NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

Institute of Catastrophe Risk Management

Evaluation of Natural Catastrophe Impact on the Pearl River Delta (PRD) Region – Flood Risk

Jian, Wei
Lo, Edmond Y M
Pan, Tso-Chien

ICRM Topical Report 2018-001
October 2018

Contact Us:
Executive Director, ICRM
(ExecDir-ICRM@ntu.edu.sg)
N1-B1b-07, 50 Nanyang Avenue,
Singapore 639798

INTRODUCTION

The Pearl River Delta (PRD) Metropolitan Region, also known as the Guangdong-Hong Kong-Macau Greater Bay Area, is the low-lying area surrounding the Pearl River Estuary in southern China. It consists of nine cities in the Guangdong province along with Macau SAR and Hong Kong SAR (Figure 1). Together they form one of the key megacity clusters in the world with a dynamic economy serving as a vital node in the global supply chain underpinned by its leading manufacturing and export hubs.

Due to its geographical location, however, flooding has been a long-standing natural hazard in the region for centuries. Situated at the downstream deltaic plain of the Pearl River basin, three major rivers, specifically Xi Jiang (West River), Bei Jiang (North River), and Dong Jiang (East River) meander across the area, interconnected by a complex network of crisscrossing tributaries before discharging to the South China Sea. Together with its long coastline, the region is naturally vulnerable to hydrological and tropical cyclone events. Rapid urbanization and economic growth over the past decades have altered the land use and land cover, which together with the increasing exposure of the immense concentrations of population, wealth and investment have greatly exacerbated the susceptibility to flood risk and climate change. While this has been evident in most coastal cities worldwide where climate change impacts have amplified the natural catastrophe (Nat Cat) risk, it is particularly so for the PRD region.

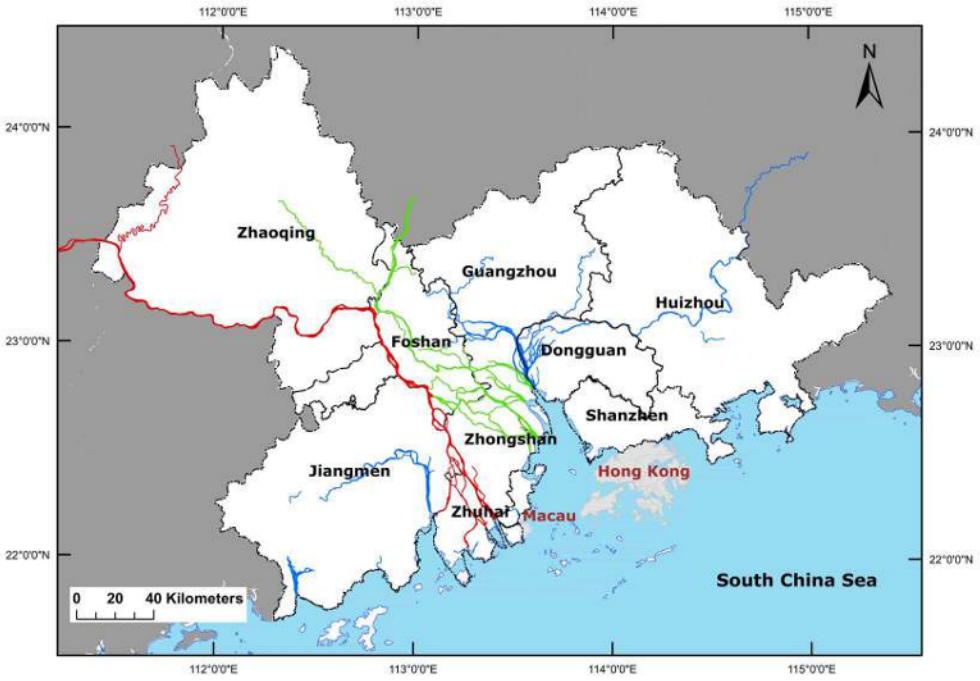

Figure 1. The administrative divisions of the PRD region. The two major river networks in the PRD region, Xi Jiang (West River) and Bei Jiang (North River), are highlighted in red and green, respectively.

Map source: NASA, GADM

In an ongoing two-year study jointly conducted by the Institute of Catastrophe Risk Management, Nanyang Technological University, Singapore and the South China University of Technology, China, a high-resolution (at city- and county-level) evaluation of flood hazard and risk ranking is being developed for the PRD region. The motivation is driven by PRD's massive urban concentration of population, economic assets and infrastructure, and its exposure to serious flood hazards (riverine, surface water and coastal floods).

