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Asian Urban Environment and Climate Change: Preface

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ABSTRACT

The Asian Network on Climate Science and Technology (www.ancst.org), in collaboration with Tsinghua University, held a conference on environmental and climate science, air pollution, urban planning and transportation in July 2015, with over 40 Asian experts participating and presentation. This was followed by a meeting with local government and community experts on the practical conclusions of the conference. Of the papers presented at the conference a selection are included in this special issue of *Journal of Environmental Science*, which also reflects the conclusions of the Paris Climate meeting in Dec 2015, when the major nations of the world agreed about the compelling need to reduce the upward trend of adverse impacts associated with global climate change. Now is the time for urban areas to work out the serious consequences for their populations, but also how they should work together to take action to reduce global warming to benefit their own communities and also the whole planet!

Introduction

The conurbations of Asia are rapidly expanding and changing faster than at any time in history, with some urban areas and populations doubling in less than 10 years. Their physical and natural states are also being transformed. Very tall buildings in business districts and new 50 story housing estates now rise to 100 m or more; urban coast-lines are moving out into the adjoining seas and lakes, with economies doubling at about the same rate, people in cities are consuming and discharging ever larger volumes of natural resources, and transforming the natural environment of their surroundings, with more people travelling across larger cities, transport facilities are having to expand, although in many cities they are still not sufficient to avoid saturation and even shut-down. In many cities, the rise in air pollution is exceeding international health standards, which particularly affect the elderly and small children. In addition to the worsening of short and long term environmental changes, an increasing numbers of people are impacted by natural hazards within these areas. Innovative cities are using a range of measures, including technologies and better planning, with cleaner transport with electric vehicles and new building systems incorporating, in tropical cities, air-conditioning to lower indoor temperatures and air-cleaners to remove fine particles from living spaces and in passenger vehicles.

It is even more important that vulnerable communities are provided with public sheltering facilities to reduce the impacts of periods of high temperature, high pollution and dangerous flooding. But many Asian cities are losing the vital contribution to public health of green spaces, despite studies showing why maintaining parks and road-side trees is a cost effective measure against high temperature and pollution, and flooding.

Atmospheric measurements and computer models confirm that, as the urban areas expand, they affect both higher layers in the atmosphere and also how they are affecting the environment over hundreds of kilometres away from the cities (Hunt et al., 2016). With urbanisation reducing the

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vegetation cover from 80% down to 1%, and enlarging the areas of high buildings, the albedo and the diurnal cycle of heating and cooling are changed substantially. The main consequence is that the mean surface temperature in urban areas has risen faster than by global warming, by about 1.4°C over the large conurbations. The pattern of precipitation has also changed. Just like other mesoscale disturbances in boundary layer flows, large change in surface conditions over the conurbation affect precipitation and temperature in areas more than 100 km down-wind (Cheng and Chan 2012).

Leaders of the major cities around the world are now well aware that the physical growth and the transformations of their regions are affecting the climate and the environment of the whole world, with serious consequences for the long term well-being of the whole of the world's population. Since the energy use by transport, housing and industry of urban areas are responsible for more than half the total consumption of carbon based fuels, large cities are responsible for the increasing global level of green-house gases and consequently for the continuing rise in global average temperature. Furthermore leaders are also showing their responsibility by explaining to their public how their urban areas are also experiencing adverse feed-back effects including rising global temperatures, changing patterns of global climate and, for coastal cities, rising sea levels and ocean acidification.

Of great concern to cities are the increased risks of more extended periods of very hot or very cold weather and high levels of dust and pollution, which can be more acute in cities than in the surrounding areas. In either of these temperature extremes there is greater incidence of illness and death among vulnerable groups such as the elderly, young children and asthmatics, which are further exacerbated when there are high levels of air pollution carried into the cities from agricultural burning, shipping in coastal cities and industries. Worsening environments on land and sea also have negative economic effects such as on tourism, fishing, agriculture and forestry.

The variability of global climate change also causes variability in natural hazards and their impacts in large urban areas, especially in Asia. Some geophysical hazard-events occur relatively slowly, such as those associated with high or low temperature, or floods from high precipitation. With very high temperatures, weak winds driven by deep turbulent convection can vary markedly across urban areas, usually with the maximum temperatures occurring towards the downwind part of the city. Also these patterns tend to vary unsteadily in time, depending on the surface conditions and density of high buildings. During extreme atmospheric events, large cities meet requirements for extra levels of energy for cooling or heating, as well as meeting the usual demands for transportation. Urban planning and design need to become more energy efficient in the future, to avoid contributing an increasing proportion of global greenhouse gas emissions. With more complete environmental data at ground level, and new data from tall meteorological masts and towers such as those in Beijing and other Asian cities, these environmental hazards could be better monitored, predicted and understood as shown recently in London where tower data have demonstrated their utility. The health of cities will also benefit from studies leading to better ventilated streets and well maintained green spaces.

