Microclimates

National Meteorological Library and Archive
Fact sheet 14 — Microclimates

(version 01)

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Introduction

A microclimate is the distinctive climate of a small-scale area, such as a garden, park, valley or part of a city. The weather variables in a microclimate, such as temperature, rainfall, wind or humidity, may be subtly different to the conditions prevailing over the area as a whole and from those that might be reasonably expected under certain types of pressure or cloud cover. Indeed, it is the mixture of many, slightly different microclimates that actually makes up the climate for a town, city or wood.

It is these subtle differences and exceptions to the rule that make microclimates so fascinating to study. These notes help to identify and explain the key differences which can be noticed by ground-level observations.

In truth, there is a distinctive microclimate for every type of environment on the Earth's surface. As far as the UK is concerned they include the following:

- Upland regions
- Coastal regions
- Forest
- Urban regions

Upland regions

Upland areas have a specific type of climate that is notably different from the surrounding lower levels. Temperature usually falls with height at a rate of between 5 and 10 °C per 1,000 metres, depending on the humidity of the air. This means that even quite modest upland regions, such as The Cotswolds, can be significantly colder on average than somewhere like the nearby Severn Valley in Gloucestershire.

Figure 1. Winter scene on Dartmoor, Devon (© D. Moore).

Occasionally, a temperature inversion can make it warmer in upland regions, but such conditions rarely last for long. With higher hills and mountains, the average temperatures can be so much lower that winters are longer and summers much shorter. Higher ground also tends to be windier, which makes for harsher winter weather. The effect of this is that plants and animals are often different from those at low levels.

Data comparison of Princetown, Plymouth and Teignmouth

If we compare the climate statistics for three locations in Devon, one upland and the other two coastal, namely Princetown, Plymouth and Teignmouth, each only 20 miles apart, you would think that the climate of these three locations would be very similar. However, looking at the statistics below, you can see that their climates are quite different. The reason for this is due, in the main, to the altitude and their proximity to the prevailing wind of these locations. Princetown, high up on Dartmoor, is at an altitude of 453 metres above mean sea-level, whereas Plymouth is 50 metres and Teignmouth is only 3 metres above mean sea-level.

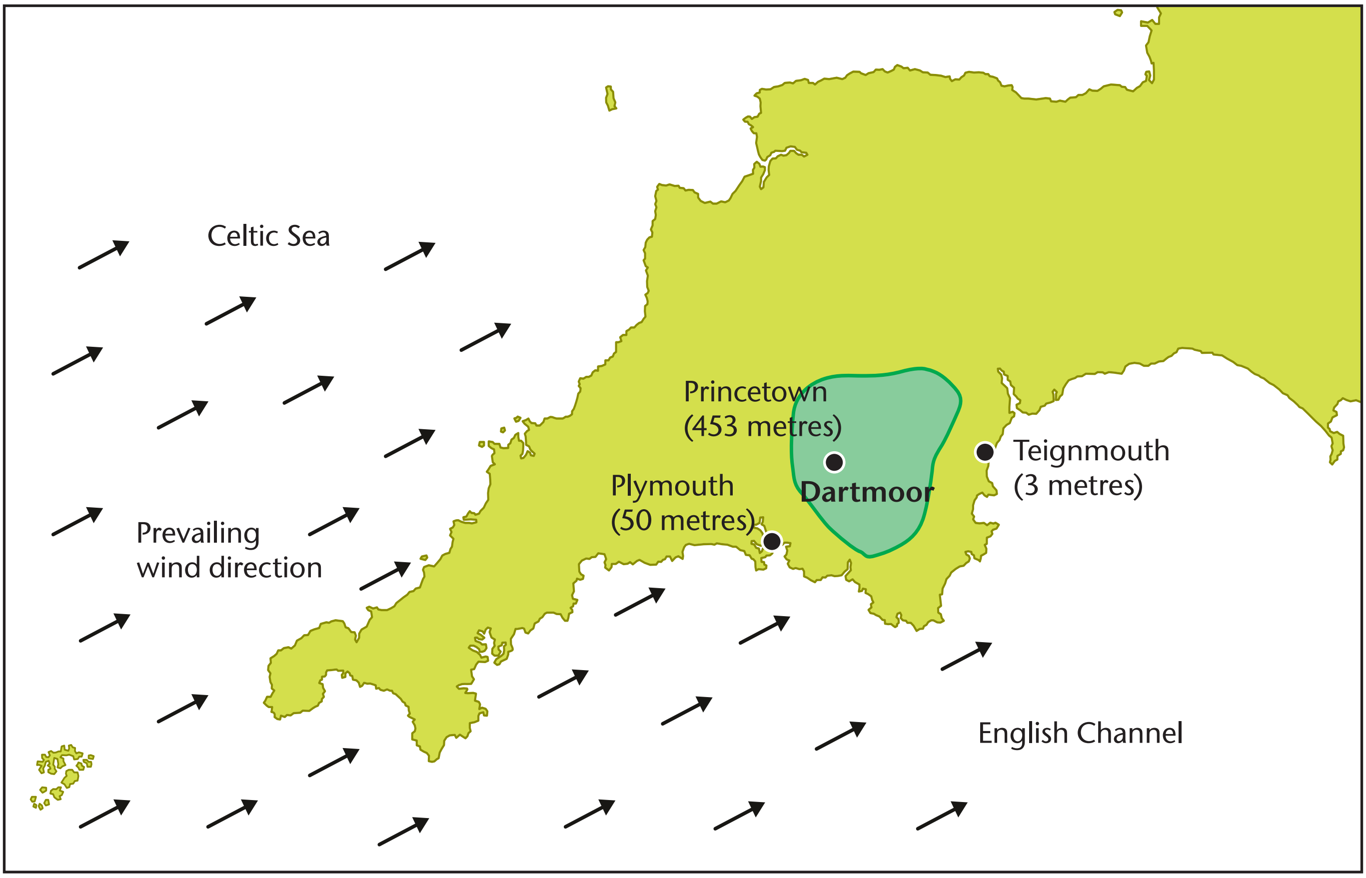


Figure 2. Location and altitudes (in metres) of the stations used in the text in South West England.

- Rainfall — the distribution of rainfall across the southwest of England, as in the United Kingdom as a whole, is very much influenced by topography as well as the exposure to the prevailing wind with the largest values occurring over the more highland regions to the west and the smallest values in the low-lying eastern regions. Princetown has over twice the annual rainfall of Teignmouth.
- Temperature — the sea plays an important role in the temperature regime of the area. The temperature of the sea changes only very slowly from month to month and the temperature of the adjacent land areas is normally not significantly higher or lower than that of the sea. Temperature shows both seasonal and diurnal variations but, due to the modifying influence of the sea, the range is less in Teignmouth than in more inland areas such as Princetown.
- Sunshine — in general, sunshine durations decrease with increasing altitude and increasing latitude although topography also plays an important role, for example, the difference between north-facing and south-facing locations. Industrial pollution and smoke haze can also reduce sunshine amounts.

