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Some resilient aspects of urban areas to air pollution and climate change, case study: Tehran, Iran

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Abstract. The effects of climate and meteorological factors on urban problems such as air pollution, heat island, and urban hydrology have increasingly become important in terms of mitigation and adaptation issues during the recent years. In the present paper, we discuss some of the climate or meteorological factors affecting air pollution in Tehran. Tehran is a unique megacity in terms of geographic setting, being mountainous and an ever-expanding urban area that suffers from acute air pollution and heat waves episodes. Recent records of air pollutants also show increased trends with some low-frequency variability caused by chaotic atmospheric motions. Moreover, the wind speed has also decreased as a result of the aerodynamic surface roughness increase and probably the decrease in the passage of cyclones over the mid-latitudes according to the recent findings. Mixed-layer height over the city, due to higher-surface heat fluxes (mainly due to the reduction in surface albedo, anthropogenic heat, and lower green spaces), is expected to increase; although it is favorable for reduction in some air pollutants such as CO, it is not eligible for ozone. Finally, an integrated framework for actions regarding impacts, emissions, urban climate change, and monitoring including adaptation and mitigation towards a climate-change resilient city is proposed.

1. Introduction

Chemical imbalance of the atmosphere, produced by anthropogenic activities, has a wide range of effects on climate and air quality at small to large scales [1]. Urban environments as evermore expanding areas with many economic and industrial activities nowadays are suffering from air pollution problems; on the other hand, they are large emitters of greenhouse gases, especially CO_2 [2]. Hence, Sustainability and resiliency to weather and climate changes of urban areas leading to poor air quality, urban heat island, and hydrological problems are becoming governance challenges for cities [3]. In order for cities to develop effective and resource-efficient integrated strategies for climate change adaptation and disaster risk reduction, the two efforts need to be connected wherever possible with ongoing policies and actions that link the two from both directions. Disaster risk reduction strategies and/or adaptation strategies can contribute to reduction of poverty levels and vulnerability, and promote economic development and resilience in an era of increasing climate change [4].

Increasing built-up areas, anthropogenic heat,

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and air pollutant emissions and change of surface albedo in urban environments alter the weather and climate over these regions [5-7]. Emerging climate change risks identified globally create new vulnerabilities for cities [3]. Global climate change has altered the wind and temperature fields of the atmosphere, especially in the mid-latitudes, shifting the storm tracks further northwards and leading to decreasing frequency of mid-latitude cyclones and, hence, less ventilation of the cities in these latitudes. For example, for North America, Leibensperger et al. [8] have shown that the effect of such climate change can partially cancel the benefit of emission reduction of air pollutants such as ozone. Christensen et al. [9], by an ensemble of about 20 GCM (general circulation model) predictions for the 21st century of world climate, have shown a temperature rise and reduction in precipitation for most of the mid-latitudes as well as Middle East. Jacob and Winner [10] have reviewed some recent works on the effect of climate change on air quality using GCM results. They show that as a result of weakening global circulations and decreasing number of cyclones in mid-latitudes due to climate warm-up, ozone and, to some extent, PM10 will increase, especially in more polluted urban areas in mid-latitude regions. Spatial data that link greenhouse gas emissions to urban form and city growth would be useful for efficient planning. This information will strengthen locally relevant policy decisions and build support by the public [11]. Crosbie et al. (2014) [12] have used a multi-year (2000-2009) aerosol dataset for Tehran and surrounding areas, showing that in the late spring and summer months, dust strongly affects the area as the precipitation is minimum. While in winter as the atmospheric mixed layer has its minimum height, the trapping of aerosols near ground reduces visibility drastically.

Tehran, a fast-growing city (grown since 1950, especially with a faster rate since 1970s), has a unique setting, being a non-coastal capital city of about 570 km^2 in the shadow of the Alborz Mountains range in the north and east and adjacent to the arid region known as Kavir. These two features create local winds known as mountain and country breezes, which only circulate the urban air within this rather poor ventilated city. Hence, more acute air pollution episodes and hot summers are serious problems to the habitants. Tehran possesses many orbital towns and some of them have also grown since 1980s. In a short period, the economic base of the city has changed from agricultural to an industrial-commercial one. The population of the city is more than 10 million; total number of vehicles was about one and a half million [13] that has increased two times since the year 2000. Direction of the streets in the city is mainly west-east, parallel to the Alborz range, while some of them are in the north to south direction along the slope of the mountains. Central and southern parts of the city have shorter buildings with older structure than buildings in the northern part. Built-up areas are not uniform, especially the northern area, being covered by more recent and taller buildings. The average height of the buildings is usually less than that of other large cities in the world (often 4-5 story buildings). The sky view factor [14] for the built-up areas of the city on average is about 0.5 corresponding to height/width ratio of about one.