Near the Equator, except when there are violent wind storms, the wind speeds are generally low, especially in the evening. The expansion of large cities, which further reduces wind speeds, also contributes to higher temperatures locally and over the whole globe. For inland urban areas over the winter months, the high concentrations of urban and rural aerosols prevent the sun's rays reaching the ground level, further reducing the temperature and even freezing small rivers, as observed in Delhi in 2014. In north Indian plain, there are increasing economic impacts as winter transport is severely disrupted for days on end not only aircraft, but even trains and road traffic reminiscent of Europe and USA before the 1960s.

The cities in South East Asia, particularly Manila, not only experience serious impacts from the worsening atmospheric environment, but they also suffer from multiple hazards resulting from severe rain, mud slides, high winds and flooding on the coasts and inland. Such events can occur simultaneously or in close succession (Hunt, 2009). The impacts of these hazards on communities are magnified in the most increasing populous areas which are often located in vulnerable locations, for example next to rivers, on hillsides or on the coasts, where typhoon flooding can devastate whole communities. Future planning has to allow for future trends that show how over the past 100 years, peak rainfall rates have doubled and their frequency has also increased, which has been partly caused as by the effects of urban growth. Since global warming is increasing and also atmospheric humidity, the severity and frequency of these flood hazards are likely to keep increasing, especially in tropical regions.

But technology can reduce the impact of these hazards through forecasting their movement a few hours ahead, for example with the aid of using weather radar systems for tracking moving clouds of intense rain. With improved modelling and communications, even to individuals, local communities can now evacuate flood prone areas and move to public refuge buildings (Lagmay et al., 2017a), which are being repositioned more appropriately using models and data of how floods build up in these critical areas. Many lives have been saved, but unless the urban infrastructure is improved, the impacts on property will keep on increasing.

A range of policies for dealing with the issues are being considered in major urban areas in Asia. In some cities in China, planning policies have focussed on reducing the continued spatial growth of some of the largest cities by creating separate new towns about 50–100 km away. In principle, this approach should produce lower air pollution in satellite cities by reducing commuting distances of car drivers, and moderate rising urban temperatures by limiting the growth of the mega city. But there is evidence that people do not necessarily behave according to plan. It is found that commuting distances can even increase because, while jobs can be moved, families may not want to be displaced. Other planning policies as in Delhi and Singapore are focusing on how to reduce air pollution whether it is produced regionally or locally within the cities. At a local level, populations are exposed to road-side traffic pollution in street canyons and densely-developed city regions. Because of low levels of

atmospheric dispersion and reduced chemical transformation in the air between the vehicle sources and the location of pedestrians in these situations, toxicological impacts differ. This is important for developing policies relating street-level traffic to the environment, and also for the interpretation of data taken at these locations. Research on complex chemistry over urban areas leading to the next air quality assessment systems will be necessary (Wang et al., 2015; Zhiqiang et al., 2016).

For policies to be effective in improving the urban environment and reducing hazard policies they should be integrated with national and global policies for the reduction of global greenhouse emissions (Shen, 2015). Having more detailed models and empirical evidence will enable politicians to implement environmental policies.

Local measures being introduced include green areas, better and greener construction with less concrete, public transport and shortening commuter distances. Following the Paris COP 21 climate meeting in 2015 and the ratification by most governments they have now agreed to the main objectives of reducing future carbon emissions. Cities are already introducing practical short term measures, and also longer term plans, perhaps with city based economics to motivate the decision making.

An emerging research topic for cities in tropical and sub-tropical regions the improvement of the measurements and modelling of the special features of where environments, notably how the winds, temperatures, rainfall and air/water pollution are caused by local thermal processes, rather than by the environmental features of the approach flows as is assumed in models for urban areas in temperate zones. This also means that these locally generated winds and associated processes such as dangerous thunderstorms can develop over much shorter periods than the longer time scales of meso-scale and synoptic scale environmental processes at higher latitudes.

Recent research has also indicated how the environmental dynamics of tropical mega cities depend differently on the planning of buildings, green spaces *etc.* compared with cities at higher latitudes (Ng and Ren, 2015). In all cities there are radial distributions of building density varying outwards from the centre; in some there may be satellite cities around the city centre, or in others there are spidery concentrations along corridors of development. Studies show that local winds, temperature and pollution patterns can be quite different in the tropics because the local thermal effects of the buildings have relatively a much bigger influence than the upwind flow, which are more dominant in high latitude cities (Fan et al., 2017), this has significant consequences for the living conditioning and functioning of growing tropical mega cities.