Below is a table of the monthly and annual statistics (1971 to 2000 averages) for Plymouth (in green), Princetown (in white) and Teignmouth (in blue).

	Mean maximum temperature (°C)			Mean minimum temperature (°C)			Days of air frost (count)			Monthly rainfall (mm)		
January	8.8	5.8	9.0	3.8	1.0	3.7	5.4	10.7	4.3	111.1	218.5	101.8
February	8.7	5.7	8.9	3.6	0.8	3.5	4.7	10.5	4.2	93.4	168.4	82.7
March	10.2	7.3	10.5	4.6	1.9	4.6	1.8	7.3	1.6	80.8	161.8	68.1
April	12.2	9.7	12.2	5.6	3.0	5.7	0.6	4.5	0.6	59.5	109.4	54.8
May	15.2	12.9	15.3	8.5	2.9	8.6	0.1	0.6	0.0	59.8	100.2	52.0
June	17.5	15.6	18.2	11.0	8.5	11.2	0.0	0.1	0.0	59.7	115.5	51.0
July	19.8	17.7	20.6	13.2	10.8	13.5	0.0	0.0	0.0	47.1	111.5	36.4
August	19.9	17.5	20.4	13.2	10.9	13.4	0.0	0.0	0.0	67.6	133.1	56.9
September	17.6	14.9	18.1	11.3	9.0	11.4	0.0	0.1	0.0	82.2	156.0	66.5
October	14.6	11.6	14.8	9.1	6.4	8.9	0.1	0.7	0.1	101.4	215.3	83.2
November	11.5	8.4	11.7	6.1	3.8	6.0	1.7	1.5	1.5	105.7	233.6	83.8
December	9.7	6.8	9.9	4.9	2.1	4.8	3.3	2.9	2.9	124.6	250.9	112.8
Annual	13.8	11.2	14.2	7.9	5.4	8.0	17.7	45.7	15.2	992.9	1974.2	850.0

Table 1. Comparisons of monthly climate statistics between Plymouth, Princetown and Teignmouth.

Hills often cause cloud to form over them by forcing air to rise, either when winds have to go over them or they become heated by the sun. When winds blow against a hill-side and the air is moist, the base of the cloud that forms may be low enough to cover the summit. As the air descends on the other (lee) side, it dries and warms, sometimes enough to create a föhn effect. Consequently, the leeward side of hills and mountain ranges is much drier than the windward side.

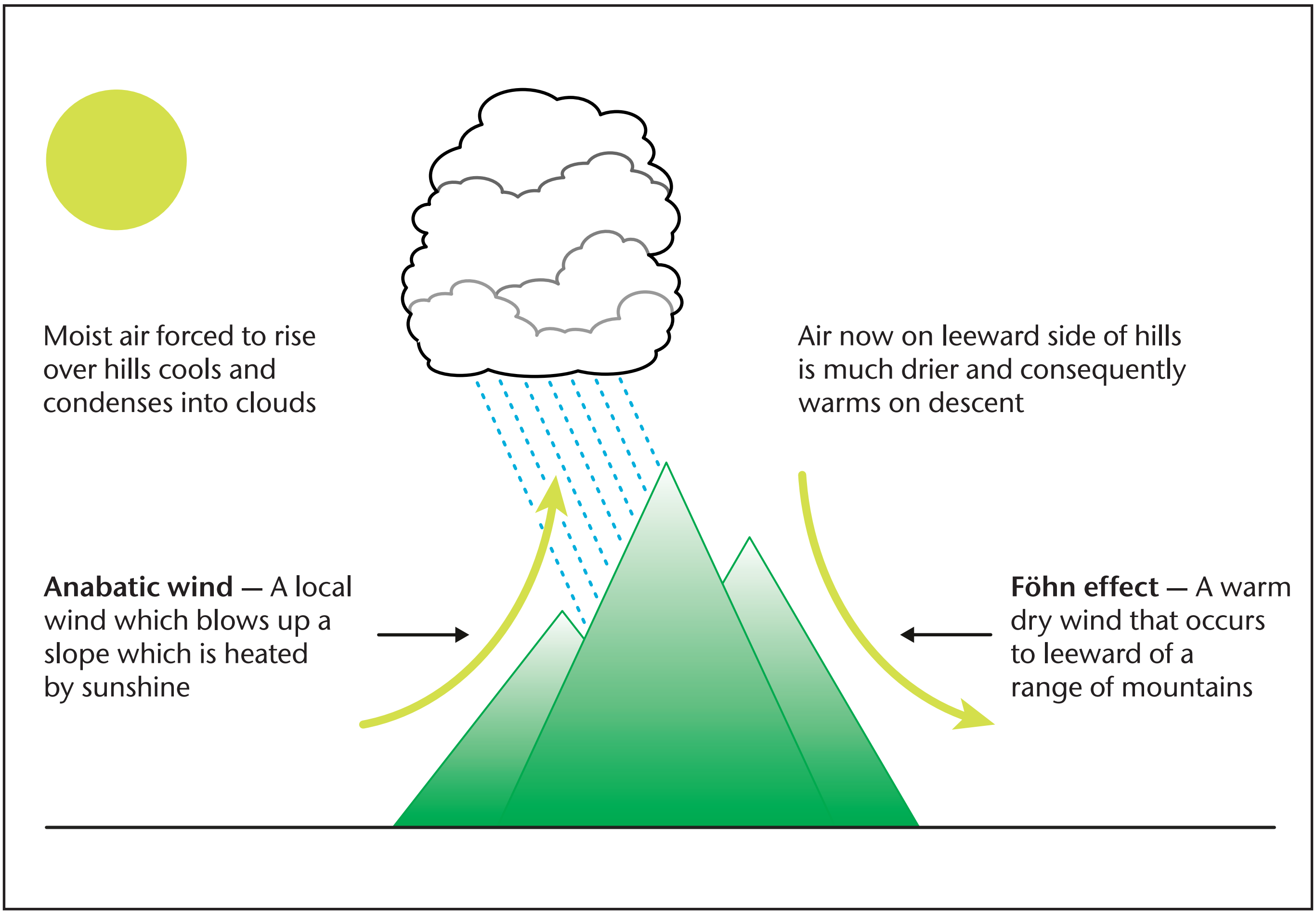


Figure 3. Diagram showing an anabatic wind and the föhn effect.