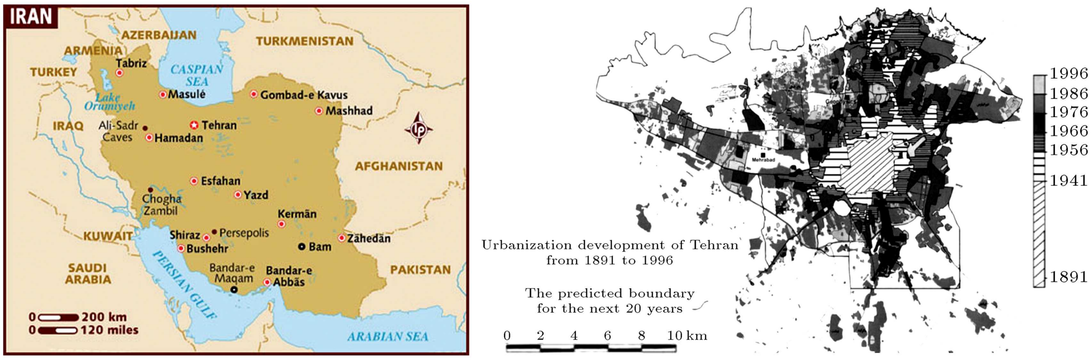
During the year, for about 300 days, the city is under dominant ridge condition, known as a calm synoptical condition. In wintertime, often, an extension of Siberian cold high (and to some extent middle-latitude westerlies) dominates, while in summertime, south easterlies related to Asian monsoon affect the weather [15]. Saadatabadi and Bidokhti [16] have shown that the temperature of the city (Mehrabad) with respect to that of Varamin, a small city southeast of Tehran, has increased dramatically as a result of urban warming.

Such setting, climate condition, and growth rate make the city prone to climate adverse effect regarding air pollution and heat waves. In this paper, we present some long-term records of climate and meteorological parameters and some recent records of air pollutant trends. We speculate on the causes of the observed trends and try to indicate the way we can encounter the adverse effects in terms of sustainability and resiliency in such environments.

2. Area and data

A map of Tehran is shown in Figure 1 in which Mehrabad (in the west) and Geophysics (in the center-north) synoptic stations, where most of the climate (since 1950) and air pollution (since 2000) data were acquired, are identified. In this figure, the built-up areas of the city at different times are also shown. It indicates that the build-up rate in Tehran has increased substantially since 1960s. For comparison of temperatures, the data for Varamin, which is a small town 50 km southeast of Tehran (shown in Figure 1), have also been used. Mehrabad (a synoptic station) is near the main airport of Tehran in the west of the city with no tall buildings (less than three stories) or tall trees, up to 1-2 km around it. The area around it is mainly dry land with short installations, such as radar antennas, that are more than 50 m away from the station. The main airport runway is about 100 m south of the station.

Various factors affect the climate of Tehran. These include northern Alborz mountain chain, Kavir (a dry arid area) in the southeast, and south to west humid winds in the colder seasons that are the most important ones. The last two factors affect the climate



(a) (b)

Figure 1. Map of Iran and surrounding areas, including (a) Iran and (b) Tehran with the built-up areas from 1891 to 1996.

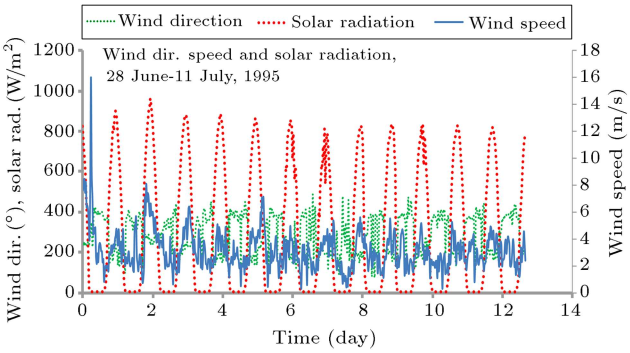


Figure 2. Typical wind direction, solar radiation, and wind speed in the Geophysics Station for calm condition at 2 m above the ground. Notice the regular flipping of wind direction from north (katabatic, nighttime) to south (anabatic, daytime). Daytime wind speed is also higher than that in nights.

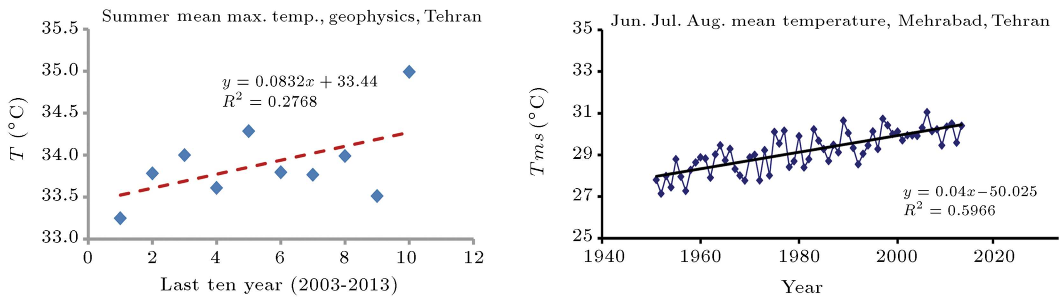
of the region and the former one modifies climate of the mountainous region and nearby valleys. Mountain forcing at synoptic level increases precipitation; but under calm conditions, it produces thermally induced winds known as katabatic and anabatic winds, namely northerly and southerly at nights and days, respectively (Figure 2), with the day-time winds being much higher than night-time winds due to stability effect of atmospheric surface layer at nights. Kavir affects Tehran climate as a source of heat and dust haze. More details of these effects can be found in [16].