UNDERSTANDING PRD'S REGIONAL FLOOD HAZARDS

The long-term annual mean precipitation over Guangdong province ranges over 1,600-2,600 mm, 85% of which occurs during April to September. Historically, three key factors contributed to major flood events in the PRD region: flooding of the upstream river reaches before entering the region, heavy rainfall within the PRD, and high astronomical tides/storm surges along the coastline. Extensive flood protection measures have been built along the river banks and coastline over the last two decades. However, while these measures are effective in protecting the cities from major flood events, they are prone to catastrophic failure when the design standards are exceeded. Furthermore, surface water flooding has become more frequent in recent years due to rapid urbanization and aging urban drainage systems. Based on the data released by the Guangdong government, approximately 10%-15% of the population in Guangdong province were affected by flood loss events on average every year over 2000-2015 (Figure 2). The direct economic loss from these flood events generally fluctuated about 0.5% of the provincial GDP despite the rapid increase in the regional GDP. The higher loss ratios from year 2006, 2008 and 2013 were owing to some major typhoon loss events such as Typhoon Chanchu (2006), Severe Tropical Storm Bilis (2006), Typhoon Prapiroon (2006), Typhoon Hagupit (2008) and Typhoon Usagi (2013) that occurred in Guangdong province.

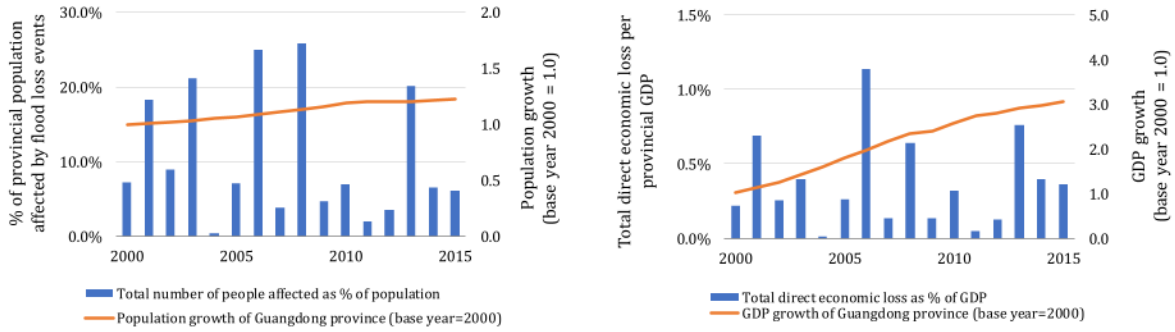

Figure 2. Number of people affected by flood loss events per total provincial population (left) and the ratio of direct economic loss in provincial GDP (right) for 2000-2015.

Data source: Guangdong Disaster Prevention and Mitigation Yearbooks, Guangdong Statistical Yearbooks

Tropical cyclones and rainstorms are the two main natural hazards occurring in the region that cause serious damage and economic losses. The trend in recent years have suggested that the number of flood loss events and direct economic loss are on the rise (Figures 3 and 4). Tropical cyclones remain the most severe threat to the PRD region in terms of the economic losses (Figure 4). On average, 4 tropical cyclones (with the intensity equal or above tropical depression) makes landfall along the coastline of Guangdong province every year. They bring strong winds, heavy rainfalls and storm surge to the communities located surrounding the cyclone tracks. Some recent events, Typhoon Hato (2017) and Super Typhoon Mangkhut (2018), highlighted the destructing power of such storm events in the region. Both typhoons made landfall slightly to the west of the Pearl River Estuary (PRE), this is most favourable for causing large storm surge in the PRE. Strong gales, heavy rainfall and severe flooding were experienced in the coastal areas surrounding the PRE, especially in low-lying and coastal areas due to over 1-2.5 m storm surges induced along the PRE. The former, a Category-3 typhoon, caused over RMB11.92 billion (US$1.73 billion) direct losses in Guangdong province, MOP12.55 billion (US$1.55 billion) losses in Macau and a reported insured loss of HK$857.9 million (US$110 million) in Hong Kong (NCDR, 2017; DSEC, 2018; HKFI, 2018). Typhoon Hato greatly exposed the vulnerability of Macau in withstanding the perils of such storm events. More than half of the Macau peninsula were hit by major flooding and property damages, especially at the downtown area where inundation was reported to be over 2 m from a post-event field survey (Takagi et al., 2018). The more recent Category-5 typhoon Mangkhut, took place in mid Sep this year, had a much higher wind intensity and wider circulation, is expected to be costlier than Typhoon Hato for Hong Kong (Huang, 2018). Macau had to close all its casinos for one day, the first time in its history. The estimated economic losses in Guangdong provinces had exceeded RMB4.2 billion (US$612 million) by 18 Sep (Leng, 2018). If we are to take a long-term perspective, the rising South China

Sea and the subsiding coast will further increase the vulnerability of these coastal communities to future storm events.