The clouds that form due to the Sun's heating sometimes grow large enough to produce showers, or even thunderstorms. This rising air can also create an anabatic wind on the sunny side of the hill. Sunshine-facing slopes (south-facing in the Northern Hemisphere, north-facing in the Southern Hemisphere) are warmer than the opposite slopes.

Apart from temperature inversions, another occasion when hills can be warmer than valleys is during clear nights with little wind, particularly in winter. As air cools, it begins to flow downhill and gathers on the valley floor or in pockets where there are dips in the ground. This can sometimes lead to fog and/or frost forming lower down. The flow of cold air can also create what is known as a katabatic wind.

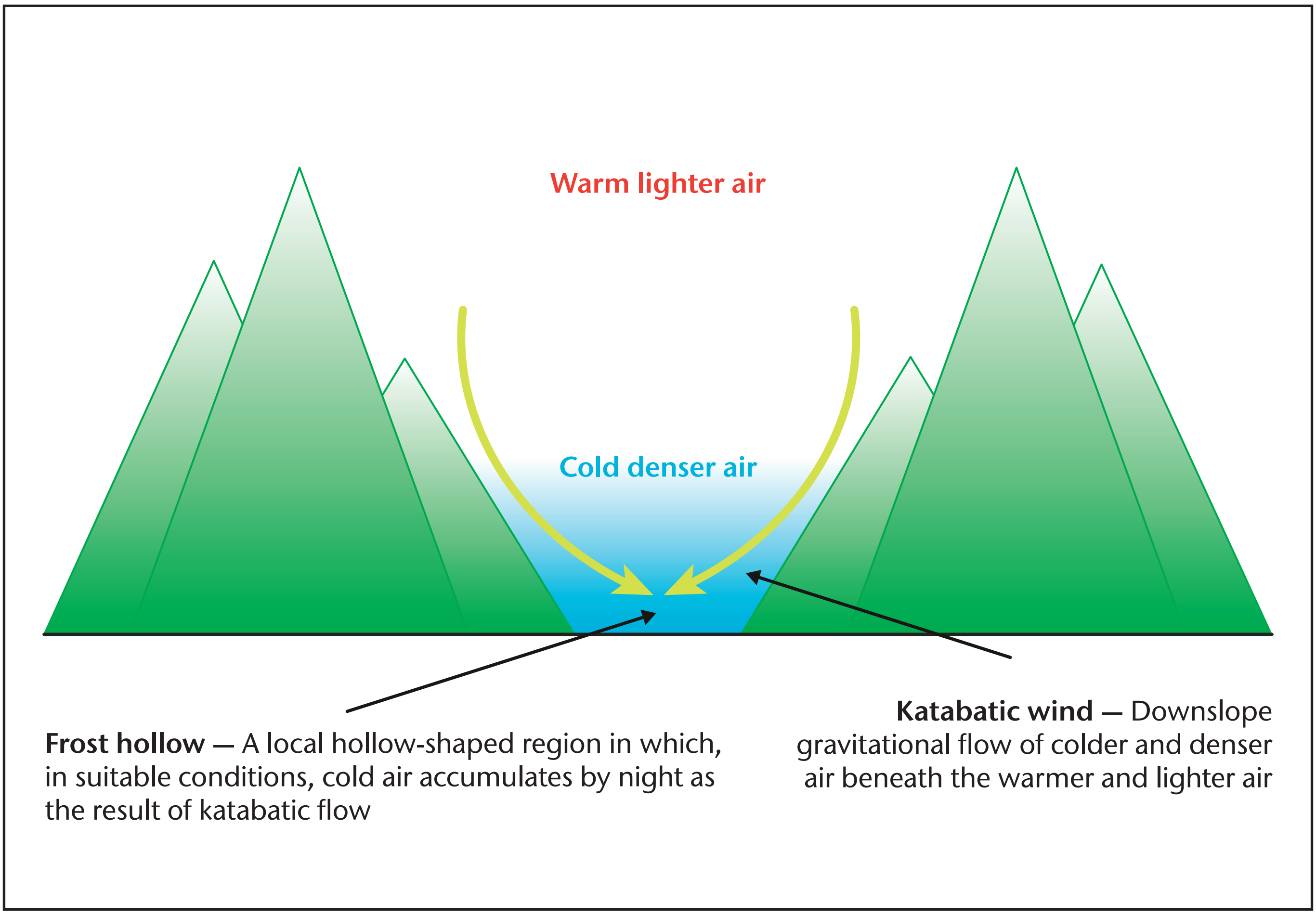


Figure 4. Diagram showing the effect of a katabatic wind.

Valley fog forms in mountain valleys. It is the result of a temperature inversion caused by heavier cold air settling into the valley, with warmer air passing over the hill or mountain above. It is essentially radiation fog confined by local topography, and can last for several days in calm conditions.

Figure 5. Valley or radiation fog (© J. Corey).

Coastal regions

The coastal climate is influenced by both the land and sea between which the coast forms a boundary. The thermal properties of water are such that the sea maintains a relatively constant day to day temperature compared with the land. The sea also takes a long time to heat up during the summer months and, conversely, a long time to cool down during the winter. Coastal microclimates display different characteristics depending on where they occur on the earth's surface.

- In the tropics — sea temperatures change little and the coastal climate depends on the effects caused by the daytime heating and night-time cooling of the land. This involves the development of a breeze from off the sea (sea breeze) from late morning and from off the land (land breeze) during the night. The tropical climate is dominated by convective showers and thunderstorms that continue to form over the sea but only develop over land during the day. As a consequence, showers are less likely to fall on coasts than either the sea or the land.

