Earthquake Prediction with Meteorological Satellite Imagery

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Abstract

Here in this paper video images of Japanese meteorological satellite "HIMAWARI" are used to develop a new method of earthquake prediction in which special cloud anomalies appear in advance of large earthquakes. The method is based on expert image interpretation system. 40 earthquakes larger than M6.0 which occurred between 2016 and 2020 in Japan are validated. The results show that 65.0% of the earthquakes larger than M6.0, 75.0% of earthquakes larger than M6.3, 88.9% of earthquakes larger than M6.5, 100.0% of earthquakes larger than M6.7 were preceded by cloud anomalies. 8 predictions were disseminated to the customers on a business base since 2020/12/2 to 2021/9/27. There were 5 perfect predictions, 2 almost correct and 1 incorrect in terms of its magnitude. Time and location of the 8 predictions were all correct. This study shows a good potential of earthquake prediction with satellite cloud anomaly.

Key Words: Earthquake prediction, cloud anomaly, Meteorological Satellite Imagery

1. Introduction

The Russian scientist Morozova in 1997 presented a scientific paper on "Dynamics of cloud anomalies above faults in periods of natural and induced seismicity" (Morozova,1997), while Harrington et al. presented a scientific paper at the UN meeting on the Bam Earthquake Prediction & Space Technology, in which cloud anomalies of meteorological satellite videos were used to predict the earthquake that occurred in Iran in 2003 (Harrington *et al.*, 2003). They found some patterns of special cloud anomalies which were strongly correlated with the occurrence of large earthquakes although a scientific mechanism has not yet been verified.

It is estimated that high temperature vapor and radioactive gases such as Radon are released into the air along linear faults or cracks in advance to the occurrence of large earthquakes. Such gases are released continuously for several hours with almost stationary status. Harrison et al.(2014) and Pulinets et al.(2015) attempted to use Atmospheric Lithosphere–Ionosphere Charge (ALICE) exchange processes to develop a physical understanding of the possible relationships between earthquakes and clouds.

Though the cloud anomalies method is thought to be useful for the earthquake prediction, the validation study has not yet been done because there were few occurrences of earthquake in ordinary countries and regions. However, as Japan is an earthquake prone country with frequent occurrences of large earthquakes and has launched a meteorological satellite "HIMAWARI" from which video data are available free of charge, the authors have undertaken validation research on the correlation between cloud anomalies and 40 earthquakes larger than Magnitude 6.0 that occurred between 2016 to 2020.

The Japanese company JESEA, for which the authors are research employees, is distributing "Weekly MEGA Earthquake Prediction" to about 40,000 customers. JESEA has already distributed eight early pinpointed predictions and warnings of impending earthquakes, which show clearly "when" (within no more than one month), "where" (near cloud anomalies) and "Scale" (Magnitude), since December 2020. Out of the eight pinpointed predictions, five were correct in terms of when, where and scale, two almost correct and one incorrect only in terms of the scale. This prediction record is the first successful early warning business service, for not only Japan but also for the world.

2.Method of Expert based Image Interpretation

Step 1: download the daily video images with 1 hour intervals of Japan islands from the archive of meteorological satellite "HIMAWARI".

Step 2: inspect cloud anomaly patterns as compared with normal clouds patterns and their movements.

Step 3: judge whether or not the cloud anomaly pattern is a precursor of an earthquake. **Figure 1** shows an example of cloud anomalies that appeared on 2021/2/20, in Miyagi Offshore of East Pacific, Japan. The judgement is based on human interpretation with expert knowledge. We have developed automated pattern recognition based on artificial intelligence, but the automated judgement has not yet been reliable because we have not accumulated sufficient training sets of cloud anomaly patterns, as the variety of cloud anomalies used are very complex and diverse. The pattern is not always simple as shown in Figure 1. The final goal of the prediction process is to rescue human life by providing early warnings in advance of large earthquakes. Therefore, we do not wish to fail in capturing the cloud anomalies as the precursors of earthquakes.

Step 4: to determine when, where and the scale of the earthquakes in terms of magnitude that may occur, based on expert knowledge such as the length of the cloud pattern, staying time etc.