We have developed a flood loss database that details the hazard footprints and loss magnitudes of major flood events that occurred in Guangdong province since 2000. This database provides the basis for understanding the characteristics of the potentially damaging flood events, and for identifying the primary drivers for different types of flood hazards in the region such as the observations made above.

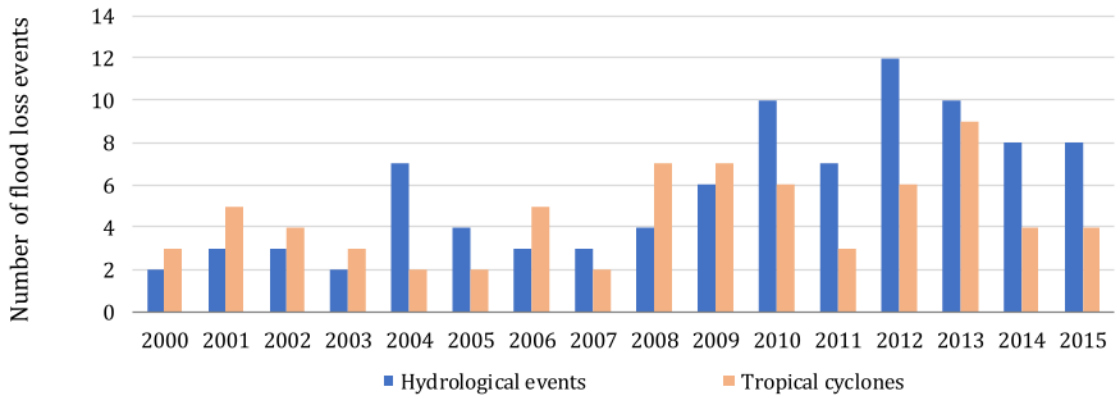

Figure 3. Number of flood loss events reported for 2000–2015 in Guangdong province.

Data source: Guangdong Disaster Prevention and Mitigation Yearbooks

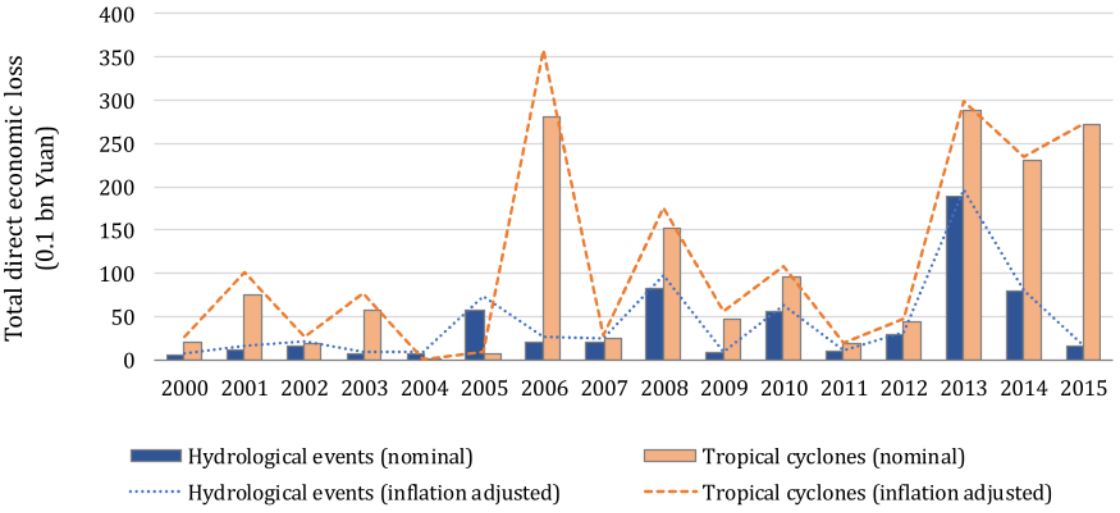

Figure 4. Total direct economic loss in Guangdong province in 2000-2015. The inflation adjustment is based on the annual general consumer price indices of Guangdong province for the same period.

