3.14 Urban microclimates

In this section you will learn about:
- the impact of urban forms and processes on local climate and weather
- urban temperatures and the heat island effect

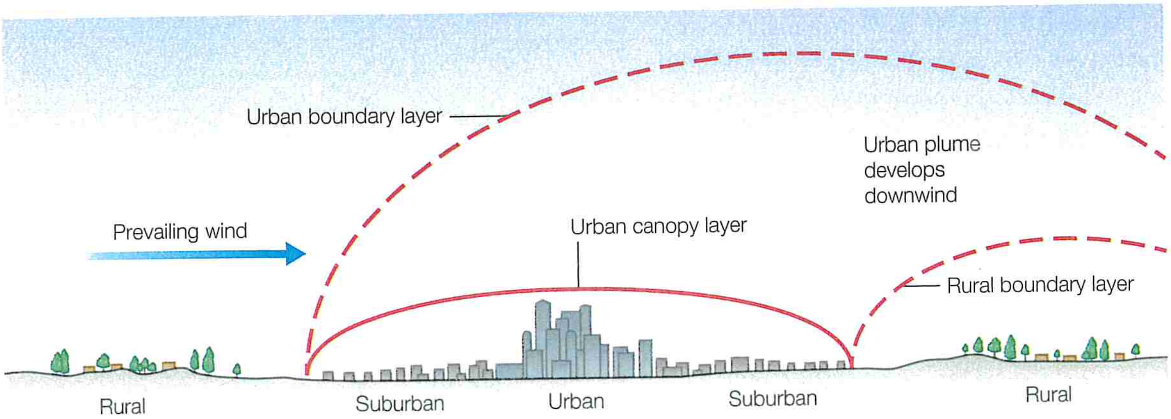
Urban microclimates

Have you ever visited a central city park early in March and wondered why the blossom was so full and the daffodils so bright – yet your garden still dull from winter? Or turned a city corner and been rocked by an unexpected wind? These examples illustrate how urban areas create their own climate and weather – their own **microclimates**.

Some geographers talk of cities creating their own *climatic dome* with distinctive:

- temperature ranges
- precipitation generation and patterns
- (relative) humidity
- wind speeds, turbulence and eddies
- (reduced) visibility.

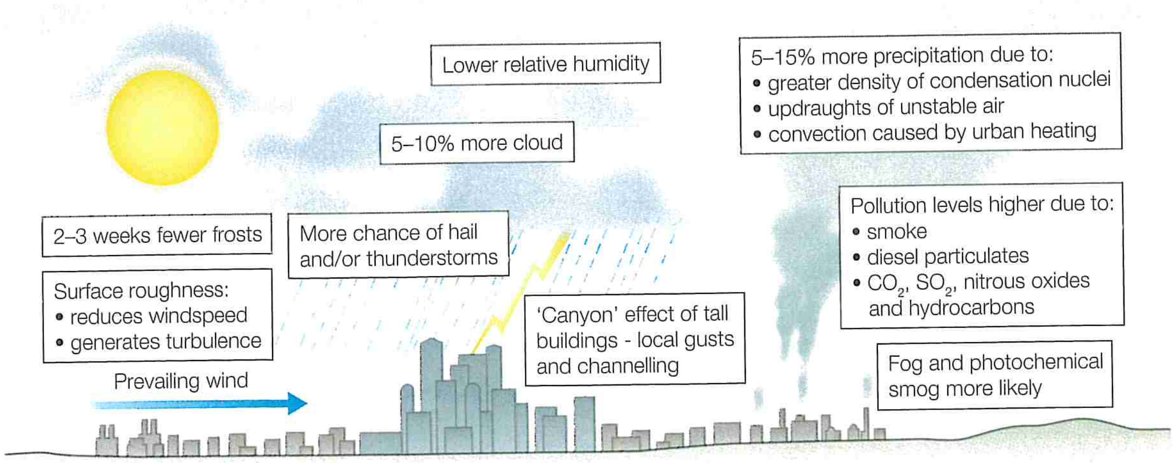
Within this dome, there are two levels – an urban canopy below roof level, where processes act in the spaces between buildings, and the urban boundary layer above. Prevailing winds extend the climate dome downwind as a *plume* into the surrounding countryside for tens of kilometres (Figure **1**). Consequently, urban patterns of precipitation and air quality, for example, can be spread to the immediate rural area downwind.