Step 5: to verify the correctness of the predictions from actual earthquake records and reconsider or improve the expert knowledge system.

Step 6: to accumulate the prediction experience and review the prediction method.

3.Validation of Earthquake Prediction with Cloud Anomalies

At first the authors would like to show a successful earthquake prediction with cloud anomaly as already shown in **Figure 1** which appeared on February 20th, 2021. Two days after the cloud anomaly pattern was recognized, JESEA distributed a prediction to warn its customers "Large earthquake with M5.5~6.5 may occur in the East Japan Area before or on March 20th." Surprisingly a large earthquake with M6.9 did occur on March 20 at Miyagi Offshore with the epicenter shown in **Figure 1**. The location of the epicenter was a small distance from the cloud anomaly and the magnitude of the actual earthquake was 0.4 larger than the predicted magnitude, but it was important to have predicted in advance to the occurrence of such large earthquake with almost correct accuracy.

3.1 Validation Study 1

The authors achieved validation studies for the prediction of 40 earthquakes larger than M6.0 that occurred in Japan, based on cloud anomalies which appeared in the video images of "HIMAWARI" from 2016 to 2020. The total image number was 5years*365days*24=43800. The validation study was executed based on the following query: were there any cloud anomalies in the month in advance of the relevant earthquake? We checked the capture rate of the prediction from cloud anomalies as shown in **Table 1a and Table 1b.**

The prediction rate was 65% for all 40 earthquakes larger than M6.0, while the capture rate was 100.0% if larger than M6.7, 88.9% if larger than M6.5 and 75.0% if larger than M6.3. The change of the prediction rate means that the reliability of prediction is higher for the larger earthquake. The number of failed predictions is greater for the smaller earthquakes less than M6.3. We also found that some cases of smaller earthquakes were not accompanied by cloud anomalies.

The number of days for which the cloud anomaly occurred in advance of the relevant earthquake, was half month (as painted in yellow in Table1a and Table 1b) for 13 cases, within a month (as painted in light brown in Table 1a and Table 1b) for 22 cases, and over 1 month (as painted in light blue in Table 1a and Table 1b) for 4 cases. There were 14 unpredicted cases as painted in blue in Table 1a and Table 1b. It can be said that 84.6% of the total predictions were captured within a month.We also calculated the false alarms for each year. False alarm is defined as the alarms without earthquake occurrence divided by the total alarms. It is 54.7%, 50%，40.6%，52%，36.6% for the year 2016 to 2020, and the average is 46.7%. Note that if anomalies appeared in consecutive 3 days were considered as one group of anomaly and just one alarm was issued, then the false alarm will decrease.

3.2 Validation Study 2

Form 2020/12/2 to 2021/7/31 the company JESEA initiated pinpoint prediction for about 40,000 individual customers using the cloud anomalies as precursors of larger earthquakes. Hereinafter pinpoint means prediction based on the three indicators of "when", "where" and "the scale of magnitude". Eight pinpoint predictions have been disseminated to the customers as early warnings for preparedness against earthquake disasters. **Table 2** shows the results of the eight pinpoint predictions. Out of the eight predictions "when" was 7 correct and 1 almost correct as the day of occurrence was within a month and "where" were all correct. One case in terms of "the scale of magnitude" was incorrect as the error of the magnitude was more than 0.5. Two cases were "almost correct" as the error of the magnitude was within 0.5. Up to now the results of the pinpoint predictions have been highly evaluated and appreciated by the company's customers.

4. Conclusions and Future Prospect

Our research shows that meteorological video imagery is useful for capturing cloud anomalies as a precursor to large earthquakes.

1. In order to establish more reliable prediction, a knowledge based expert system will perform better than automated pattern recognition based on artificial intelligence, since insufficient training sets of cloud anomaly patterns have been accumulated so far.
2. In the case of smaller earthquakes, for example smaller than M6.3 in Japan, about one third of the earthquakes are not captured in the video images of meteorological satellite. However, this would not be a major loss as the expected disasters or damages are minor in the case of smaller earthquakes.
3. More than 80% of the captured cloud anomalies may appear within a month of the occurrence of the associated earthquake according to the validation results.
4. Though there were only eight cases of early warnings and actual pinpoint prediction which were the basis of the business operations, all cases were almost successful in terms of "when" within a month, "where" near the cloud anomalies, and "magnitude scale" within an error of 0.5. According to the validations shown in Table 2, two cases out of eight cases were incorrect in terms of the magnitude scale. But the error has not

had a serious impact for the company’s client base.