Data source: Guangdong Disaster Prevention and Mitigation Yearbooks, Guangdong Statistical Yearbooks

GROWING REGIONAL EXPOSURE

The PRD region is home to almost 60 million inhabitants at the end of year 2016, a large portion of which live in the low-lying coastal zones and flood plains that are most vulnerable to flood damage (Figure 5). Traditionally a manufacturing hub, its recent establishment of industrial and science parks and emerging industries of high-tech and innovation continues to draw talents and migrants to the area. The population growths at most counties and county-level cities were between 1.0%-3.0% over the last six years on average (Figure 5). The steady inflow of migrants into the coastal counties is evident.

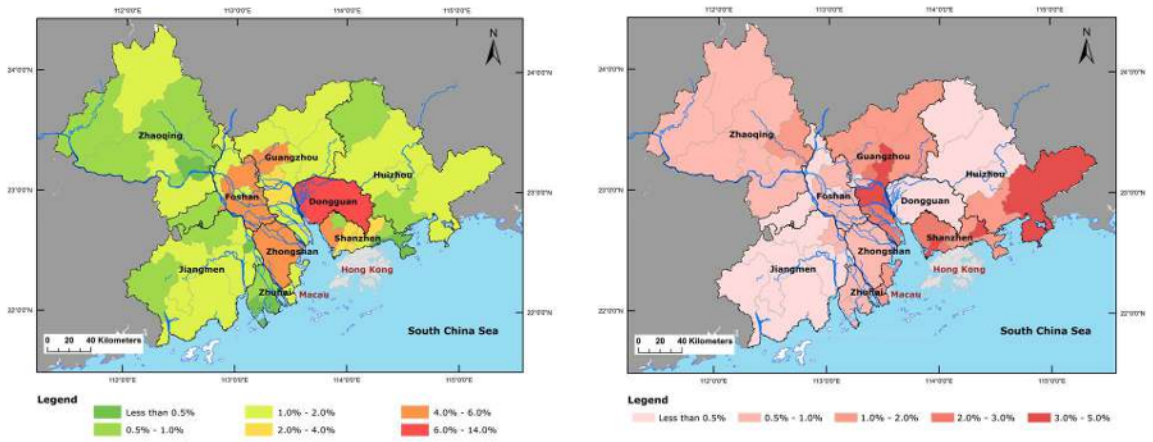

Figure 5. Spatial distribution of the total permanent population in the PRD region at the end of year 2016 (left) and the average annual population growth for 2010-2016 period (right).

Source: Guangdong Provincial and Municipal Statistical Yearbooks, NASA, GADM

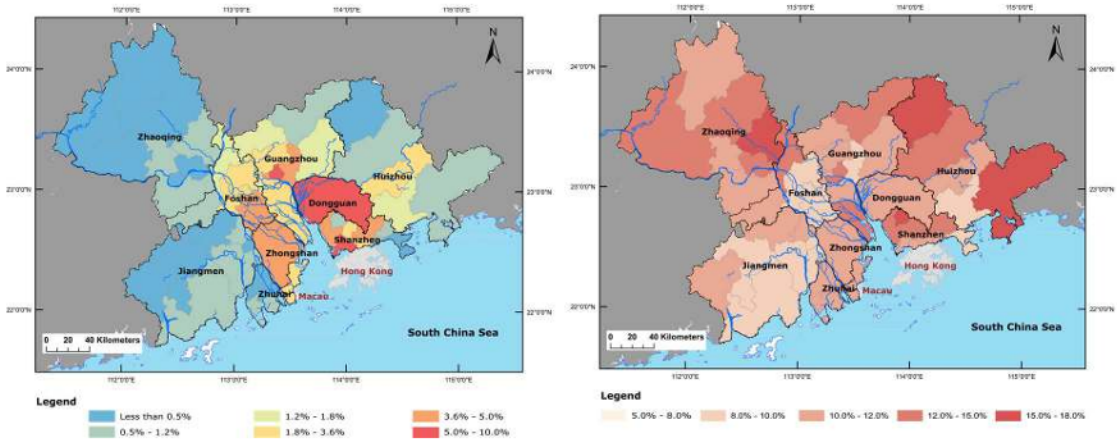

Figure 6. Spatial contribution of the regional GDP in percentage in the PRD region at the end of year 2016 (left) and the average annual GDP growth for 2010-2016 period (right).

