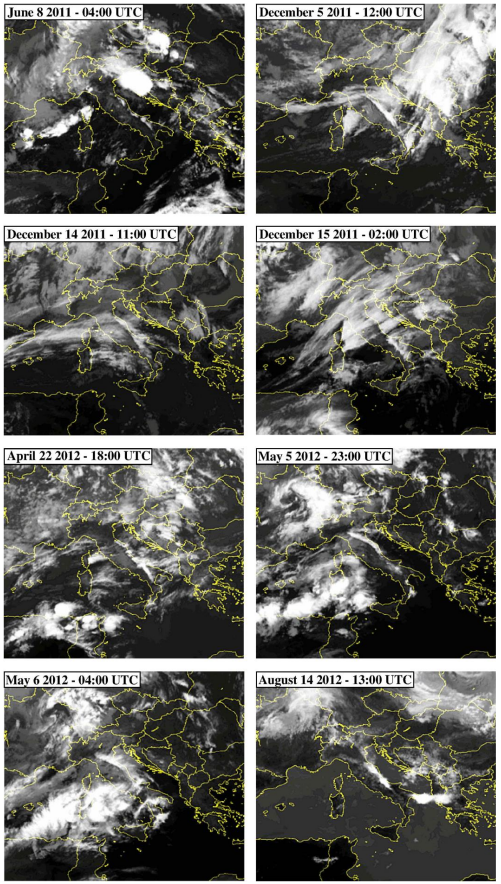

Figure 1a. Twenty-four separate examples of linear-cloud formations over Italy (January 2010 to December 2013), including the instance for 22 April 2012 that Guangmeng and Jie (2013) claim led them to predict the M = 6.0 Earthquake on 20 May 2012.

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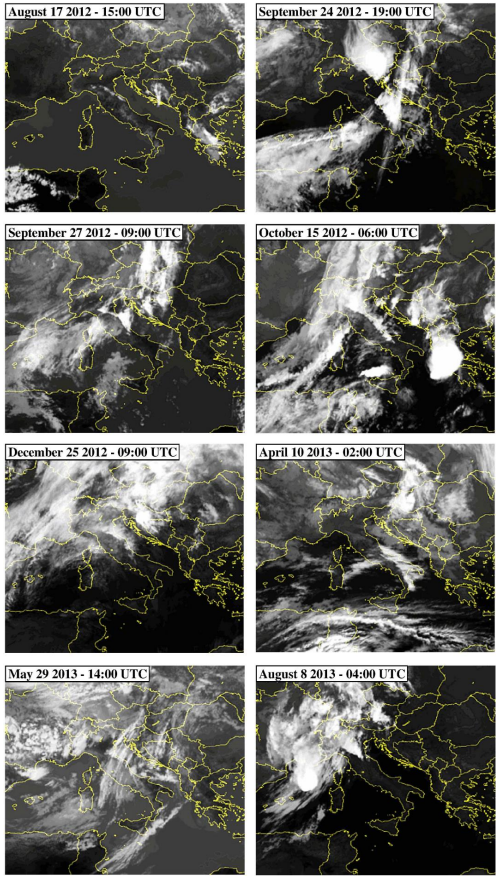

Figure 1b. Continued.

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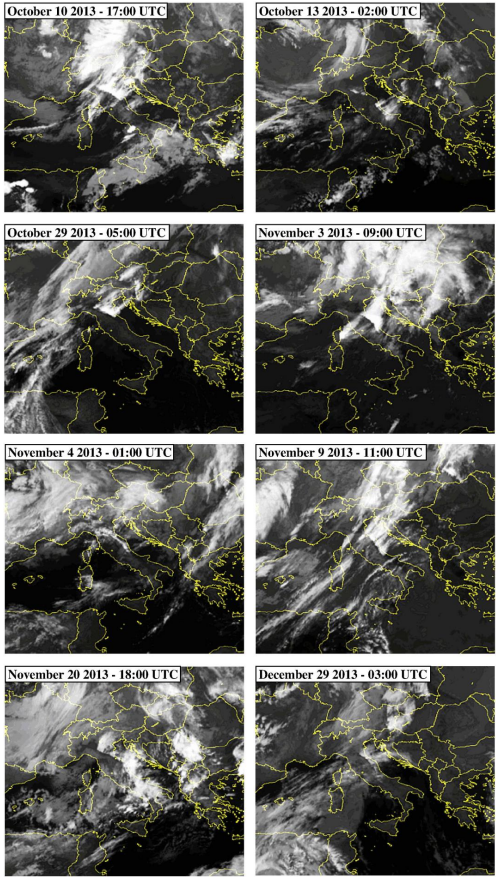

Figure 1c. Continued.

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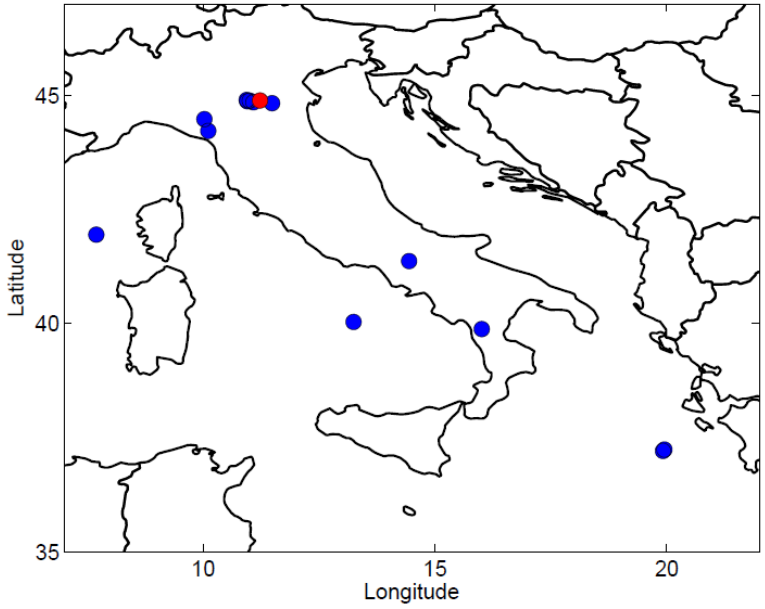

Figure 2. Map showing locations of magnitude $M > 5$ earthquakes listed in Table 1 that occurred in and near Italy (lat. 35–48° N; long. 6–20° E) during 2010 to 2013. The red circle indicates the location of 20 May 2012 earthquake that Guangmeng and Jie (2013) claim to have predicted.

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