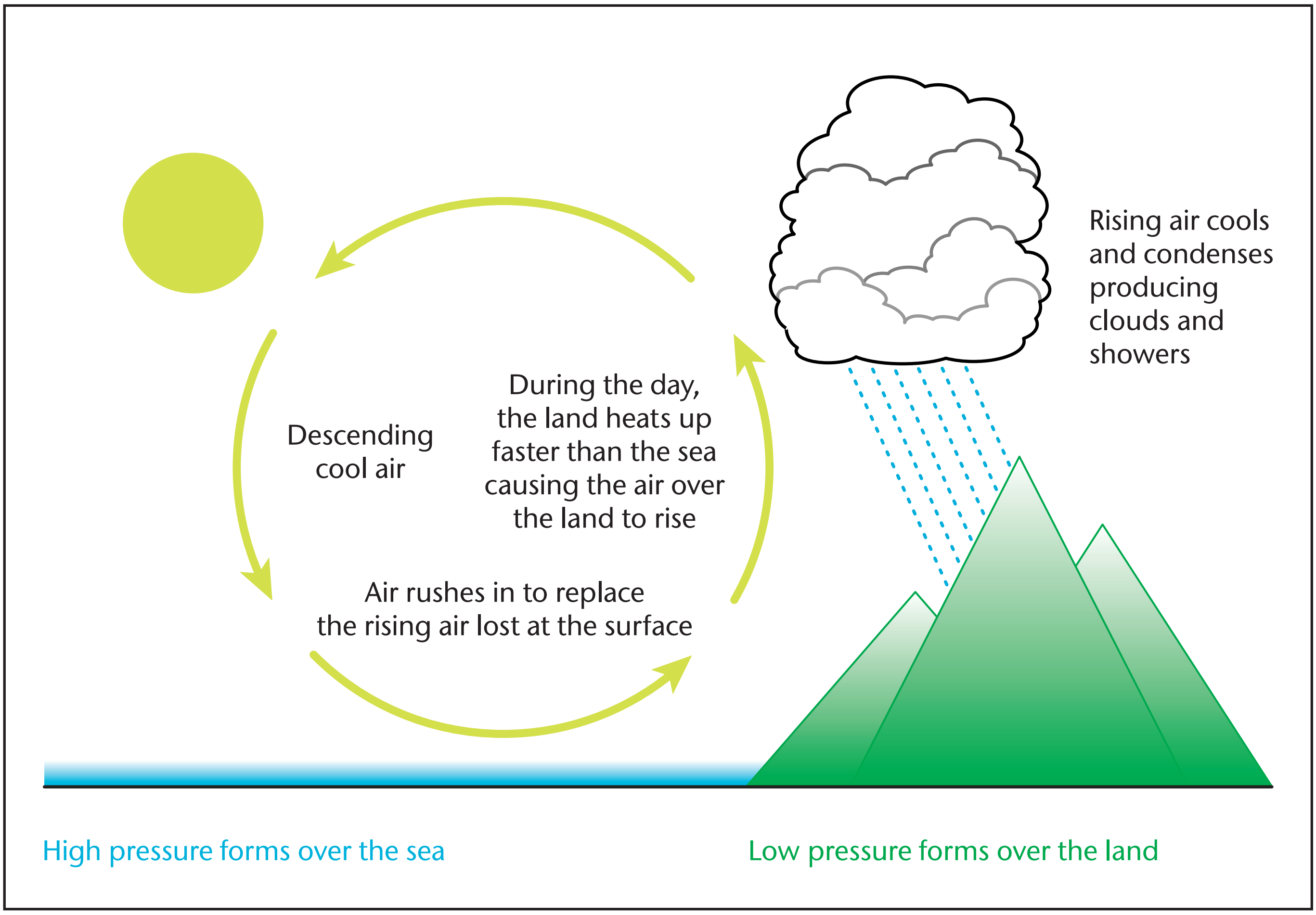
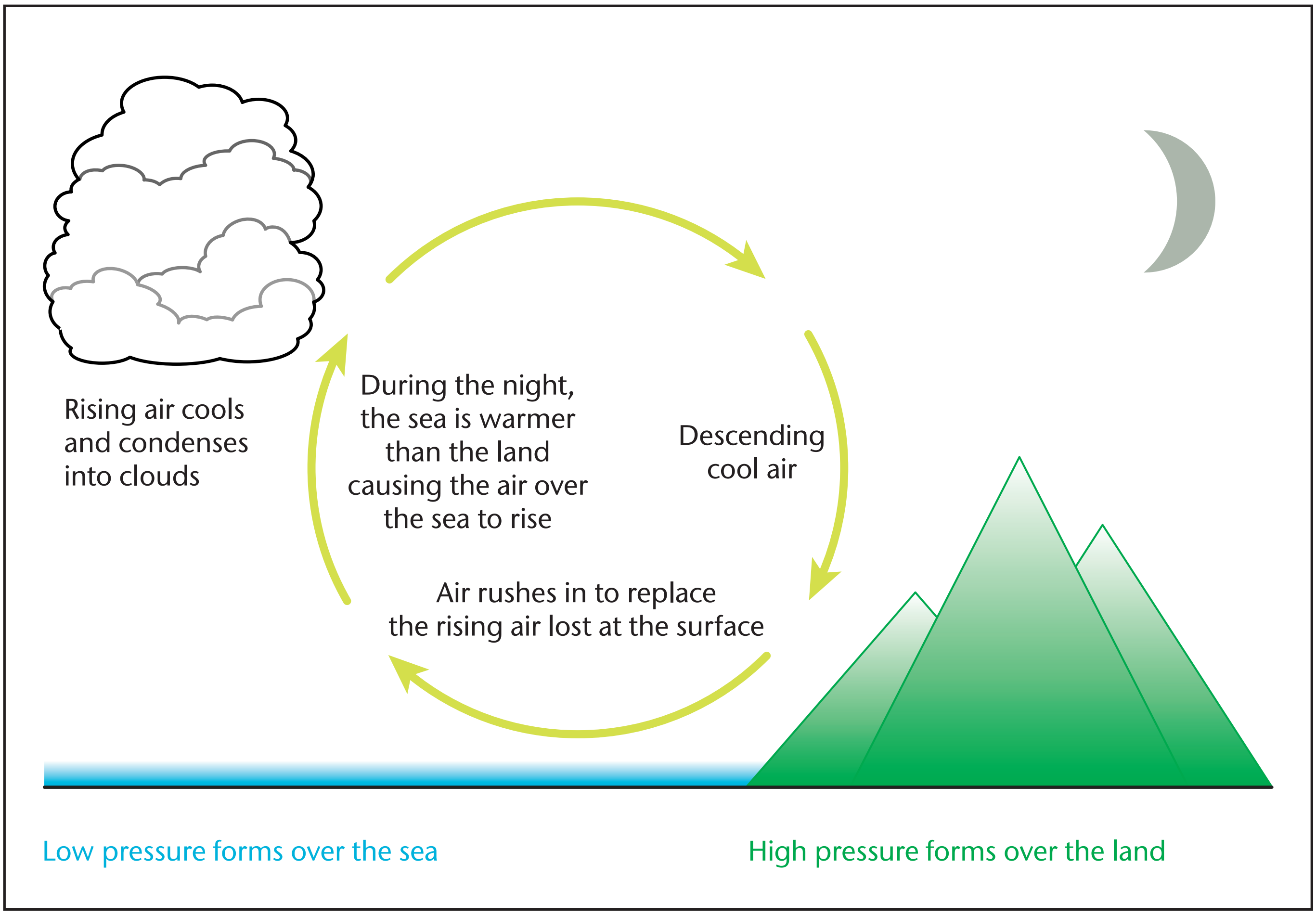


Figure 6. Development of a sea breeze during the day.

