E06

Natech events caused by tropical storms in the United States from 1990 to 2017: Analysis of spatial-temporal variation

○Xiaolong LUO, Ana Maria CRUZ

Introduction

There exists a unique type of technological accidents triggered by natural hazards called Natechs[1,2]. Natech accidents are accompanied by chemical releases which can cause long-term effects on human health and the environment[1] and result in significant economic losses.[3] In recent years, more and more researchers have focused on these kinds of accidents[4–7]. Many kinds of natural hazards can lead to Natechs. In particular, this study focuses on tropical storm induced Natechs (TSNatech).

Tropical storms in the Atlantic Ocean are called hurricanes. Hurricanes can impact industrial facilities, causing hazardous materials releases exacerbating the impacts of hurricanes on people and property[12]. Several researchers have noted that the dramatic rise in terms of intensity, size, duration, and frequency of hurricanes around the Atlantic Ocean since the early 1980s can be attributed to climate change[8–11]. The need to investigate the effects of climate change on the incidence of Natechs has been highlighted[13]. Analyzing spatial-temporal variation of TSNatech can be used to describe whether climate change has had an effect on the occurrence of Natechs or not, and how it works. That can make large contributions to Natech prevention and risk reduction. For the study, we select the United States (US) as a case study area (Fig. 1) to analyze the spatial-temporal variation of TSNatech from 1990 to 2017.

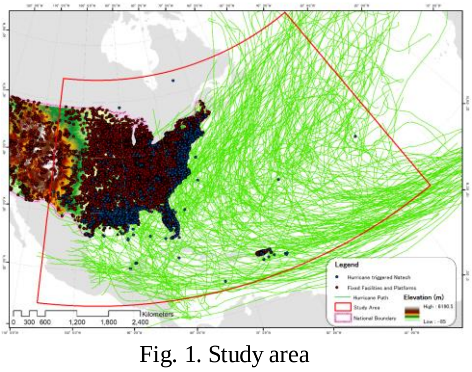

Fig. 1. Study area

Martials and methodology

This study is focused on the TSNatechs that happened in fixed facilities and oil drill platforms. The National Response Center (NRC) data were used to extract TSNatechs based on SINIF, which is a deep learning method-based Natech identification framework[14]. Finally, 7,552 TSNatech reports located in the study area were extracted from the NRC database. Meanwhile, the methodology shown in Fig 2 was employed to analyze the spatial-temporal variation of TSNatech. The retrieved TSNatech reports data were organized as annual and monthly sequential data. The Mann-Kendall Trend Test (MKT Test) method was used to find the global trend of annual data; and the Breaks for Additive Season and Trend (BfAST) method was used to analyze the monthly data to find the breakpoints. Then, the Wavelet Analysis[15] method was used to analyze the periodic characteristic of the monthly data. Finally, the area change intensity analysis method was used to find the spatial variation of the TSNatech.

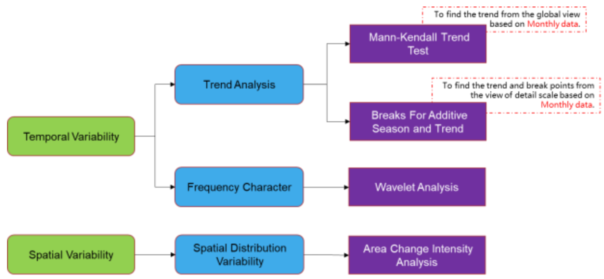

Fig. 2. Methodology

Results

The p-value (2.22e-16) of the MKT test shows that there is a significant increasing trend on TSNatech in the US from 1990 to 2017. The results of the BfAST test showed an increasing trend first but broken at the point of June 2005 and continued by a decreasing trend after that. However, the lowest point of the decreasing curve is over the highest point of the increase curve. Based on the above-observed results, we can get the conclusion that the trend of monthly TSNatech data increased with one breakpoint, which is the same as the conclusion of the MKT test. The results of the wavelet analysis showed there are two return periods passed the 0.75 level significant test on the scales 0.5 and 1, especially, the one on scale 0.5 also passed the 0.95 level significant test. But the intensity of the periodic is not so strong before June 2005. The results of intensity analysis showed that the frequency and density of TSNatech increased

Discussions

Through analyzing the results, we considered that there will be three effect factors in this study: 1) changes to regulations, laws and reporting forms; 2) the spatial-temporal variation of facilities and platforms; and 3) the variation of tropical storms. In Fig. 3, the time series data of facilities, platforms, all incident reports, and all Natech reports in the NRC database, and TSNatech reports were compared. The increasing trend on the number of TSNatech and all Natech reports, with the decreasing trend on the number of facilities, platforms, and all incident reports, as well as the different details on each time point, can be clearly observed. Furthermore, the moving track of the mean centers of facilities, platforms, and

TSNatech were analyzed. The results show that the moving tracks are quite different from each other. All the above observations mean that the change of regulations, laws, reporting forms and the spatial-temporal variation of facilities and platforms have a weak contribution on the temporal variation of TSNatech. In summary, the variation of tropical storms could be the major factor resulting in the spatial-temporal variation of TSNatech. In the study of Sengul et al.[12] there was a similar trend regarding TSNatechs. According to the historical hurricane data from NOAA, since 2005, there were several major hurricanes affecting the United States. This can help explain the occurrence of the spatial-temporal variation of TSNatech.