3. Results and discussion

3.1. Some long-term climate trends

Initially, some long-term trends of temperature and wind of Tehran are presented for almost the last 50 years to show signs of climate change. Figure 3 shows trends of annual mean summer temperature for the period of 1950-2013 for Mehrabad and mean maximum summer temperature of the last ten years (2003-2013) for the Geophysics Station. The mean summer temperature has increased at a rate of 0.04°C/year, while the summer mean maximum temperature has had a steeper rise of 0.0832°C/year during the recent years, although the annual mean temperature has a typical rate of about 0.0654 ± 0.018°C/year (graph not shown). The approximate 0.01°C/year can be due to regional warming in this area [17]. Hence, urban warming in Tehran appears to be imminent that should be of concern and appropriate steps should be taken to curb such trends. These records are from two off-center stations in the city; thus, the central parts are bound to have steeper warming.

As the city build-up areas are rather patchy, especially in the northern areas, there might be a few



(a) (b)

Figure 3. (a) Mean summer maximum temperature for the geophysics station. (b) Annual mean summer temperature for Mehrabad station, Tehran, Iran.

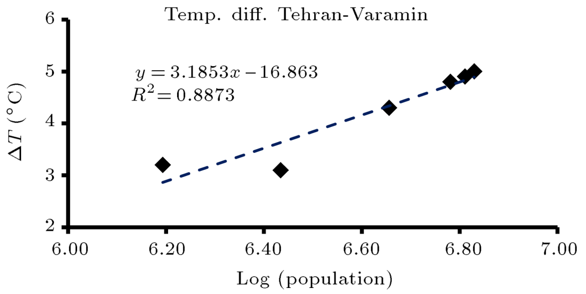


Figure 4. The annual mean temperature difference of Tehran (Mehrabad) and Veramin against the population of Tehran for 1950-2000; for the years, data are available in [16].

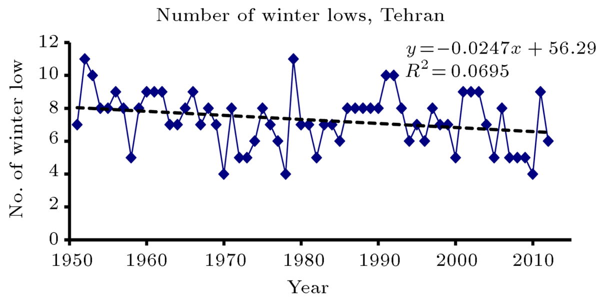


Figure 6. Number of winter lows passing over Tehran.

heat island centers that require to be explored. More details of variations as seasonal and daily ones have been reported by Saadatabadi and Bidokhti (2011) [16] that also show the correlation of such temperature (the annual minima) increase with that of Varamin (as a rather non-urban site) as a function of population of Tehran, shown in Figure 4. They fitted a relation as follows:

$$\Delta T = 3.185\log(pop) - 16.86, \tag{1}$$

where ΔT is the temperature difference between Tehran and Varamin. They called this a climatic kind of heat island intensity (although different from actual recorded relation for Urban Heat Island (UHI)); however, it is rather similar to North American cities UHI-population relationship [18].

The wind records also show changes, implying slowdown in the wind over the city, especially its northerly component (katabatic wind) as shown in Figure 5(a). The mean annual winter wind speed has not only been reduced, but also decreased to smaller than the annual mean, as the springtime wind speed is usually higher. Such slow winds in this populated area cannot ventilate it efficiently, leading to strong adverse effect on air pollution. This factor can lead to strong episodic air pollution periods, especially when the mid-latitude jet stream (which often has a barotropic nature) is far from this area [19] in cold seasons. It should be mentioned that the upper air (above atmospheric boundary layer) winds, known as synoptic winds, are still the main driving force of the near-surface air, responsible for sweeping polluted air from this urban areas.

Figure 6 shows the long trend of the number of winter low-pressure centers, usually associated with frontal systems that can sweep the near-surface air, passing over Tehran, indicating a slight reduction in these systems over the area during the last sixty years. Hence, part of the near-surface wind reduction can be due to the factor that [8] atmospheric global circulation has shown to be weakened, leading to a decreasing frequency of mid-latitude cyclones. [20] have also shown by numerical study that urban heat island can induce circulation over the cities such as Tehran that can interact with mountain led circulation, enhancing the daytime anabatic wind and weakening nighttime katabatic winds as shown in Figure 5.

Surface roughness length (z_0) increases as a result of building taller structures that has also occurred in this period. This can be partially responsible for the observed slowdown in wind trends. The surface wind stress, τ_0, is given by:

$$\tau_0 = \rho C_d U_{10}^2, \tag{2}$$

in which ρ is the air density, U_{10} is the wind speed at 10 m above ground, and C_d is the drag coefficient and is given by (using logarithmic law for surface layer

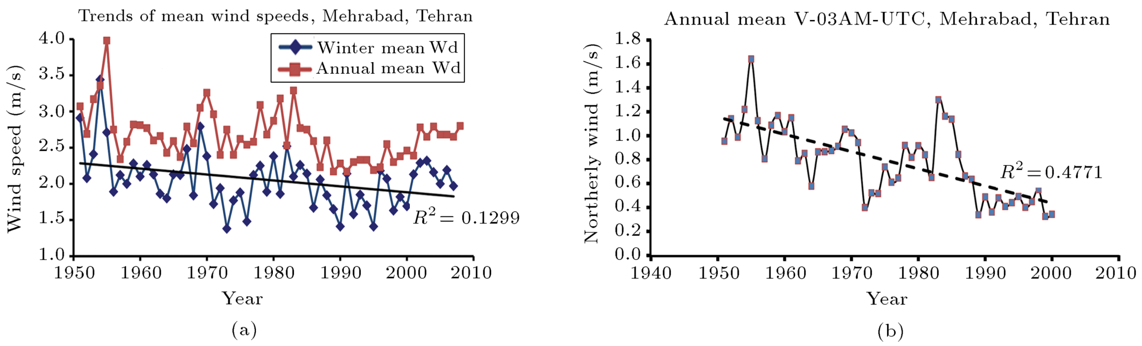


Figure 5. (a) Long-term records of annual mean values of total wind. (b) Its early morning northerly annual mean component.