Source: Guangdong Provincial and Municipal Statistical Yearbooks, NASA, GADM

The region is also a major contributor to China's national GDP, contributing almost 1 trillion USD (6.78 trillion Yuan) at the end of year 2016. The majority of this are from the more developed cities concentrated along Pearl River Estuary (Figure 6). While these core cities grew at an average rate of approximately 10% over the past six years, other cities in the PRD region (Zhaoqing, Jiangmen and Huizhou) are speeding up their development with their average growth rates between 12%-18% over the same period. As the Guangdong province continues to transform and develop, the exposure of the PRD region, and more importantly its density, will be on an accelerated growth which will accentuate its vulnerability to future flood events.

FLOOD RISK EVALUATION AND RANKING

The flood risk evaluation currently developed is based on two flood risk models: inland and coastal. The former considers the riverine and surface water floods which are primarily caused by intense rainfalls. Engaging the Geographic Information System (GIS) based fuzzy comprehension evaluation method (Lai et al., 2015, 2017), key indices addressing the disaster-inducing factors (such as precipitation intensity and frequency) and hazard-inducing environment (such as natural and man-made capacities to infiltrate and channel/retain runoffs, river networks) are considered in the computation of flood hazard levels. Extensive datasets covering the meteorological, topographic, spatial and socio-economic data have been collected and processed. The modelling and analyses for risk rankings will be based on hazard, vulnerability and exposure indicators over 1km grids in the PRD region. The work on coastal flood risk evaluation will further consider the cyclone/storm surge induced flooding in the coastal areas and its potential impact on communities further upstream. This will be based on the developed surge response functions along the PRD coastline from historical and large sets (30000) of synthetic cyclone tracks for the northern South China Sea region (Lin et al., 2012; Yap et al., 2015) and estimates of the flooding potential inland.

The outcome of this study will provide a robust evaluation of the flood impact in the PRD and provide foundation for future higher-resolution Nat Cat risk studies and risk management in a wider region.

ACKNOWLEDGMENTS

The authors acknowledge support provided by the Sino-Singapore International Joint Research Institute.

REFERENCES

China National Commission for Disaster Reduction (NCDR) (2017, Aug 25). 台风"天鸽"致 5 省份 12 人死亡失踪.

Hong Kong Federation of Insurers (HKFI) (2018, Mar 14). Insurance alleviates public's suffering from catastrophic loss. Retrieved from https://www.hkfi.org.hk/#!/media-release/430

Huang, C (2018, Sep 19). Hong Kong's losses from Typhoon Mangkhut to be bigger than Typhoon Hato. *The Straits Times*. Retrieved from https://www.straitstimes.com/asia/east-asia/hong-kongs-losses-from-typhoon-mangkhut-to-be-bigger-than-typhoon-hato

Lai, C., Chen, X., Chen, X., Wang, Z., Wu, X., Zhao, S. (2015). A fuzzy comprehensive evaluation model for flood risk based on the combination weight of game theory. Natural Hazards, 77, 1243-1259.

Lai, C., Chen, X., Wang, Z., Xu, C., Yang, B. (2017). Rainfall-induced landslide susceptibility assessment using random forest weight at basin scale. Hydrology Research, 49 (5), 1363-1378.

Leng, S (2018, Sep 18). Southern China counts cost of Typhoon Mangkhut – and more billion-dollar storms. *South China Morning Post*. Retrieved from https://www.scmp.com/economy/china-economy/article/2164701/southern-china-counts-cost-super-typhoon-mangkhut-and-more

Lin, N., Emanuel, K., Oppenheimer, M., Vanmarcke, E. (2012). Physically based assessment of hurricane surge threat under climate change. Nature Climate Change, 2(6), 462-467.

Statistics and Census Service (DSEC), Government of Macao Special Administrative Region (2018, Feb 26). "8.23" Typhoon caused Macao an estimated economic loss of MOP12.55 billion. Retrieved from https://www.dsec.gov.mo/Statistic/Other/Report/823Report.aspx?lang=en-US

Takagi, H. Xiong, Y., Furukawa, F. (2018). Track analysis and storm surge investigation of 2017 Typhoon Hato: were the warning signals issued in Macau and Hong Kong timed appropriately? Georisk: Assessment and Management of Risk for Engineered Systems and Geohazards. DOI: 10.1080/17499518.2018.1465573.

Yap, W., Lee Y., Gouramanis C., Switzer A. D., Yu F., Lau A. A. Y., et al. (2015). A historical typhoon database for the southern and eastern Chinese coastal regions, 1951 to 2012. Ocean & Coastal Management, 108(SI), 109-115.