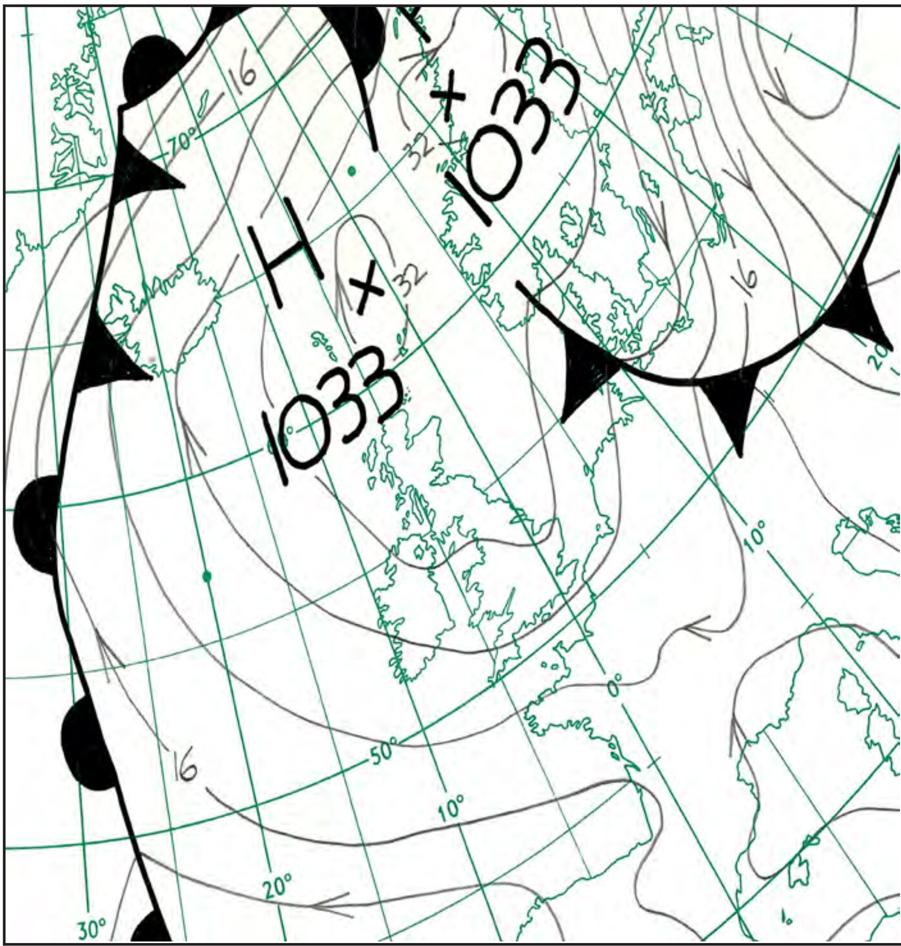
Figure 7. Development of a land breeze during the night.



- In temperate latitudes — the coastal climate owes more to the influence of the sea than of the land and coasts are usually milder than inland during the winter and cooler in the summer. However, short-term variations in temperature and weather can be considerable. The temperature near a windward shore is similar to that over the sea whereas near a leeward shore, it varies much more. During autumn and winter, a windward shore is prone to showers while during spring and summer, showers tend to develop inland. On the other hand, a sea fog can be brought ashore and may persist for some time, while daytime heating causes fog to clear inland. A lee shore is almost always drier, since it is often not affected by showers or sea mist and even frontal rain can be significantly reduced. When there is little wind during the summer, land and sea breezes predominate, keeping showers away from the coast but maintaining any mist or fog from off the sea.

Figure 8 below shows extensive sea fog or haar across coastal areas of eastern Scotland and northeast England. The sea fog hugs the coast whereas a few miles inland the sky is clear and the area is fog free.

Figure 8. 1500Z on 26 April 1984 satellite image showing extensive sea fog (haar) in the North Sea (© University of Dundee).



Summary of the weather on 26 April 1984

In most regions of the United Kingdom the sky remained clear and it was a very warm and sunny day.

However, in northern and eastern Scotland it was dull and misty with patchy drizzle on coasts and this misty weather persisted around the coasts throughout the day, keeping it rather cold in these areas.

Low cloud and misty conditions extended southwards along eastern coasts of England during the day.

Figure 9. Synoptic chart for 1200Z on 26 April 1984.

Table 2. Weather conditions for coastal stations affected by sea fog on 26 April 1984.

	Edinburgh Airport		Aberdeen Airport		Boulmer (Northumberland)	
	0900Z	1500Z	0900Z	1500Z	0900Z	1500Z
Cloud cover (oktas)	8	2	8	8	8	8
Weather type	Fog	Haze	Mist	Mist	Fog	Drizzle
Air temperature (°C)	6.6	9.2	6.1	8.7	6.0	6.8
Visibility (m)	600	3000	1500	4500	900	1500
Wind (degrees/knots)	040/05	050/11	000/00	130/05	010/08	020/07

Table 3. Weather conditions for inland stations not affected by sea fog on 26 April 1984.

	Aviemore (Highland)		Glenlivet (Moray)		Newcastle Weather Centre	
	0900Z	1500Z	0900Z	1500Z	0900Z	1500Z
Cloud cover (oktas)	0	2	0	0	0	7
Weather type	Haze	Sunny	Sunny	Sunny	Haze	Haze
Air temperature (°C)	7.6	23.0	10.4	21.2	10.8	9.1
Visibility (m)	3000	25000	45000	45000	8000	7000
Wind (degrees/knots)	100/02	020/10	320/02	320/02	040/08	060/06

- Around the poles — sea temperatures remain low due to the presence of ice, and the position of the coast itself can change as ice thaws and the sea re-freezes. One characteristic feature is the development of powerful katabatic winds that can sweep down off the ice caps and out to sea.