wind profile near ground, $U(z)/u_* = (1/k)\ln(z/z_0)$ for nearly neutral condition):

$$C_d = k/\ln(z_r/z_0), \tag{3}$$

in which k is the von Karman constant (about 0.4), $z_r = 10$ m, and z_0 is surface roughness that is about 0.1 h, where h is about the mean height of the buildings in this area. Hence, as h increases, C_d is expected to increase and moving air over this area would lose more momentum, leading to further near-surface stagnations.

Hence, the city planners of Tehran should consider arranging build-up areas so that the newly built structures have appropriate spacing and orientations for dominant winds (often westerly) to ventilate the area more efficiently.

3.2. Some air pollution trends

The available Tehran air pollution data are of the last 15 years. Before presenting such records, some long records of visibility, which are usually measured at synoptic station as other meteorological parameters, are shown. Figure 7(a) reveals annual mean daytime visibility trends for Mehrabad. Deterioration of visibility is an unfavorable consequence of urbanization in this area, which is related to particle matters in the atmosphere. In fact, urban (and occasional dust) aerosols as haze in Tehran area are related to visibility (Figure 7(b)) and such aerosol loading is responsible for the poor visibility. The variations of visibility in Tehran are related to the meteorological parameters that have been studied by [21]. They showed that winter visibility has been deteriorated worst and relative humidity can worsen visibility as expected due to fine urban aerosols growth, known as swelling, by water vapor absorption.

It is clear that the atmospheric aerosols concentration in Tehran has increased, leading to poor visibility. The origin of the urban aerosols is often traffic emission, which enhances the nitrate and sulfate gases that can form fine secondary urban aerosols. Also, occasional fugitive dust from the Middle Eastern dry areas, especially Iraq and Saudi Arabia, in recent years has led to occasional dust events over the western parts of Iran, even affecting Tehran. One of the severe dust events that reached Tehran created very poor visibility and its PM10 increased to as large as about 700 microg/m^3, shown in Figure 7 (right, the last point on the left of the figure). Such events have led to the closure of the main institutions and organizations in recent years.

In the study done by [12], it has been shown that dust strongly affects the region during the late spring and summer months (May-August) when Aerosol Optical Depth (AOD) is at its peak and precipitation accumulation is at minimum. In addition, the peak AOD that occurs in July is further enhanced by a substantial number of seasonal wildfires in upwind regions. Conversely, AOD is at minimum during winter; however, reduced mixing heights and a stagnant lower atmosphere trap local aerosol emissions near the surface and lead to significant reductions in visibility within Tehran.

Typical records of air pollutants in Tehran using some of the existing data are presented. Figure 8 shows the trend of mean November CO concentration for a station north-east of Tehran, showing a decreasing trend and improvement in its emission in recent years as the quality of cars have improved and also the highway networks over the city have expanded. It may also be partly due to the more use of LNG as fuel for vehicles and domestic uses. Similar trends for other air monitoring stations of gaseous primary pollutants are also observed. However, the trends for PM10 and ozone (O_3), as secondary pollutants, are rising (see below). Similar trends have been reported by [10] for some of the cities in US. Tropospheric ozone is also rising in the Iran area [22] as also seen in Figure 8(a). It appears to be mainly due to industrial activities as well as urbanization. However, part of it is transported from upwind sources as well as from the stratosphere.

Figure 9(a) and (b) show the daily variations of CO and O3, respectively, for 2001 and 2011, indicating reduction in CO as a primary pollutant; but, increase

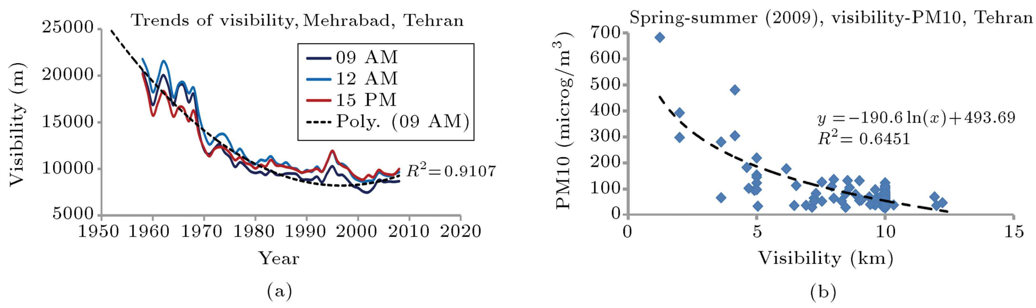


Figure 7. (a)Visibility trends for three daytime hours (local time) at Mehrabad in the last 50 years. (b) Spring-summer time visibility versus PM10 in Tehran in 2009. Note that the large PM10 concentrations are associated with dust events, being more frequent in recent years.