Look at Figure **2**. It is the structure of the built-up area and the activities within it that cause these changes to climate and weather. For example, buildings and streets interfere with airflow, and high levels of pollution play a part too. However, the best known microclimatic impact of built-up areas is the *urban heat island* effect.

Figure 1 *The urban climate dome*

Figure 2 *Characteristics of urban microclimates. Note that relative humidity is the amount of water vapour that is in the air as a percentage of the total amount that the air can hold at that temperature.*



The urban heat island

The urban heat island defines the urban area as a significantly warmer 'island' surrounded by a rural 'sea' of cooler temperatures. There are several reasons for this:

- Urban areas have lower **albedo**. Extensive dark surfaces such as tarmac and roofs absorb heat during the day and release it slowly at night.
- Large expanses of glass and steel reflect heat into surrounding streets.
- Although the vegetation in urban parks and gardens provides moisture through evapotranspiration, and urban lakes and ponds evaporate, there is far less vegetation, so less evapotranspiration. Furthermore, drains and sewers remove surface water quickly so the amount of moisture in the air (humidity) is reduced. Consequently less heat energy is lost in evaporating it.
- Buildings 'leak' heat through poor insulation in winter and air conditioners pump hot air into the streets in summer.
- Power stations, industries, vehicles and the inhabitants themselves all generate their own heat.
- Rising heat, water vapour from power stations and industry, and condensation nuclei from air pollution provide the conditions necessary for precipitation. Consequently, heavier and more frequent convectional thunderstorms occur in urban areas.

The temperature decline from urban centre to rural–urban fringe is known as the *thermal gradient*. This difference can be more than 6 °C in late summer and around 2 °C in winter. Furthermore, it is usually strongest at night with additional urban cloud and dust acting as a blanket to reduce long-wave radiation losses – this is effectively a locally-enhanced *greenhouse effect* (see 5.18)

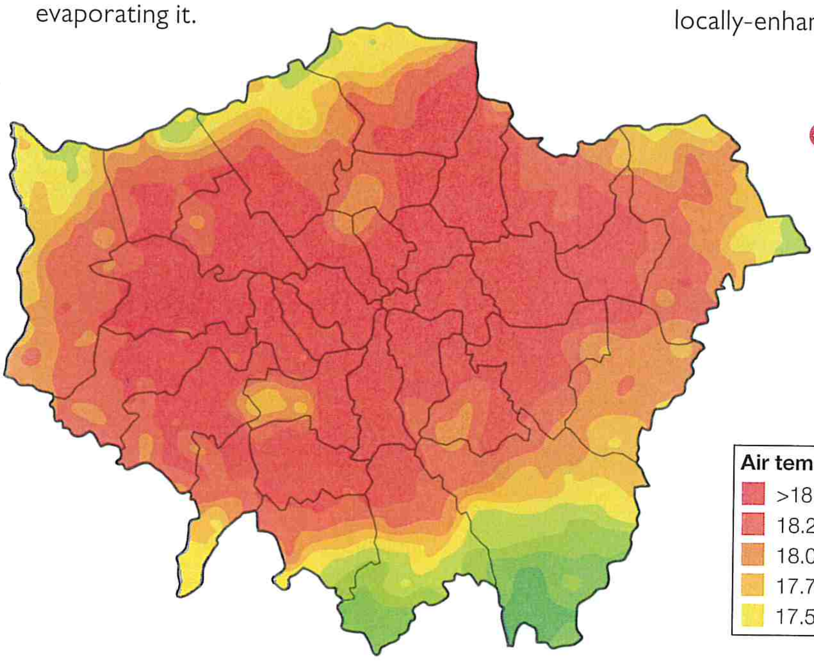


Figure 3 *Temperature distribution across London (August 2013)*

Air temperature (°C)	
>18.5	16.51–16.75
18.26–18.49	16.76–17.00
18.01–18.25	17.01–17.25
17.76–18.00	17.26–17.50
17.51–17.75	<16.50

ACTIVITIES

1 Study Figure **3**.
  a Describe and suggest reasons for the temperature variations across London.
  b What might account for the linear extensions to the north, west and east, and the islands of lower anomalies elsewhere?