The implication of global climate change on cities, and conversely their effects on regional and global climate, is also critically affected by the concentration of the growing world population in expanding urban areas. This raises the questions that the consequences for the environment and transportation be better if city planning should be based on groups of smaller satellite cities, or local high-rise cities within cities?

In the following, we summarise the main points of the ten papers in this special issue.

1. Urban climate variations

Matsumoto et al. (2017) reviews the trends over 140 years of measured climate variables in the Tokyo metropolitan area. He concluded that there has been rise in annual mean temperature of 3°C since 1900, compared with ~1.3°C in the rural areas. Extremes of hourly rainfall have also risen. Both these trends are similar to those in Hong Kong, although in the latter, extreme rainfall rates have risen much faster (see below). He pointed out that extensive studies are currently underway for planning the Tokyo Olympics in 2020, especially the significant spatial variations in meteorological conditions such as temperature and precipitation. It will be interesting to compare the results with comparable studies for the Beijing (2008) and London (2012) Olympics.

Chen et al. (2017) describe in detail the extraction of surface temperature distribution in urban areas using data from the series of Landsat missions for land surface temperature over 42 years, since the launch of its first satellite in 1972. Other thermal data such as emissivity of the surface material are also analysed which is still a challenge, especially for urban areas. In addition the paper discusses atmospheric correction, radiometric calibration, and validation for urban areas. The main aim is to understand the potential challenges for the continuity of Landsat observation for global change monitoring, and relating these to several climate data records programs that are currently in progress.

Lagmay et al. (2017a, 2017b) describes how the science-based disaster warning system (NOAH) provides hazard maps for floods, landslides, and storm surges from tropical cyclones, which are used to plan resilience systems that are more effective because the local community and non-government organisations were fully engaged during the development of the system. This internationally-leading system provides real-time protection of communities through their participation by sending online data about flood levels to a centre where online computer modelling predicts the evolving hazard and impact in affected areas, and then sends warning advice back to the local communities. The effectiveness of this system has been demonstrated by the fact that the casualties were much lower in recent severe flooding events. The same method could be applied in other countries.

Fan et al. (2017) report on certain meteorological trends in Hong Kong within the central business district (CBD) and outside, showing how the temperature is rising faster in the CBD. The annual average wind speed also decreased until 1995, but it has remained relatively steady since then. Where the approach mean wind speeds of the approach flows are very low, characteristic buoyancy and turbulence-driven atmospheric circulations occur in dome- like zones over the urban area, where, because of the low wind speed, surface temperatures are significantly higher than those in the external rural areas. These flow mechanisms are studied here through laboratory experiments and modelling. The studies show that the mean streamline pattern converges at a low level, with additional low-level inflow from external rural areas and a divergent outflow in the opposite direction in the upper part of the mixed layer. The diurnal variation of these recirculations also affects the net ventilation of the

flow, and the dispersion of pollution emitted from sources below the inversion height within the dome-like zone. This leads to a rise in the mean concentration. Low-level air entrained from rural areas in the evening can lower this concentration. Greater dispersion occurs if the recirculating structures of the dome-like flow regions over urban areas break down as a result of the surface temperature distribution not being symmetrical. Breakdown of the flow pattern also occurs if the approach wind speed increases to a level comparable with the mean velocity of circulation, or (except near the equator) the urban area is large enough that the Coriolis acceleration is significant.

Holst et al. (2017) analyse the causes of the steady rise in the peak precipitation that is observed over mega cities, such as Hong Kong (where for rainfall of 100 mm/hr, the return period is now <18 years), Singapore and Tokyo. The question is whether this significant environmental trend is driven more by the growth and physical nature of these urban areas or by global climate change. In their detailed meteorological study of a pre-monsoon rainfall episode over the Pearl River Delta region, the WRF computational model (from USA) was applied at a high resolution of 1 km. The focus was on how rainfall rates varied with surface anthropogenic heating and the overall size of the urban area. The results confirmed that the highest precipitation rates (excluding tropical cyclones) above 100 mm/hr are several times more likely to occur in large and dense urban areas than in rural areas, where the main cause of precipitation increase is global warming.