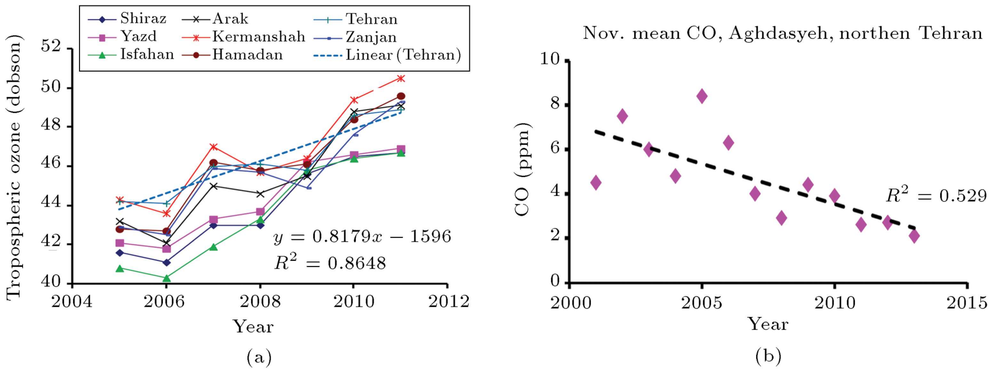


Figure 8. (a) Records of tropospheric ozone in some cities of Iran, including Tehran. (b) A record of mean November CO concentration for a station in the north of Tehran.

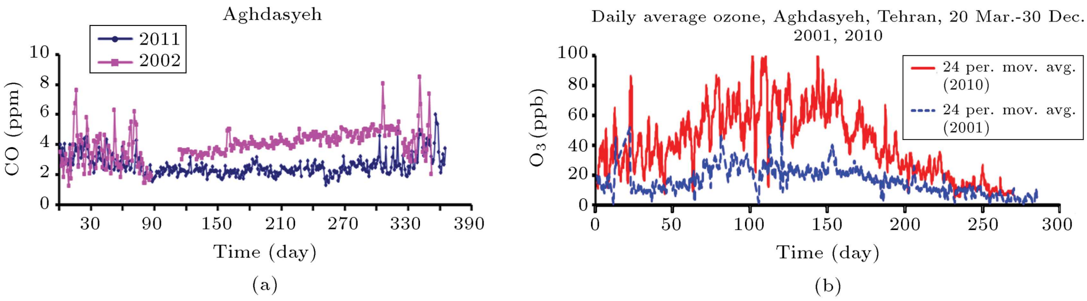


Figure 9. (a) Variations of CO, and (b) O_3 for about 2001 and 2011.

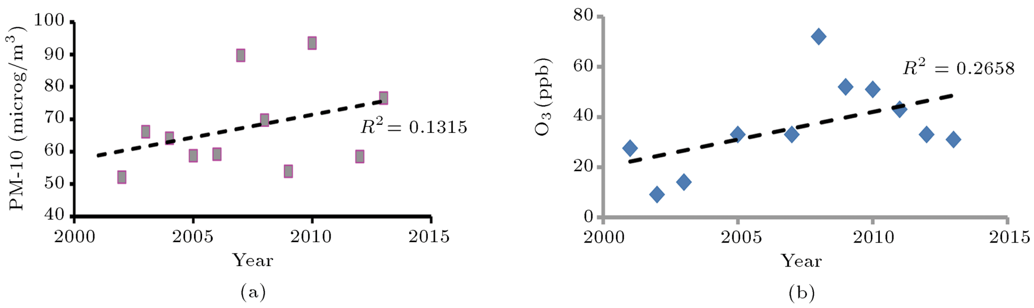


Figure 10. Trends of (a) November means of PM10, and (b) ozone summer means for Aghdasyeh, north of Tehran, Iran.

in O_3 has occurred during this decade in rather warm periods of the year. Larger day to day variation of CO has also occurred in cold months, indicating the role of cold front passage and residence of subsequent high-pressure weather systems, while variation of ozone is more pronounced in spring and summer as its concentration is also much higher.

Figure 10 shows typical trends for PM10 (November average) and O_3 (summer average) in the Aghdasieh Station, north-east of Tehran, respectively. Annual variability is rather large, but the trends are on the rise. November mean values of PM10 have also strong annual variability due to the more frequent dust events in the area in recent years. November data were chosen, because due to more predominant stagnant weather conditions and stronger near-surface inversions (Figure 11), higher air pollution episodes exist.

Ozone is also on the rise that can be due to more emission of precursor gases as VOCs (Volatile Organic Compounds), particularly in warmer urban areas [10]. Water vapor can destroy ozone; hence, lower humidity may also contribute to this increase.

Stronger urban heat island effect, as shown in Figure 3(a), may be responsible for ozone increase in summer. Warming up of the area can enhance the growth of atmospheric mixed layer, which could reduce the concentration of primary pollutants like CO (Figure 8) as they disperse in larger volumes of air over the city, especially in summer.