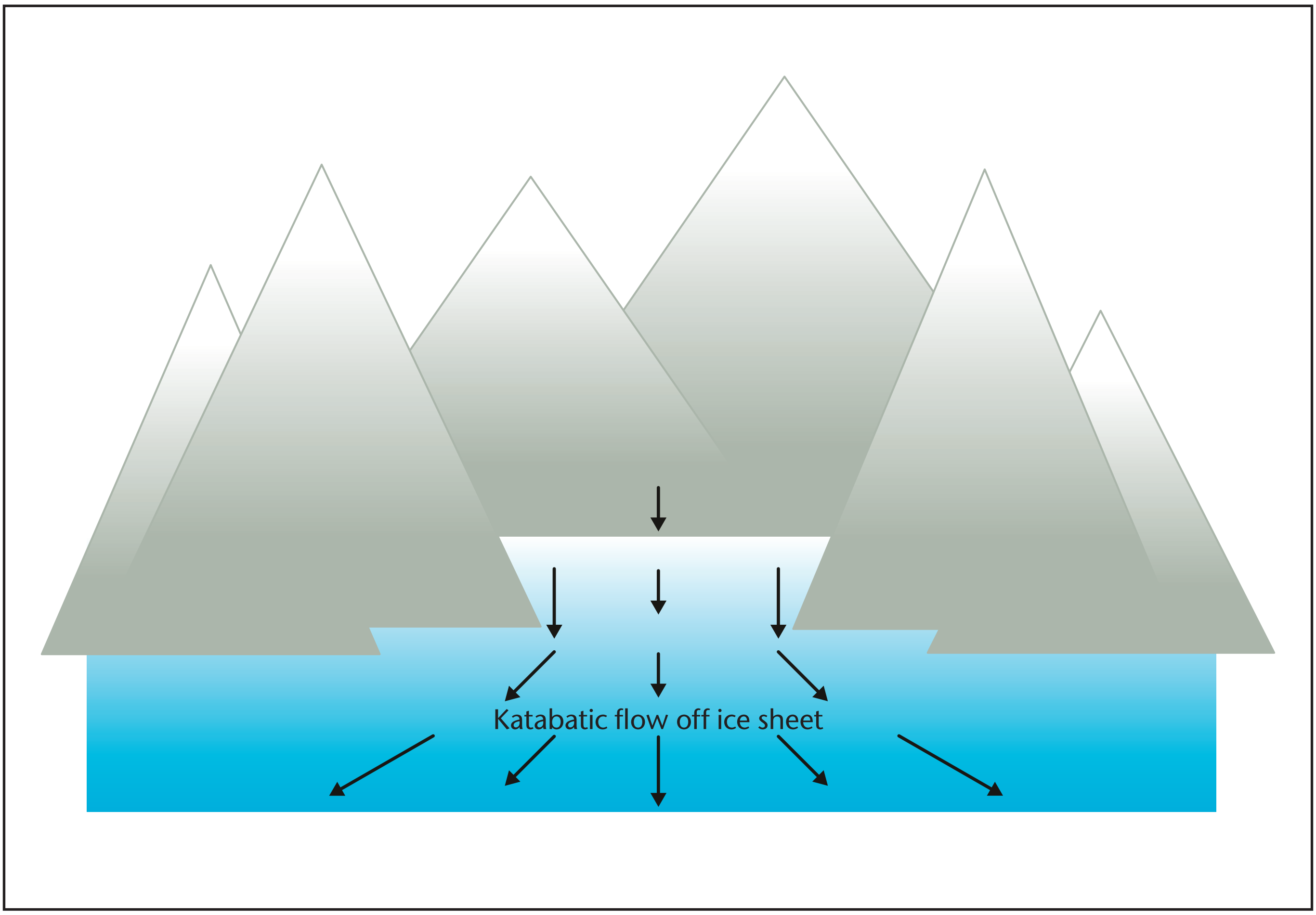


Figure 10. Cold katabatic winds blow off ice caps and out to sea.

Sea-breeze front

A sea-breeze front is a weather front created by a sea-breeze. The cold air from the sea meets the warmer air from the land and creates a boundary like a shallow cold front. When powerful this front creates cumulus clouds, and if the air is humid and unstable, cumulonimbus clouds, the front can sometimes trigger thunderstorms.

Forest regions

Tropical rainforests cover only about 6% of Earth's land surface, but it is believed they have a significant effect on the transfer of water vapour to the atmosphere. This is due to a process known as evapotranspiration from the leaves of the forest trees.

Figure 11. Temperate forest in Germany (© D. Moore).

Figure 12. Temperate forest in South Wales (© J. Corey).

Woodland areas in more temperate latitudes can be cooler and less windy than surrounding grassland areas, with the trees acting as a windbreak and the incoming solar radiation being 'filtered' by the leaves and branches. However, these differences vary depending on the season, i.e. whether the trees are in leaf, and the type of vegetation, i.e. deciduous or evergreen. Certain types of tree are particularly suitable for use as windbreaks and are planted as barriers around fields or houses.

Urban regions

These are perhaps the most complex of all microclimates. With over 75% of the British population being classed as urban, it is no surprise that they are also the most heavily studied by students of geography and meteorology. Therefore, the rest of these notes focus on the various elements that constitute an urban microclimate.

What is an urban microclimate? The table below summarises some of the differences in various weather elements in urban areas compared with rural locations.

Sunshine duration	5 to 15% less
Annual mean temperature	0.5 to 1.0°C higher
Winter maximum temperatures	1 to 2°C higher
Occurrence of frosts	2 to 3 weeks fewer
Relative humidity (in winter)	2% lower
Relative humidity (in summer)	8 to 10% lower
Total precipitation	5 to 10% more
Number of rain days	10% more
Number of days with snow	14% fewer
Cloud cover	5 to 10% more
Occurrence of fog (in winter)	100% more
Amount of condensation nuclei	10 times more

Table 4. Comparisons of urban and rural microclimates.

Urban heat islands

The formation of a heat island is the result of the interaction of the following factors:

- The release (and reflection) of heat from industrial and domestic buildings.
- The absorption by concrete, brick and tarmac of heat during the day, and its release into the lower atmosphere at night.
- The reflection of solar radiation by glass buildings and windows. The central business districts of some urban areas can therefore have quite high albedo rates (proportion of light reflected).
- The emission of hygroscopic pollutants from cars and heavy industry act as condensation nuclei, leading to the formation of cloud and smog, which can trap radiation. In some cases, a pollution dome can also build up.
- Recent research on London's heat island has shown that the pollution domes can also filter incoming solar radiation, thereby reducing the build up of heat during the day. At night, the dome may trap some of the heat from the day, so these domes might be reducing the sharp differences between urban and rural areas.
- The relative absence of water in urban areas means that less energy is used for evapotranspiration and more is available to heat the lower atmosphere.
- The absence of strong winds to both disperse the heat and bring in cooler air from rural and suburban areas. Indeed, urban heat islands are often most clearly defined on calm summer evenings, often under blocking anticyclones.

