Urban Climate 17 (2016) 135–145

Contents lists available at ScienceDirect

Urban Climate

journal homepage: http://www.elsevier.com/locate/uclim

Projection of coastal floods in 2050 Jakarta

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ARTICLE INFO

Article history:
Received 9 February 2016
Received in revised form 20 May 2016
Accepted 22 May 2016
Available online xxxx

Keywords:
Jakarta
Coastal flood
Land subsidence
Sea-level rise
Oceanic tide
Urbanization
Abnormal high tides
ENSO
18.6-year lunar nodal cycle

ABSTRACT

The present work projects the extent of coastal floods by the year 2050 in Jakarta, one of the fastest growing megacities in the world, using a coastal hydrodynamic model that considers abnormal high tides, sea-level rise, and land subsidence. The tidal constituents were adjusted in a manner to reproduce the observed tidal record during the extensive coastal floods that took place on November 2007, when it is likely that a La Niña event, the 18.6 year lunar nodal high-tide cycle, and other abnormal tide mechanisms took place simultaneously. The simulations demonstrate that by the middle of this century extensive floods could potentially reach several kilometers inland in Jakarta. Land subsidence is clearly one of the major challenges facing the city, as considering only the influence of sea-level rise indicates that such floods may be limited to within a few hundred meters of the coastline. From 2000 to 2050 the potential flood extent is estimated to increase by 110.5 km^2. Land subsidence is responsible for 88% of this increase. The results also indicate that the rate of flood area expansion in the 2025–2050 period would be 3.4 times faster than during the 2000–2025 period, demonstrating a non-linear increase in flood risk with the passage of time.

1. Introduction

Jakarta, the capital of Indonesia, is one of the largest coastal megacities in the planet, with a resident population exceeding 9.6 million in 2010, plus approximately 2.5 million daily commuters from the adjacent cities, and a total land area of 662 km^2 (Djaja et al., 2004; Firman et al., 2010). The population growth rate reached 1.39%/year over the period 2000–2010 (Central Board of Statistics, 2010), which has made Jakarta

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http://dx.doi.org/10.1016/j.uclim.2016.05.003
2212-0955

one of the most densely populated cities in the world, and is expected to reach 30 million inhabitants by 2030. Greater Jakarta has also been experiencing rapid economic growth over the last decades, offering its resident a variety of opportunities in terms of working and accommodation (Sagala et al., 2013).

As a consequence of this rapid development Jakarta has been facing many urban development issues, though the issue of land subsidence appears to have become especially serious over the last couple of decades. In fact, the occurrence of land subsidence was clearly recognized as far back as 1978, when substantial cracks were found in buildings and a bridge in downtown Jakarta (Djaja et al., 2004). In Jakarta, the subsidence rates along the coast vary from 9.5 to 21.5 cm/year in the period between 2007 and 2009 (Chaussard et al., 2013). Land subsidence can be classified into four types, namely: subsidence due to groundwater extraction, subsidence induced by the load of buildings, subsidence caused by natural consolidation of alluvium soil, and geotectonic subsidence. For the case of Jakarta the first type, subsidence due to groundwater extraction, appears to be the main cause for the lowering of the land. In particular, the extraction of water for industrial uses is a widespread practice which can induce rapid rates of land subsidence. Such subsidence can lead to severe damage to buildings and infrastructures, increase the extent of flooded areas, destroy local ground water systems or increase seawater intrusion (Braadbaart and Braadbaart, 1997; Abidin et al., 2009; Ng et al., 2012).

Jakarta has already experienced many severe river floods due to heavy monsoon rains, particularly in the years 1996, 2002, 2007, 2013, and 2014. Particularly, the floods that took place in January 2013 resulted in 40 deaths, 45,000 refugees, and substantial economic damage. Such extreme flooding events might become more frequent in the future due to the impacts of land use and climate change (Kure et al., 2014). The floods in February 2007 also caused extensive economic losses, mounting up to between 4.1 and 7.3 trillion IDR (450–800 million USD, see Sagala et al., 2013). In fact, Jakarta is considered to be one of the most vulnerable cities to coastal floods (Firman et al., 2010, Ningsih et al., 2011). Though Jakarta is not on the route that tropical cyclones take and thus is unlikely to face a significant typhoon storm surge event, coastal areas could experience the indirect minor impact of a major typhoon which travels near the Philippines or Vietnam in the western north Pacific (Ningsih et al., 2011; Takagi et al., 2014). As highlighted by the Intergovernmental Panel on Climate Change 5th Assessment Report (or IPCC AR5), coastal floods are likely to become more common in coastal areas around the world due to the consequences of future climate change, including sea-level rise (SLR) and tropical cyclone intensification, and other factors such as population increase, urbanization, and land subsidence. In this sense it is worth noting that at the present global losses due to floods and other natural disasters are generally increasing (Esteban et al., 2015a, 2015b; Jonkman and Dawson, 2012; Jongman et al., 2012; Nguyen et al., 2014).

As at present CO_2 emissions continue to increase, it appears logical that a significant amount of SLR due to thermal expansion of the oceans would be inevitable, unless significant actions are taken by the international community to reduce emissions. Aside from this constant and ongoing increase in sea levels due to the effects of climate change, interannual sea surface oscillations are also likely to increase the risk of floods in low-lying coasts. One such interannual variation is the El Niño Southern Oscillation (ENSO). During the 1997–1998

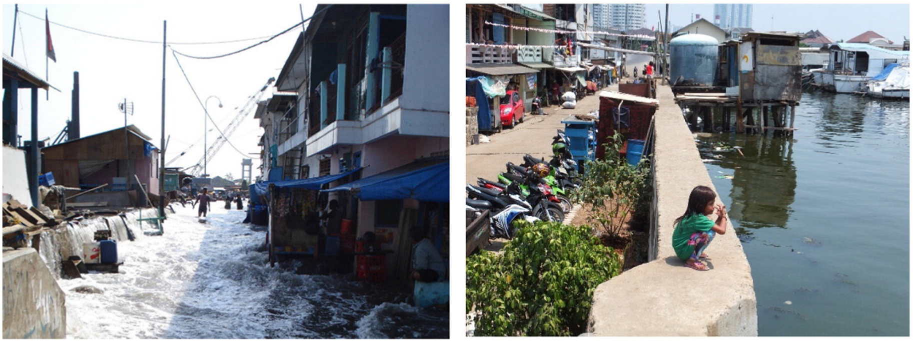

Fig. 1. Coastal town in Jakarta situated below sea level, which was extensively inundated during a high tide on November 26, 2007 (Left). The thin dyke protecting the settlement was raised by the local government by about a meter after the flood event, obstructing people's vision of the sea (Right). (Photo Left: courtesy of Brinkman J.J., Deltares - Jakarta flood hazard mapping 2007–2014, Right: taken by one of the authors on Sep. 2, 2015).