As the sources of air pollutants are near the surface, near-surface stability (here, temperature inversion or temperature difference between 20 m and 10 m or 2 m above the ground) and, hence, wind can be important for air pollution concentrations. Figure 11,

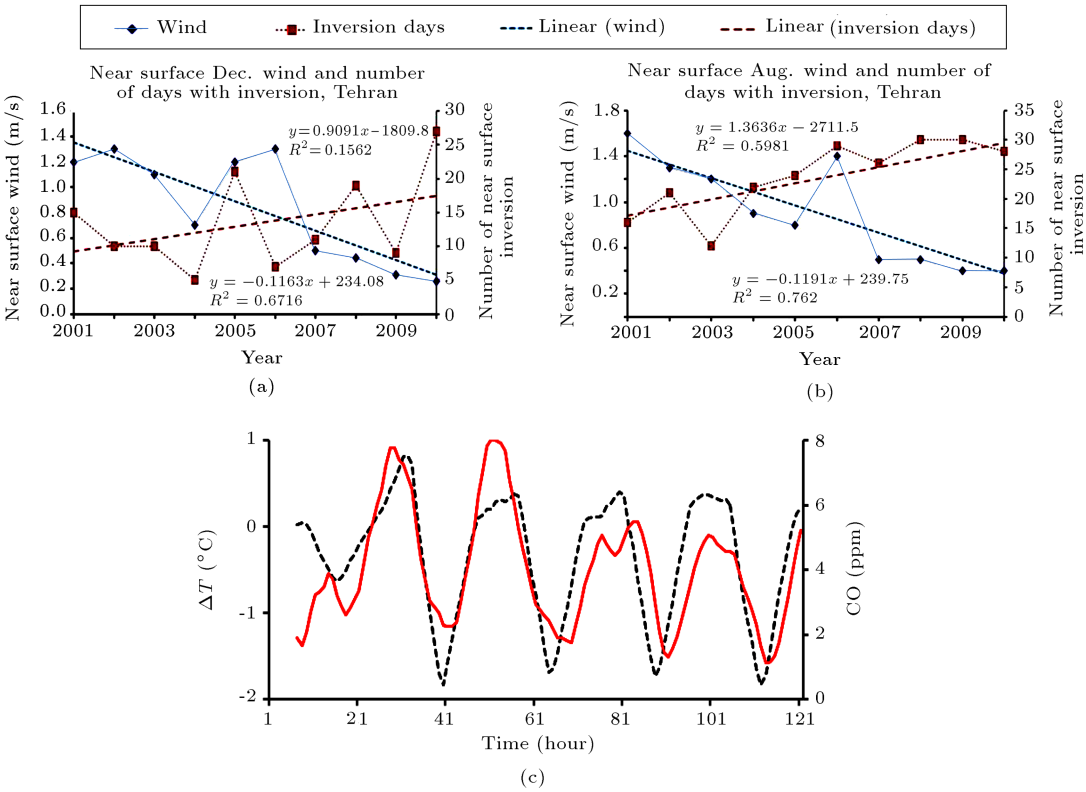


Figure 11. (a) Near-surface average winds and number of days with inversion for December and August; (b) in 2001-2010 for a station east of Tehran (Resalat Tower); (c) typical variations of near-surface temperature differences between 20 m and 10 m and CO; positive ΔT corresponds to stability and vice versa.

for example, shows near-surface wind at 10 m and number of days with inversion for 2001-2010, indicating more days with inversion and lower winds. Daily variations of air pollutants for the Aghdasyeh Station (north-eastern part of Tehran, not shown) indicate that the overall average of CO is higher in December than in July, while NO_2 and SO_2 are larger in July and ozone, a secondary pollutant, is much higher in summer as expected, since the temperature is much higher. For the primary pollutant of CO, the increase in early day and later in the afternoon is due to traffic peak hours, while the mid-day reduction is mainly due to the increase in mixed layer height because of thermal convective processes over the city, especially in summer months. This has also been shown by [23] using a model based on turbulence kinetic energy for variations of the urban mixed layer growth. NO_2 and SO_2 have more complicated behaviors as their sources are tied up to the formation of ozone and local circulation over the city, respectively. $PM_{2.5}$, which has been measured in recent years, has a behavior like CO daily variation.

Occasional periods of high air pollution have occurred particularly in recent years. Such episodes have led to disruption to major activities in the city and public health problems. Figure 12 shows a typical record of P index (the ratio of number of observations

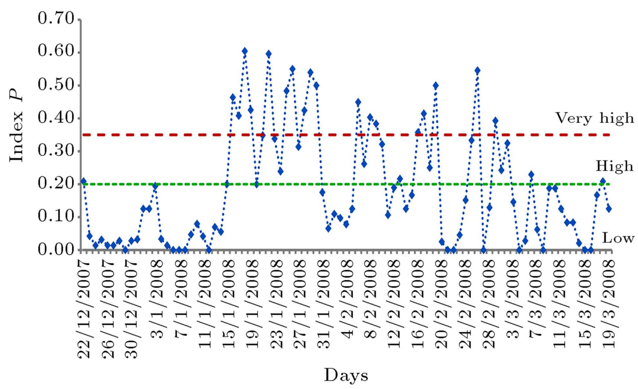


Figure 12. An example of air pollution record in winter 2007-2008 for Tehran. Broken lines show low, high, and very high levels of air pollution. (This is based on CO; other gaseous primary pollutants as NO_x also show the same behavior.)

with concentrations 1.5 times the mean seasonal concentration value for at least three monitoring stations, to the total number of observations used) for a period in which, in January 2008, we had such a disruption to city activities. This type of events can be regarded as extreme events of air pollution that require evaluation of their risk and harmfulness. Action planning (at the local scale over a short time period) of coordinated intensive actions for a limited area over a short period should be performed in such an acute air pollution episode.