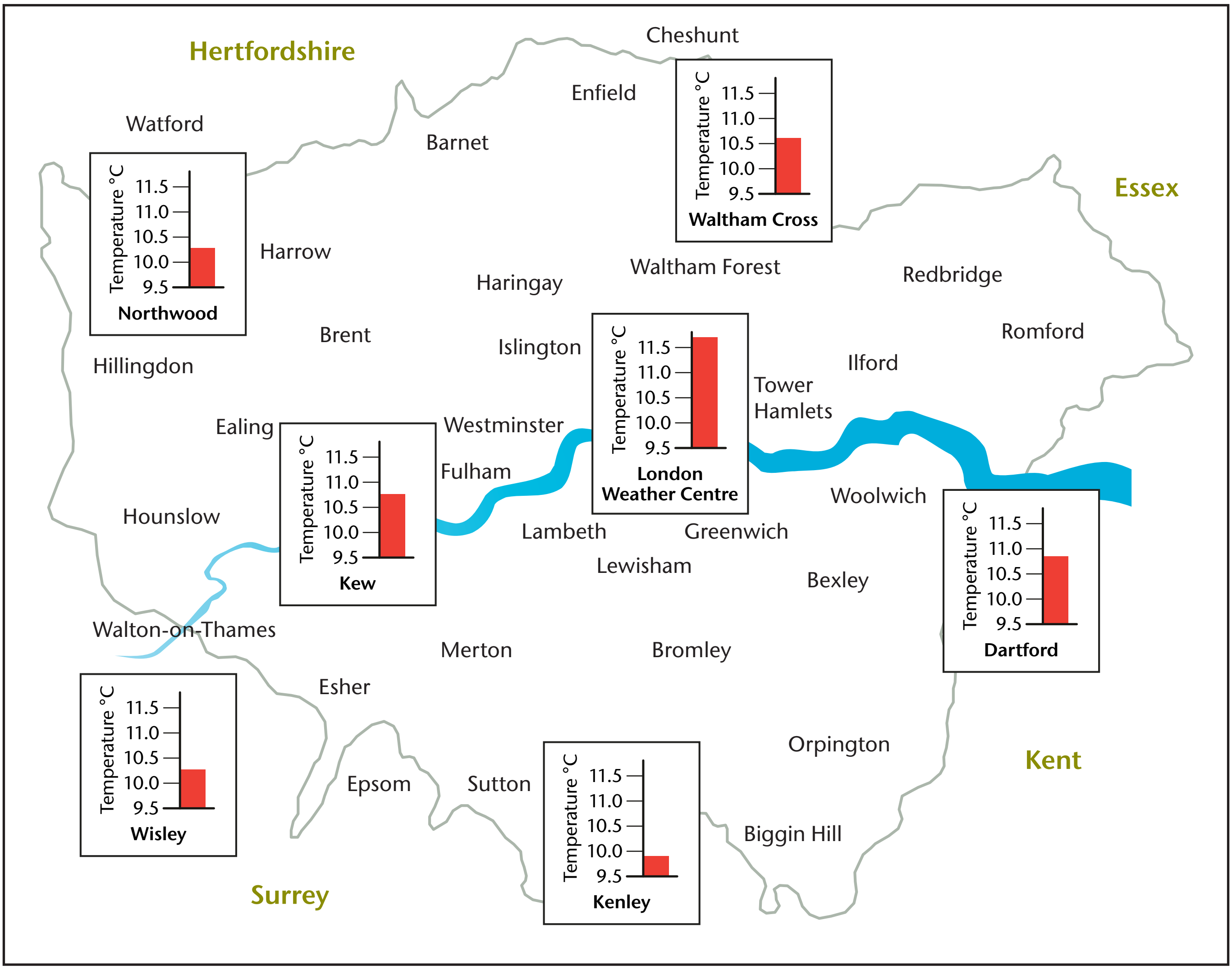


Figure 13. Mean annual temperatures for a number of stations around London.

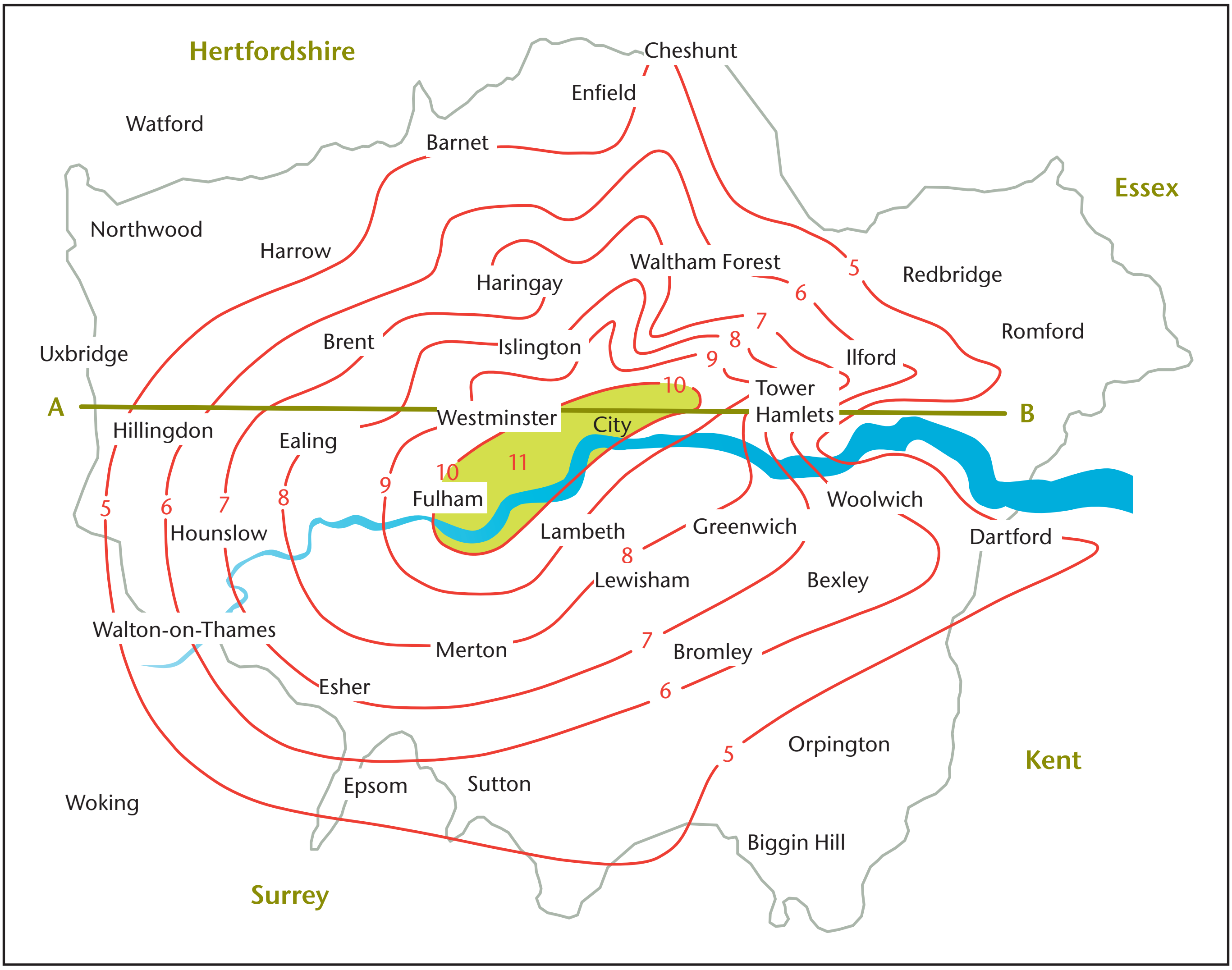


Figure 14. London 'heat island' (minimum temperatures in °C) (mid-May: clear skies and light winds).