2. Urban environment and policies

In China the policies for reducing the growth of high temperatures and air pollution in urban areas also have to be related to policies for reducing the rapid growth of urban transportation. These policies are increasingly associated with the transcontinental networks extending from Beijing to Tibet and central Asia. In fact these networks are now stimulating the growth of large cities, where the higher energy consumption leads to more frequent occurrence of very high temperatures. In July 2015, temperatures of 40°C were again recorded in Beijing (Shi, 2015).

The Future Transport Research Centre at Tsinghua University is developing policies, with international partners, for low carbon and sustainable transport systems. These are based on advanced systems for measuring and controlling road transport such as the FLOWSIM model (Wu et al., 2003), as well as new technologies such as electric vehicles (Du et al., 2015) and real-time information systems on road-side and in vehicles (Yang et al., 2017). The interacting roles of the individual driver and the central control system, in relation to the patterns of traffic and variable pollution across the urban area, are leading to optimal operation.

Du and Wu (2017) address the interaction between energy consumption and air pollution by studying the effects of fuel consumption by various types of vehicles and also the effects of other e factors, such as the relationship between fuel consumption and the impact factors, using the massive vehicle data that is now available. The fuel consumption pattern and congestion pattern based on large samples of historical Floating Vehicle Data are explored. Also drivers' information and vehicles' parameters from different group classification are probed, and average velocity and average fuel consumption on temporal dimension and spatial dimension are analysed respectively. The fuel consumption forecasting model is established by using Back Propagation Neural Network. Part of the sample set is used to train the forecasting model and the remaining part of the sample set is used as the input of the forecasting model.

Hu et al. (2017) describe a heavy 15-day pollution episode that occurred in Beijing from December 17 to 31, 2015. The mean daily Air Quality Index and $PM_{2.5}$ were 212.53 and 179.4 $\mu g/m^3$. The spatio-temporal characteristics of air pollutants, meteorology and road space speed are analysed during this period. Using previous correlation analysis with observational data and a multivariate mutual information model reveals the combined effect of traffic restrictions and meteorology on urban air quality. Results of spatio-temporal analysis have shown that five stages of pollution stages were identified in relation to patterns of variations of $PM_{2.5}$ concentration and of weather conditions. The southern sites in Beijing experienced heavier pollution than the northern site. Some situations revealed combined effects of meteorology and traffic restrictions with some time delay between these two effects. Air quality-Traffic-Meteorology indexes revealed that traffic restrictions, in certain conditions of relative humidity and wind speed, were more effective for particle removal than for gas pollutants, which is an important conclusion for managing air pollution in mega cities.

Liu et al. (2017) present another innovative study of real-time mapping of the population's exposure to particulate pollution ($PM_{2.5}$) in Beijing. The data also included medical data for lung cancer and heart diseases. Monthly data were recorded for 808 sites in China as a whole, 35 of which are located in Beijing. The measurements of the considerable spatial and temporal variabilities of population exposure are explained by the wavy form of the concentration contours recorded across the city, which probably occur in most low-wind conditions that are typical of Asian cities.

Equally serious pollution occurs in medium sized cities, such the famous historic city of Agra that is located within a semi-arid region of northern India. Local real-time measurements (Saini et al., 2017) of the pollutants, especially those caused by intense road traffic and domestic heating, show how they interact chemically, especially at high temperatures, the resulting production of ozone and atmospheric chemical components are directly damaging to human health and vegetation.

Urban floods from thunderstorms cause severe problems in Metro Manila due to road traffic. Lagmay et al. (2017a, 2017b) use Light Detection and Ranging (LiDAR)-derived topography, flood simulations and anecdotal reports to identify the root of surface flood problems in Metro Manila. Possible solutions include the elevation of roads or construction of well-designed drainage structures leading to the creeks. Proposed solutions to the flood problem of Metro Manila may avoid paralysing traffic problems due to short-lived rain events, which according to Japan International Cooperation Agency (JICA) cost the Philippine economy 2.4 billion pesos/day.

Other developments in the study of the environment of Asian cities have been recently reviewed by Hunt et al. (2016). A few points are summarised here that are relevant to this special issue. It is critical that meteorological and environmental measurements be made both near ground level, by remote sampling, by and using towers and also tall buildings such as in China. Another aspect of measurement of air pollutants is to establish personalised records of air pollution of people moving in urban areas and also secondary air pollutants, both of which can lead to critical warnings, especially when large crowds gather, whether planned or accidental.