Unfortunately, such conditions have increased in recent years, making the city more vulnerable to air pollution episodes. The behaviors of long-term climate trends, shown in Figure 11, are likely to be the cause for these conditions. We are trying to find weather indices that could be used in prediction of onset of such periods. These can include characteristics of large-scale atmospheric circulation over this region, e.g. geopotential height anomalies related to large-scale atmospheric flows and pressure patterns that determine vertical motions (high pressures are related to providing calm conditions with more frequent inversions). We have found that there can be some relations between such large-scale indices and air pollution in Tehran, especially for the stations further away from mountains in the north. The near-mountain air pollution station data show that the northern parts of Tehran are much more affected by the local circulations, due to the presence of mountain, rather than upper air weather conditions. The correlations between air pollutant concentrations for the stations near mountain (like Aghdasyeh and Ponak in the north of Tehran) and those further away from mountain (like Ray and Bazar in the south) are good, but those between southern stations and northern stations are poor as shown in Figure 13.

It is clear that the processes (emission sources, local circulations, large-scale circulations, chemical changes) affecting the northern or southern stations may act similarly in air pollution variations, but differently for those locations near the mountain and those away from it, requiring more investigation.

4. Discussion

Based on this and other studies, temperature rise by climate change in urban areas is particularly marked, especially for higher latitudes and altitudes that would lead to stronger heating, hence enhancing the heat island effect for cities like Tehran, and also less snow (more related to global climate) that is a major source of water over this mountainous area, leading to water supply problem. In order to combat such thermal effects in this city, the building materials used should have greater albedo (whiter) and less heat storage capacity and the buildings should have more green areas in between to reduce the emission of greenhouse gases, especially CO_2, due to fossil fuel burning to combat more warming.

Regarding pollutants, especially ozone and aerosols, more trees and green spaces are required, which in turn can also be effective in reducing heat. In order to better reduce emissions, non-polluting transport, creation of more walk-able areas in order to encourage less use of cars and taxing for car users (polluters pay more), more efficient use of energy for systems that use fossil fuels, or even use of renewables, especially solar energy, should be considered. Reduction in emission of pollutants, especially VOCs that lead to production of ozone in warm seasons (in summer smog), from cars also depends on quality of cars that should all be equipped with catalytic converters (used for CO and VOC filtering of car emissions). Such devices are not often used in cars in Tehran and the use of them should be mandatory. Hotter temperature could cause more emission of VOCs from asphalt surfaces as well as even parked cars. It should be mentioned that ceiled car parks in the city are rather scarce and should be expanded in order to reduce such emissions. Use of higher quality brake pads in cars is also important in reductions of PM10 emission, especially more harmful ones.

Knowledge facts of climate change impacts should be transferred to dwellers as well as decision makers to create stronger infrastructures, policies, and human resources response capabilities in order to have a climate-resilient city. The less resilient cities (called hot cities) on the other hand would be less flexible; having deteriorating air, water, and soil pollutions problems;

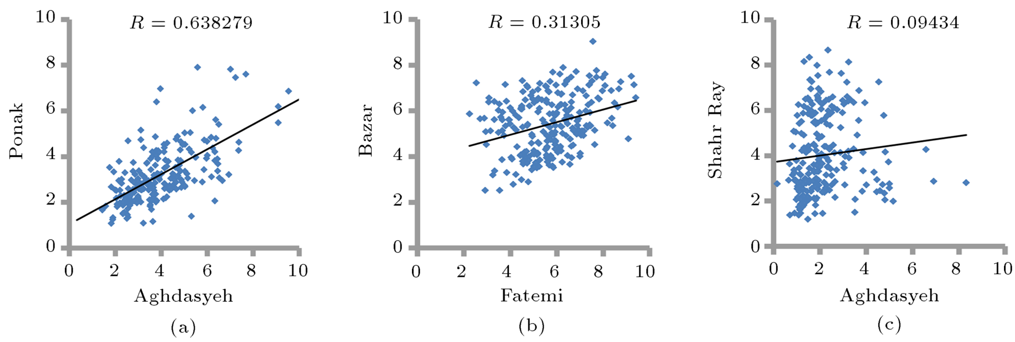


Figure 13. The correlations between CO concentrations: (a) Ponak and Aghdasyeh (north, near mountain); (b) Bazar and Fatemi (further south, away from mountain); and (c) Aghdasyeh (north) and Shar Ray (south). Available data are for daily winter values of CO for years 2002-2007.

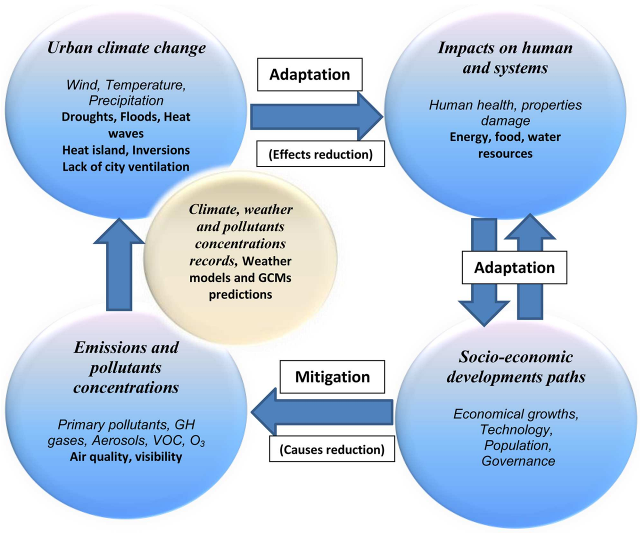


Figure 14. An integrated framework for urban climate change, impacts, and developments through adaptation and mitigation that can lead to steady-state conditions or resiliency of urban environments. Monitoring of climate and pollutants changes is done through data records and predictions of numerical models (shown in khaki circle) for various scenarios (partly adapted form [24]).

as well as less prepared to combat climate change causes (mitigation) and effects (adaptation). As time scale of climate change is long, no policy of "wait and see" should be considered and actions should be taken now. All such actions (strategic planning at the city-wide scale over a long time period with multispectral coordination of sectorial planning, sectorial investment plan, financial resources, and institutional frameworks) can be integrated into a comprehensive plan to work for a resilient city, as an example shown in Figure 14.