2 Describe and explain how microclimate might differ in a city in an LDE compared to a city in a HDE.

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3 Alternative techniques to show these temperature changes include line and bar graphs drawn as transects (cross-sections across the city).
  a Using the figures from the choropleth key, construct a north–south line graph and an east–west bar graph.
  b Comment on the comparative advantages and disadvantages of all three techniques.
  c Suggest an alternative technique to show these temperature changes. Compare the two techniques.

3.15 Urban precipitation and wind

In this section you will learn about precipitation and wind in urban environments

Urban precipitation

Look again at 3.14, Figure **2**. Notice that urban areas have 5–15 per cent more precipitation than rural areas, in both quantity and also in number of days of rainfall. This may seem counterintuitive given that relative humidity levels are up to 6 per cent lower because of less urban vegetation and surface water. However, urban air pollution results in more condensation nuclei – the tiny particles essential for cloud droplets to form – which helps in the formation of clouds. Furthermore, air is warmer in cities, all leading to higher precipitation.

Remember, in order for precipitation to form, air has to rise, cool below the **dew point** and allow water vapour to condense. Both air turbulence amongst buildings of varying heights and also heat island-related convection promote this uplift. Dust and pollution from industry and vehicles increase the density of condensation nuclei and 'seed' the cloud droplets.

Precipitation falling as snow tends to lie on the ground for less time in urban areas. Both the generally higher urban temperatures and heat-retaining darker road and roof surfaces encourage more rapid melting than in the countryside.

Fog

Fog, and mist if less dense, is effectively cloud at ground level. Again, the higher concentration of condensation nuclei over cities encourages their formation, especially during cooler overnight temperatures. Fog and mist tend to be thicker and persist longer in anticyclonic (high-pressure) conditions where winds are too weak to blow them away.

The relationship of fog to condensation nuclei is emphasised further when weather records are compared to industrialisation. During the height of the Industrial Revolution in the nineteenth century, the centres of manufacturing across Britain experienced an increase in the number of days of winter fog – especially associated with the burning of coal. Today, Beijing and New Delhi suffer similarly although vehicle emissions, as well as coal burning, are responsible for the thick fog that can cause chaos (Figure **1**).

Figure 1 *Fog hangs over New Delhi, India; fog is a threat to health, not only by causing breathing difficulties but also by increasing the risk of road accidents*

Figure 2 *Thunderstorm over Beirut, Lebanon*

Thunderstorms

Look at Figure **2**. While fog and mist are most associated with winter, urban convection is especially powerful in summer. The rising heat (including water vapour and condensation nuclei from power stations, industry and, to a lesser extent, vehicles) can trigger heavier and more frequent late afternoon and early evening thunderstorms. The more intense the heating, the more violent the storm. This is because updraughts of hot, humid air can rise higher in the atmosphere – and more quickly. The air cools and condenses rapidly, forming water droplets, hail and ice which charge the thundercloud and discharge as lightning.