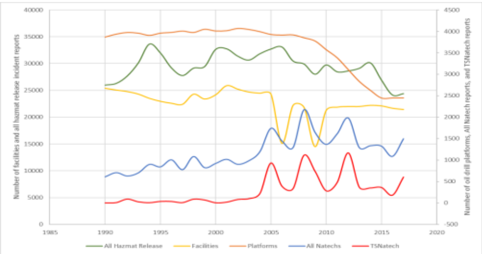

Fig. 3. Comparison on the number of facilities, platforms, incidents reports, Natech reports, and TSNatech reports in the study period

Based on the above analysis, we find that climate change may influence the occurrence of TSNatech by changing tropical storm intensity and frequency of extreme events. In order to test whether this, two widely used indices, the North Atlantic Oscillation (NAO) and the Oceanic Niño Index (ONI), were employed by using a cross wavelet analysis method with TSNatech (see Fig. 4). The results show that both the NAO and ONI have a significant correlation with TSNatech, especially after the year 2005 when the frequency of TSNatech started increasing and the periodicity of TSNatech start becoming stronger than before.

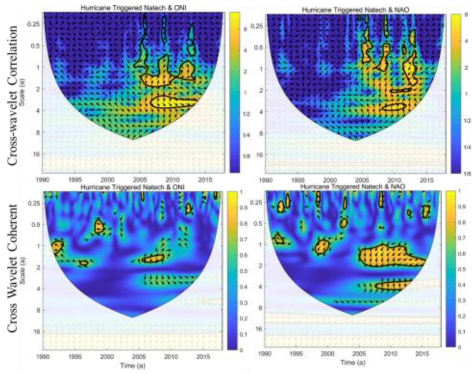

Fig. 4 results of cross wavelet analysis

Conclusions

In this study, we used the MKT method, BfAST method, and Wavelet Analysis method to analyze the temporal variance of TSNatechs in the US during the period of 1990 to 2017. The results show that the TSNatechs have an increasing trend on annual data and an increasing-decreasing order trend with one breakpoint from a monthly scale view. Meanwhile, there are two significant return periods on 0.5 scale (passed the 0.95 level of significant test) and 1 scale (passed the 0.75 level of significant test). From the view of spatial variation, the density and frequency of TSNatech were increasing. By using a statistical, spatial, and cross wavelet analysis, we found that the spatial-temporal variation of TSNatechs could be attributed to climate change. The changing climate will affect the occurrence of TSNatechs by causing stronger tropical storms. The results of this study show to the managers of chemical industries and oil industries that they should pay more attention on the TSNatech risk under the changing climate. Although this study analyzed the increasing number of TSNatech during 1990 to 2017 in the US is probable attributed to climate change, whether climate change will effect on the conditional probability of TSNatech or not is still unclear. We believe more work on that sense need to be done, in the future.

References

1. Krausmann, E. & Cruz, A. M. Impact of the 11 March 2011, Great East Japan earthquake and tsunami on the chemical industry. *Nat. Hazards* **67**, 811–828 (2013).
2. Cruz, A. M. & Steinberg, L. J. Industry preparedness for earthquakes and earthquake-triggered hazmat accidents in the 1999 Kocaeli earthquake. *Earthq. Spectra* **21**, 285–303 (2005).
3. Krausmann, E. & Salzano, E. Chapter 3 - Lessons Learned From Natech Events. in (eds. Krausmann, E., Cruz, A. M. & Salzano, E. B. T.-N. R. A. and M.) 33–52 (Elsevier, 2017). doi:https://doi.org/10.1016/B978-0-12-803807-9.00003-6
4. Spatial distribution and temporal variation of drought in Inner Mongolia during 1901–2014 using Standardized Precipitation Evapotranspiration Index.
5. Young, S. Natural-technologic events: the frequency and severity of toxic releases during and after natural disasters with emphasis on wind and seismic events. *NIST Spec. Publ. SP* 1–6 (2002).
6. Cha, M., Han, S., Lee, J. & Choi, B. A virtual reality based fire training simulator integrated with fire dynamics data. *Fire Saf. J.* **50**, 12–24 (2012).
7. Suarez-Paba, M.C., Perreur, M., Munoz, F. and Cruz, A. M. Systematic literature review and qualitative meta-analysis of Natech research in the past four decades. *Saf. Sci.* Under review (2019).
8. Emanuel, K. Environmental factors affecting tropical cyclone power dissipation. *J. Clim.* **20**, 5497–5509 (2007).
9. Knutson, T. R. *et al.* Modeled Impact of Anthropogenic Warming on the Frequency of Intense Atlantic Hurricanes. *Science (80-.).* **327**, 454–458 (2010).
10. Torn, R. D. & Snyder, C. Uncertainty of Tropical Cyclone Best-Track Information. *Weather Forecast.* **27**, 715–729 (2012).
11. Landsea, C. W. & Franklin, J. L. Atlantic Hurricane Database Uncertainty and Presentation of a New Database Format. *Mon. Weather Rev.* **141**, 3576–3592 (2013).
12. Sengul, H., Santella, N., Steinberg, L. J. & Cruz, A. M. Analysis of hazardous material releases due to natural hazards in the United States. *Disasters* **36**, 723–743 (2012).
13. Cruz, A. M. & Krausmann, E. Vulnerability of the oil and gas sector to climate change and extreme weather events. *Clim. Change* **121**, 41–53 (2013).
14. Xiaolong, L., Ana Maria, C. & Tzioutzios, D. Extracting Natechs from large databases: Development of a semi-intelligent Natech identification framework. *Int. J. Disaster Risk Sci.* **(Under review)**, (2019).
15. Torrence, C. & Compo, G. P. A Practical Guide to Wavelet Analysis. *Bams* **79**, 61–78 (1998).