Figure 14 shows some of the components for an integrated framework leading to city resiliency (a quasi-steady state condition) in terms of urban climate and air quality factors that have been followed in this paper. In a clockwise direction in this diagram, emissions lead to changes in the atmospheric pollutants concentrations as well as greenhouse (GH) gases that change the energy balance of urban climate and increase certain pollutants that impact both human being and natural and anthropogenic systems. These affect natural resources and human health and life that in turn affect all aspects of human developments.

Adaptation (effects reduction as opposed to cause reduction by mitigation) of developments to the impacts can go in both ways; for example, urbanization can lead to deforestation and loss of recourses. Urban climates and pollutants concentrations are monitored by atmospheric data records, as in this study some are presented. The behaviors of systems like cities towards forcing such as climate change can be qualitatively represented in Figure 15, as an instance, in which the resilient case and non-resilient case are separated

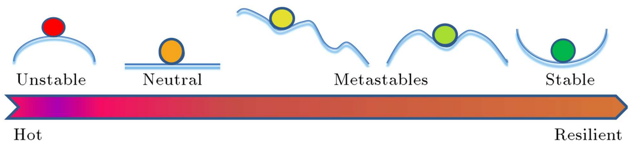


Figure 15. Systems (city) stability spectrum. Stable progress: resilient state; unstable: non-resilient or hot.

by meta-stable or neutral cases, although quantities should be assigned to the cases that could include all possible impacts.

5. Conclusion

Here we have presented some climate and weather records for Tehran along with some air quality ones. Clearly, the records show that temperature related to urban heat island in such a growing city is on the rise. Climate change, as greenhouse warming, could have aggravated the warming condition for Tehran. The warming trends have led to the increase in near-surface ozone concentration, a potential hazard to public health and properties. Winds have also been slowing down due to weakening large-scale atmospheric circulation as well as increase in surface roughness over this urban area. Built-up areas as well as the locations of some industrial sites (often upstream of the prevailing winds) appear to have been often expanded irrespective of weather and climate conditions; hence, ventilation of the city is becoming an ever-deteriorating problem. Emission of polluted gases as well as particle matters seem to have increased PM10 concentrations and resulted in poorer visibility over the city. Fugitive dust has also become frequent due to the transport of dust from long-distance sources. Such events could increase particle matters in the atmosphere by substantial amounts and have led to disruption of city activities at an increasing rate that could be due to long-term trend of climate change and emission, affecting air quality conditions. Episodes of acute air pollution periods have also increased, leading to the more frequent hampering of the city activities.

It is also shown that occasional stagnation periods have led to increase in air pollutants to alarming levels, leading to closure of major institutions that has become more frequent in recent years. It is also interesting that the air pollution concentrations appear to be more correlated between either the northern (near mountain) or southern (further away from mountain) stations of the city and not between those of the north and those of the south, indicating that the northern mountain has a strong influence on the air pollution distributions over the city. As the city is not in a horizontally homogenous terrain, spatial variations in distributions of pollutant concentrations are also marked (recent still unpublished results), indicating that mitigation concerning control of emissions should not be holistic.

The climate, meteorological, and air pollution records demonstrate the challenges this city could face. Part of air pollution regulation is by emission control; however, such control can be modulated by weather and climate factors as shown in this paper. Tehran is the commercial and industrial hub of Iran, requiring more effective coordination among different departments and governmental levels to become adaptive as well as have resiliency in the face of natural hazards such as those associated with climate change with adverse effects on air quality, heat waves, and drought. Although it is a non-coastal city, other natural hazards as earthquake in this area are also a major threat; thus, a disaster risk reduction management has been set up in recent years for such hazards. Although Tehran is unstable against natural hazards such as earthquake, it has the potential to be considered as a stable system which has the resiliency to air pollution by observing some mitigation and adaptation methods that pave the way for reaching this goal as follow:

- Control of emissions (presently done by traffic restrictions and prevention of activities under the supervisions of Department Of Environment (DOE) and Air Quality Control Company (AQCC));
- Using less-emitting cars (presently done by car emission checks: part of Japan International Cooperation Agency (JICA) project instructions (2004) and AQCC), using cleaner fuels, possibly using hybrid cars;
- Faster expansion of metro subway;
- Creation of greener areas ("green fingers") and water bodies (as in District 22 of Tehran);
- Using brighter construction materials to more reflect daytime heating;
- Use of more ceiled car parks as well as better quality asphalts for surfaces to reduce volatile organic compounds (VOCs) emission;
- More nocturnal cooling by less emission of greenhouse gases like CO_2;
- Planning according to dominant winds;
- Promoting more public awareness of air pollution and urban heat as land hazard.

At the moment, we are planning to do some numerical simulations regarding various scenarios of urban modifications in wind and temperature fields over this expanding urban area.

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