Wind

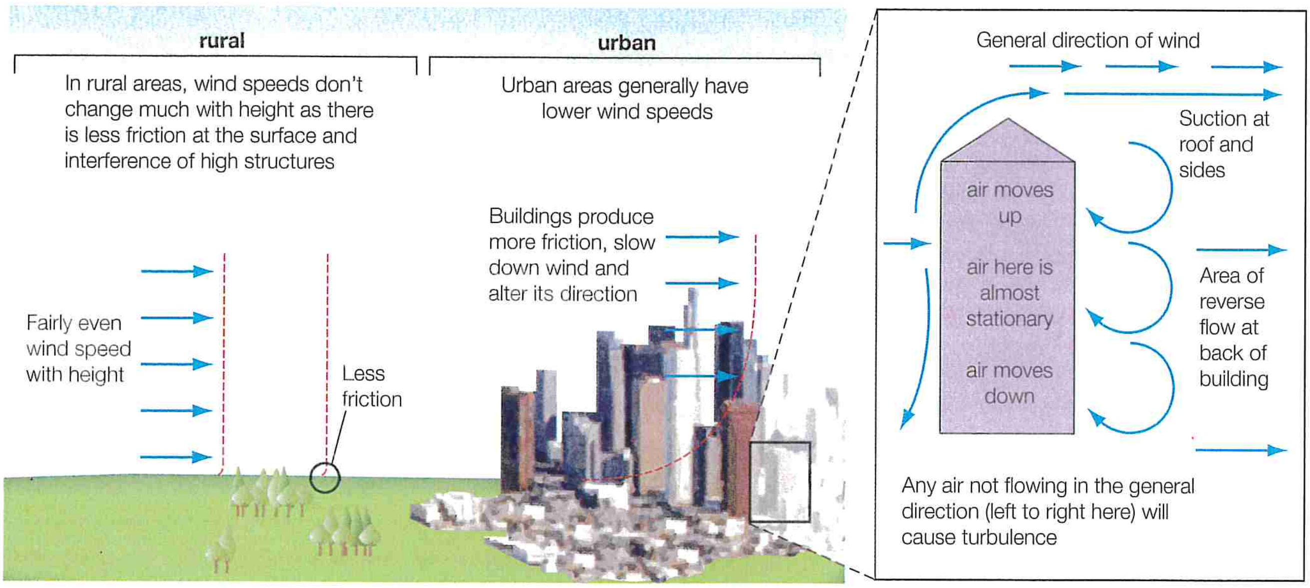
Urban structures greatly interfere with wind by slowing, redirecting and generally disturbing the overall airflow (Figure **3**). For example, buildings create friction and act as windbreaks resulting in urban mean annual velocities up to 30 per cent lower than in rural areas. Indeed, as a general rule, the effects of buildings extend downwind by ten-times the height of the building. In short, the heights, shapes, orientation and layout of buildings, as well as connecting roads and transport infrastructure, all have microclimatic impacts. Indeed, as building designs become ever more dramatic and ambitious, so architects and structural engineers have to consider the potential impacts of airflow, turbulence and emissions (pollution). Two key effects, *urban canyons* and *venturi effect* are of particular significance:

- Urban canyons – relatively narrow streets bordered by high-rise buildings funneling and so concentrating winds
- Venturi effect – a particularly violent form of gusting caused in particularly narrow gaps by air rushing to replace low pressure vortices beyond structures (in the lee of buildings).

Did you know?

Major urban areas experience 25 per cent more thunderstorms than non-urban areas and hailstorms are 400 per cent more likely!

Figure 3 *Tall buildings interfere with airflow in urban areas*



ACTIVITIES S

Any discussion on urban microclimates is likely to involve interpretation of actual/located statistics given. Anticipation and understanding of urban rural contrasts is therefore important.

Referring to all information in sections 3.14 and 3.15 summarise microclimatic contrasts between urban and rural areas. You might want to present these in a table:

Microclimatic contrast	Urban compared to rural areas
Annual mean temperatures	
Occurrence of frosts	
Precipitation amount and frequency	
Occurrence of fog and mist	

STRETCH YOURSELF

'Statement architecture' is an increasingly apparent feature of megacities and world cities in LDEs and EMEs. Research a small selection of recent, ambitious building designs. Locate them and explain what parallels can be drawn between urban microclimates and earthquake-proof design (*AQA Geography A Level & AS Physical Geography, 5.10*).

3.16 Urban air pollution

In this section you will learn about air quality and pollution reduction

'A dense, green-yellow fog choked the streets. Cars edged forwards with passengers sitting on the bonnets shouting instructions. From behind the wheel, drivers could not even see as far as their own headlights.' (*Daily Mail*)

The Great Smog of late November/early December 1952 was the worst of London's infamous winter fogs – 'pea-soupers' (Figure **1**). Such was the death toll (12 000 in just 4 days) due to respiratory problems and, to a lesser extent, traffic accidents that it contributed to the most life-changing legislation ever passed in Britain – the 1956 Clean Air Act.

This Act, and subsequent legislation, consigned such horrors to British history. However, many cities throughout the world still have seriously high and dangerous levels of air pollution. It is one of the great urban issues of our time.