In future when more successful prediction achievements with enough training sets accumulated, an automated cloud pattern recognition method based on artificial intelligence could be developed. As there are many other anomalies revealed except the meteorological video images, for example crustal changes derived from Global Navigation Satellite System (GNSS), infrasound anomalies (Wang etal., 2021), geomagnetic anomalies, ionospheric anomalies (Liu et al., 2004) etc., these multi anomalies could be integrated to reduce the false alarms and improve the reliability of the predictions. The authors would like to continue our efforts to improve the prediction method, expand to the Asian Region and provide well organized preparedness against tragic disasters from large earthquakes.

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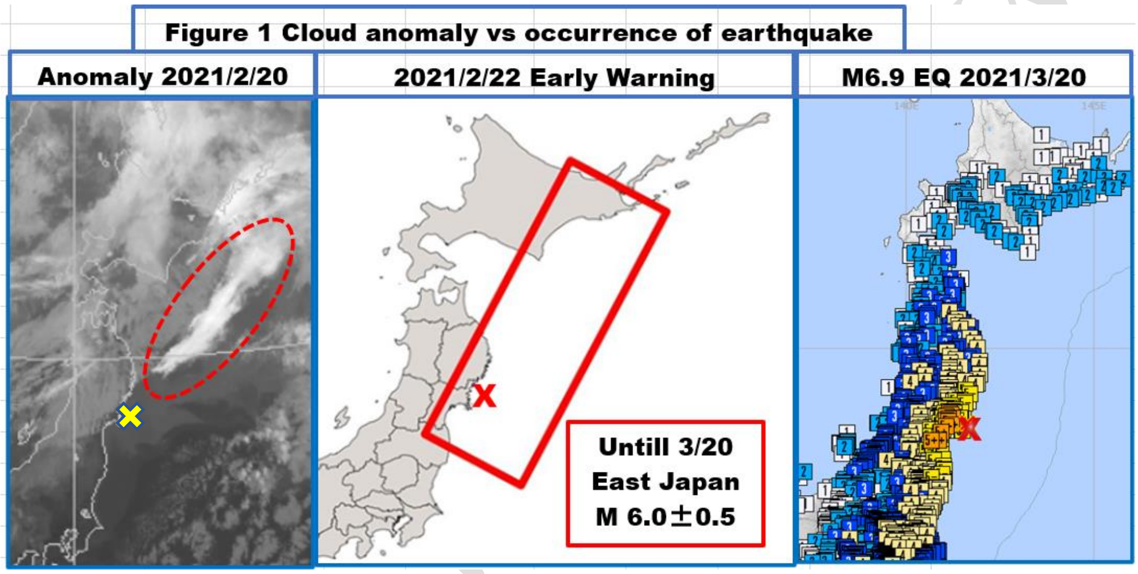

Table 1a Validation of cloud anomaly vs earthquakes					
YY/MM/DD	Earthquake	M	Anomaly	DD before	Captured
2016/11/22	Fukushima Offshore	7.4	2016/10/26	27	100.0
2016/4/16	Kumamoto	7.3	2016/3/23	24	100.0
2016/1/14	Urakawa Offshore	6.7	2015/12/25	20	100.0
2018/9/6	Iburi middle east	6.7	2018/8/22	15	100.0
2019/6/18	Yamagata Offshore	6.7	2019/6/17	1	100.0
2016/10/21	Central Tottori	6.6	2016/10/8	13	100.0
2019/7/28	Mie SE Offshore	6.6	none	none	85.7
2016/4/1	Mie SE Offshore	6.5	2016/3/23	9	87.5
2016/4/14	Kumamoto	6.5	2016/3/23	22	88.9
2016/4/15	Kumamoto	6.4	2016/3/23	23	90.0
2016/8/20	Sanriku Offshore	6.4	2016/7/6	45	90.9
2017/5/9	Miyako Island	6.4	none	none	83.3
2019/8/4	Fukushima Offshore	6.4	2019/6/17	48	84.6
2016/12/28	North Ibaraki	6.3	2016/12/19	9	85.7
2017/9/21	Sanriku Olffshore	6.3	2017/9/12	9	86.7
2017/10/6	Fukushima Offshore	6.3	2017/10/3	3	87.5
2018/1/24	East Aomori Offshore	6.3	2018/1/14	10	88.2
2018/10/24	Yonakuni Island	6.3	none	none	83.3
2018/11/5	Kunashori Island	6.3	none	none	78.9
2019/5/10	The Sea of Nada	6.3	none	none	75.0