Forecasting of pollutants is now becoming more accurate for all scales of urban area, which are particularly beneficial for people suffering from lung diseases and other breathing difficulties. The use of renewable energy in Pakistan for manufacturing, such as brick making, is beginning to replace highly polluting coal. The environment of overcrowded settlements in equatorial mega cities, such as those in Indonesia, is now being modelled to enable architects, planners and transport engineers to reduce the adverse impacts of high temperature, high humidity and generally low wind speed. One proposal is for mega cities to have within them 'super-blocks' which enable people to live with less travel, so as to reduce emissions from transport systems. But there are disadvantages which are being studied.

3. Conclusion

An important conclusion of the papers included in these proceedings and other papers summarised by Hunt et al. (2016) is that local levels of pollution in large urban areas are highly variable in time and space. Information and forecasting of pollutants and of environmental variables are becoming vital tools for managing and improving the quality of urban living. But there are other hazards associated with the growing size of cities and their contribution to the increasing occurrence frequency of natural hazards. Detailed studies of the urban structure, including the various types of buildings and open space, together with all types of transport systems, are combined with detailed measurements and modelling of the atmospheric environment to provide forecast and planning tools. These contribute to policies for minimising the impacts of pollution and natural hazards. These solutions and planning tools must take into consideration the very different topography, regional environment and climatology for the different areas and geographical latitudes of Asia. The concept of natural capital (Hunt et al., 2016) may provide an economic insight for planning and investing in the natural environment within and surrounding mega cities. The influence on global climate and more severe natural hazards resulting from growing emissions from Asian megacities are dominant factors that local and national policy makers also have to consider.

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REFERENCES

Chen, F., Yang, S., Yin, K., Chan, P., 2017. Challenges to quantitative applications of Landsat observations for the urban thermal environment. J. Environ. Sci. 59, 80–88.

Cheng, C.K.M., Chan, J.L.C., 2012. Impacts of land use changes and synoptic forcing on the seasonal climate over the Pearl River Delta of China. Atmos. Environ. 60, 25–36.

Du, Y.Y., Wu, J.P., Hu, K.Z., Guo, Y., 2015. Simulation study on improvement of air quality by introducing electric vehicles. Int. J. Model. Simul. Sci. Comput. 06, 1550042.

Holst, C.C., Chan, J.C.L., Tam, C.Y., 2017. Sensitivity of precipitation statistics to urban growth in a subtropical coastal megacity cluster. J. Environ. Sci. 59, 6–12.

Hu, D.M., Wu, J.P., Tian, K., Liao, L.C., Xu, M., Du, Y.M., 2017. Urban air quality, meteorology and traffic linkages: evidence from a sixteen-day particulate matter pollution event in December 2015, Beijing. J. Environ. Sci. 59, 30–38.

Hunt, J.C.R., Chan, J.C.L., Wu, J.P., 2016. Asian urban environment and climate change. Curr. Sci. 110 (8), 25.

Lagmay, A.M.F.A., Racoma, B.A., Aracan, K.A., Alconis-Ayco, J., Saddi, I.L., 2017a. Disseminating near-real time hazards information and flood maps in the Philippines through web-GIS. J. Environ. Sci. 59, 13–23.

Lagmay, A.M., Mendoza, J., Cipriano, F., Delmendo, P.A., Lacsamana, M.N., Moises, M.A., et al., 2017b. Street floods in Metro Manila and possible solutions. J. Environ. Sci. 59, 39–47.

Liu, Z., Xie, M.H., Tian, K., Gao, P.C., 2017. GIS-based analysis of population exposure to PM2.5 air pollution — a case study of Beijing. J. Environ. Sci. 59, 48–53.

Matsumoto, J., Fujibe, F., Takahashi, H., 2017. Urban climate in the Tokyo metropolitan area in Japan. J. Environ. Sci. 59, 54–62.

Ng, E., Ren, C., 2015. Integrated policies for environmental resilience and sustainability. Hunt, J., Proc. Inst. Civ. Eng. Eng. Sustain. 162.3 (2009), 155–167 (Print).

Saini, R., Taneja, A., Singh, P., 2017. Surface ozone scenario and air quality in the north-central part of India. J. Environ. Sci. 59, 72–79.

Shen, G.F., 2015. Quantification of emission reduction potentials of primary air pollutants from residential solid fuel combustion by adopting cleaner fuels in China. J. Environ. Sci. 37, 1–7.

Wu, J.P., Brackstone, M., McDonald, M., 2003. The validation of a microscopic simulation model: a methodological case study. Transp. Res. Part C: Emerg. Technol. 11 (6), 463–479.

Yang, S.Y., Wu, J.P., Du, Y.M., He, Y.Q., Chen, X., 2017. Ensemble learning for short-term traffic prediction based on gradient boosting machine. J. Sensors 2017. http://dx.doi.org/10.1155/2017/7074143.