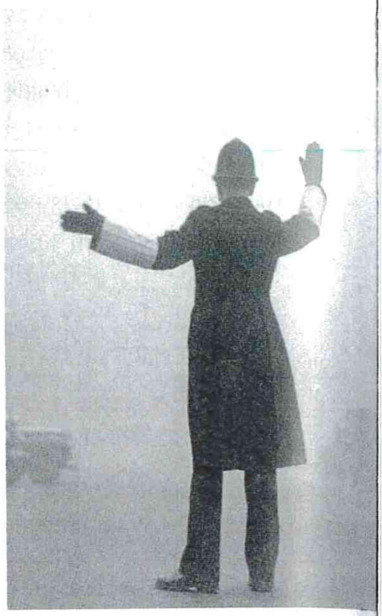


Figure 1 *A London 'pea-souper'*

Urban air quality

Air quality in urban areas is invariably poorer than in the surrounding countryside. This results in damaging impacts upon our environment and health. For example:

- carbon monoxide causes heart problems, headaches and tiredness
- twice as much carbon dioxide enhances the greenhouse effect (see 5.18)
- ten times more nitrous oxides causes haze, respiratory problems and acid rain (which weathers buildings)
- two hundred times more sulphur dioxides than in rural areas causes haze, respiratory problems, acid rain and damage to plants.

In addition, photochemical oxidants cause eye irritation, headaches and coughs, and **particulates** from power stations and vehicle emissions cause respiratory problems and dirty buildings. Both cause smog.

Smog

Smog is a mixture of smoke and fog. It occurs when smoke particulates and sulphur dioxide from burning coal mix with fog. The London smogs were caused by anticyclones trapping these pollutants in a pollution dome. During these conditions, the cold air, unusually, lies below warmer air. However, such temperature inversion is more commonly associated with cold air sinking to the floor of sheltered valleys and displacing the warmer air above it (Figure **2**). Smog today is far more likely to be photochemical – caused by sunlight reacting chemically with industrial and vehicle emissions to form a nasty cocktail of secondary gases. Although present in all modern cities, it is most common in those with warm, dry, sunny climates such as Los Angeles (Figure **3**).

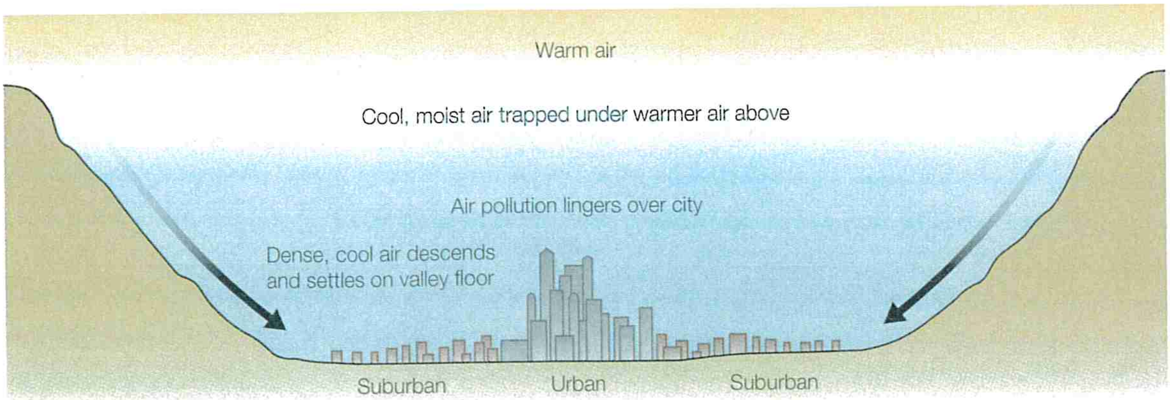


Figure 2 *Temperature inversion traps urban pollution in calm weather conditions*

Think about

Anticyclones

Anticyclones are areas of high air pressure where descending air 'piles up' on the surface. They are slower moving than areas of low pressure (depressions), which bring cloud, precipitation and wind. Although infrequent, once established, anticyclones are likely to last for many days or even weeks. Descending air warms as it falls and picks up moisture. Consequently, condensation is unlikely and so clouds are rare. However, early morning dew and mist is likely in summer with frost and fog in winter. Gentle winds blow clockwise and outwards from the high pressure centre. The clear skies ensure calm, sunny weather in summer, and bright, but cold conditions in winter.

Pollution reduction

Reducing air pollution is a major challenge in all urban areas, particularly in rapidly developing LDEs and EMEs. Strategies involve a mixture of legislation, vehicle restrictions and technical innovations.