Table 1b Validation of cloud anomaly vs earthquakes					
YY/MM/DD	Earthquake	M	Anomaly	DD before	Captured
2016/1/12	Hokkaido NS Offshor	6.2	2015/12/21	22	76.2
2016/5/31	Ishigaki Offshore	6.2	none	none	72.7
2016/6/24	Yonakuni Island	6.2	none	none	69.6
2016/8/21	Sanriku Offshore	6.2	2016/7/6	46	70.8
2016/11/24	Fukushima Offshore	6.2	2016/10/26	29	72.0
2018/9/15	Okinawa Offshore	6.2	none	none	69.2
2019/3/2	Nemuro SE Offshore	6.2	2019/2/24	6	70.3
2019/4/11	Sanriku Offshore	6.2	2019/3/20	22	71.4
2017/9/27	Iwate Offshore	6.1	2017/9/12	6	72.4
2018/4/9	West Shumane	6.1	none	none	70.0
2018/6/18	North Osaka	6.1	none	none	67.7
2018/10/23	Yonakuni Island	6.1	none	none	65.6
2019/8/29	Aomori East Offshore	6.1	2019/7/27	33	66.6
2016/10/24	Hokkaido East Offshc	6.0	2016/10/15	9	70.6
2017/11/13	Sanriku Offshore	6.0	2017/11/10	3	68.6
2018/7/7	Chiba East Offshore	6.0	2018/6/8	29	69.4
2018/9/16	Okinawa Offshore	6.0	none	none	67.6
2019/1/8	Tanegashima Island	6.0	none	none	65.8
2019/3/11	Fukushima Offshore	6.0	2019/3/9	2	66.6
2019/7/13	Amami Oshima Offsh	6.0	none	none	65.0

	Table 2 Achievement of pinpoint prediction as early warning to the customers				
No.1	Prediction	Results	No.5	Prediction	Results
Date	2020/12/2~12/14	2020/12/12	Date	2021/4/21~5/7	2021/5/1
Location	East Japan Pacific	Iwate Offshore	Location	East Japan Pacific	Miyagi Offshore
M	6.0 ±0.5	5.6	M	5.5 ±0.5	6.8
Correct?		Perfect	Correct?		Incorrect
No.2	Prediction	Results	No.6	Prediction	Results
Date	2020/12/2~12/14	2020/12/21	Date	2021/5/5~5/31	2021/5/14
Location	East Japan Pacific	Aomori Offshore	Location	East Japan Pacific	Fukushima Offshore
M	6.0 ±0.5	6.5	M	6.0 ±0.5	6.3
Correct?		Almost correct	Correct?		Perfect
No.3	Prediction	Results	No.7	Prediction	Results
Date	2021/1/2~1/13	2021/1/12	Date	2021/5/5~5/31	2021/5/16
Location	East Japan Pacific	Hokkaido Offshore	Location	Hokkaido Pacific	Kushiro Offshore
M	5.5 ±0.5	5.6	M	6.0 ±0.5	6.1
Correct?		Perfect	Correct?		Perfect
No.4	Prediction	Results	No.8	Prediction	Results
Date	2021/2/22~3/20	2021/3/20	Date	2021/7/7~7/31	2021/7/26
Location	East Japan Pacific	Miyagi Offshore	Location	Aomori ~Hokkaido	Aomori Offshore
M	6.0 ±0.5	6.9	M	6.0 ±0.5	5.1
Correct?		Almost Correct	Correct?		Almost correct