Legislation

Many countries set strict controls on emissions, including smoke-free zones. Clean Air Acts throughout HDEs have been hugely influential, but there is never room for complacency. For example, there is further contemporary research on the hazardous effects of diesel particulates. In the UK, air quality targets are set and monitored by the Department for Environment, Food and Rural Affairs (DEFRA), which has created a simple banding system to allow the publication of specific, targeted pollution warnings during, for example, weather forecasts.

Vehicle restrictions

Simply reducing the number of vehicles in central urban areas is achieved through various means. For example, pedestrianisation of city centres and Park and Ride schemes are common throughout the UK. Selective vehicle bans (on specified days determined by their number plates) operate in Mexico City. Switzerland even goes so far as banning all but emergency, utility and electric vehicles throughout some resorts (Figure **4**). Congestion charging in London, Singapore, Stockholm and Oslo has proven to be effective, but still contentious. Such is the rate of development of GPS vehicle tracking and driver monitoring systems, that the management and convenience of vehicle restriction systems can only improve.

Technical innovations

Industrial pollution controls have forced factories to reduce gas and particulate emissions, which can be as simple as using filters. Lead-free petrol and catalytic converters on vehicle exhausts have long been established and the current pace of development of lean-burn engines is remarkable. However, it is the development of hybrid electric (HEVs), 'plug-in' hybids (PHEVs) and fully electric vehicles (EVs) that is most exciting new technology, although this raises new concerns about battery toxins. Boserup's 'necessity is the mother of invention' (see 4.26) is particularly well illustrated in all these innovations.

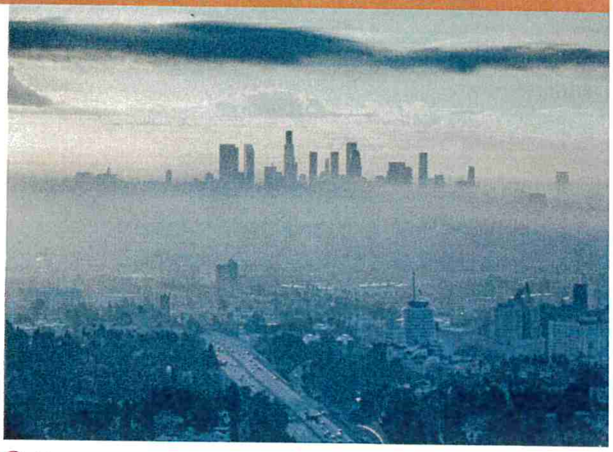


Figure 3 *A photochemical smog hangs over Los Angeles, California, USA*

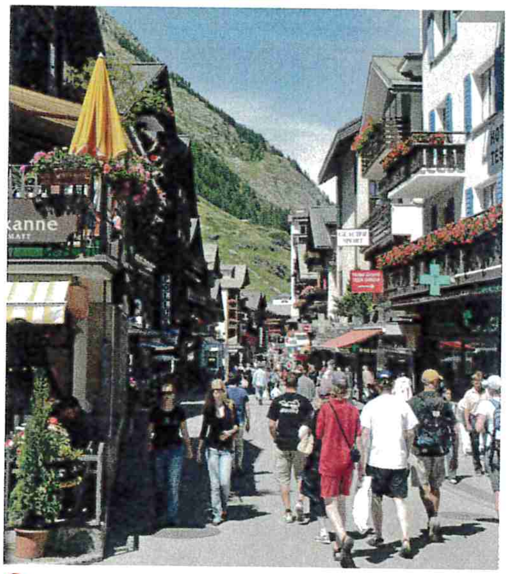


Figure 4 *Car-free Zermatt, Switzerland*

ACTIVITIES

1. a What are the main sources and types of urban pollution?
   b What is the difference between smog and photochemical smog?
2. New Delhi plans to introduce congestion charging, but New York rejected similar plans for Manhattan. Outline the environmental, economic, social and political arguments for and against managing urban traffic in this way.

STRETCH YOURSELF

Switzerland lies at the geographical heart of Europe yet enjoys remarkable air quality. Research the Swiss government's environmentally-friendly policies to combat air pollution and promote 'ecological forms of mobility'. What lessons can the rest of Europe, including the UK, learn from these policies?