Marked differences in air temperature are some of the most important contrasts between urban and rural areas shown in the table above. For instance, Chandler (1965) found that, under clear skies and light winds, temperatures in central London during the spring reached a minimum of 11 °C, whereas in the suburbs they dropped to 5 °C.

The precise nature of the heat island varies from urban area to urban area, and it depends on the presence of large areas of open space, rivers, the distribution of industries and the density and height of buildings. In general, the temperatures are highest in the central areas and gradually decline towards the suburbs. In some cities, a temperature cliff occurs on the edge of town. This can be clearly seen on the heat profile for London. (Line drawn from A to B in Figure 14).

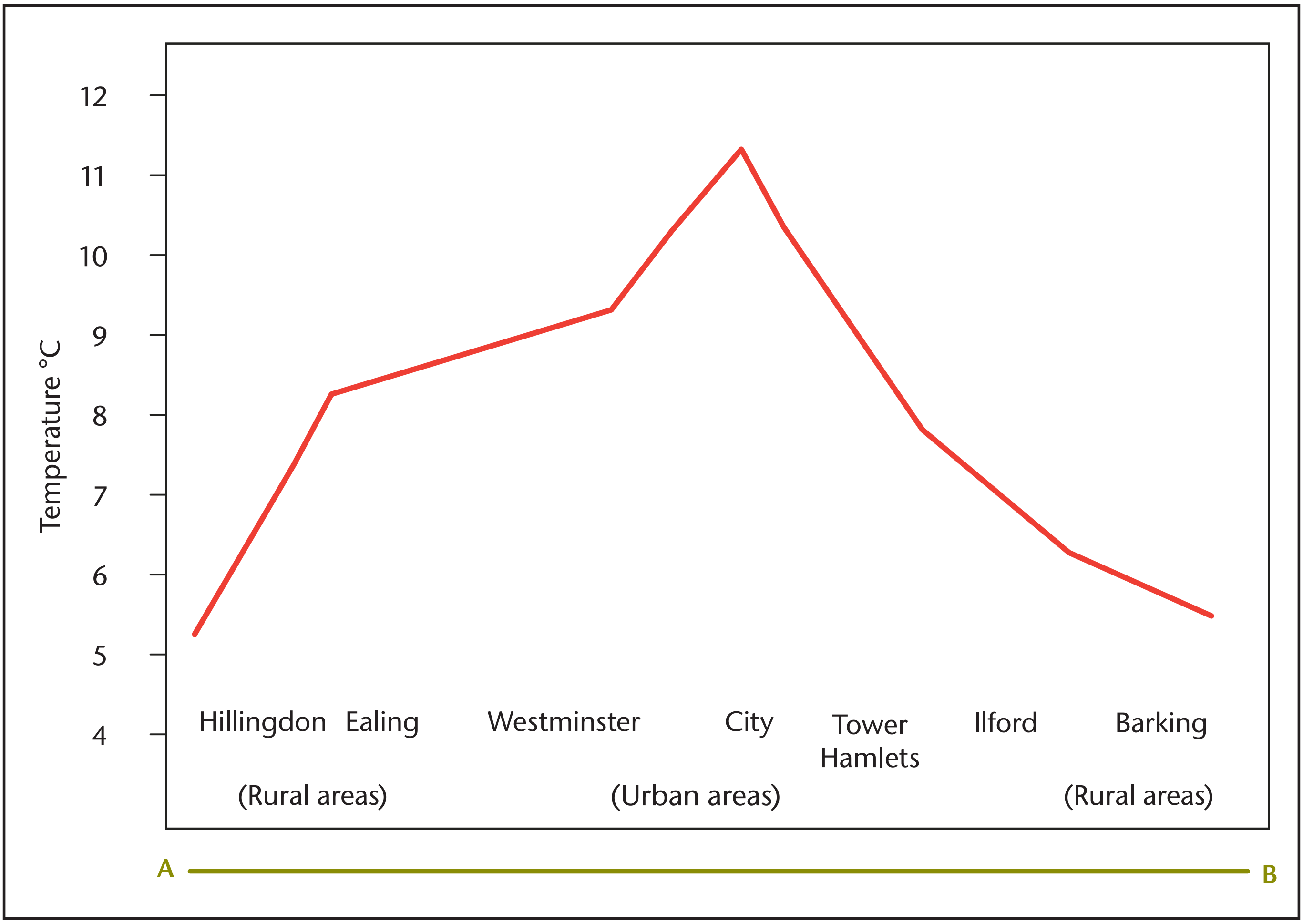


Figure 15. Temperature profile for London.

Urban precipitation

The distribution of rainfall over a town or city is very much influenced by topography with the largest values occurring over the more hilly regions and lowest values in more low—lying areas. The map below illustrates this point quite clearly. Kenley on the North Downs, at an altitude of 170 metres above mean sea-level has an average annual rainfall of nearly 800 mm whereas London Weather Centre, at 43 metres above mean sea-level, has an average annual rainfall of less than 550 mm.

However, other factors also play a major role, especially the heat islands. These can enhance convectional uplift, and the strong thermals that are generated during the summer months may serve to generate or intensify thunderstorms over or downwind of urban areas. Storm cells passing over cities can be 'refuelled' by contact with the warm surfaces and the addition of hygroscopic particles. Both can lead to enhanced rainfall, but this usually occurs downwind of the urban area.

The nature of rainfall varies during the year. In summer, rainfall is often of a showery nature, falling over short periods, and is normally more intense than in winter, when rainfall tends to be more frontal in character with falls occurring over longer periods. As a rough guide, an average day of steady rain gives 10 to 15 mm and a heavy thunderstorm, lasting an hour or so, 25 to 50 mm. 25 mm of rainfall is equivalent to about 200 tonnes of water on a football pitch.

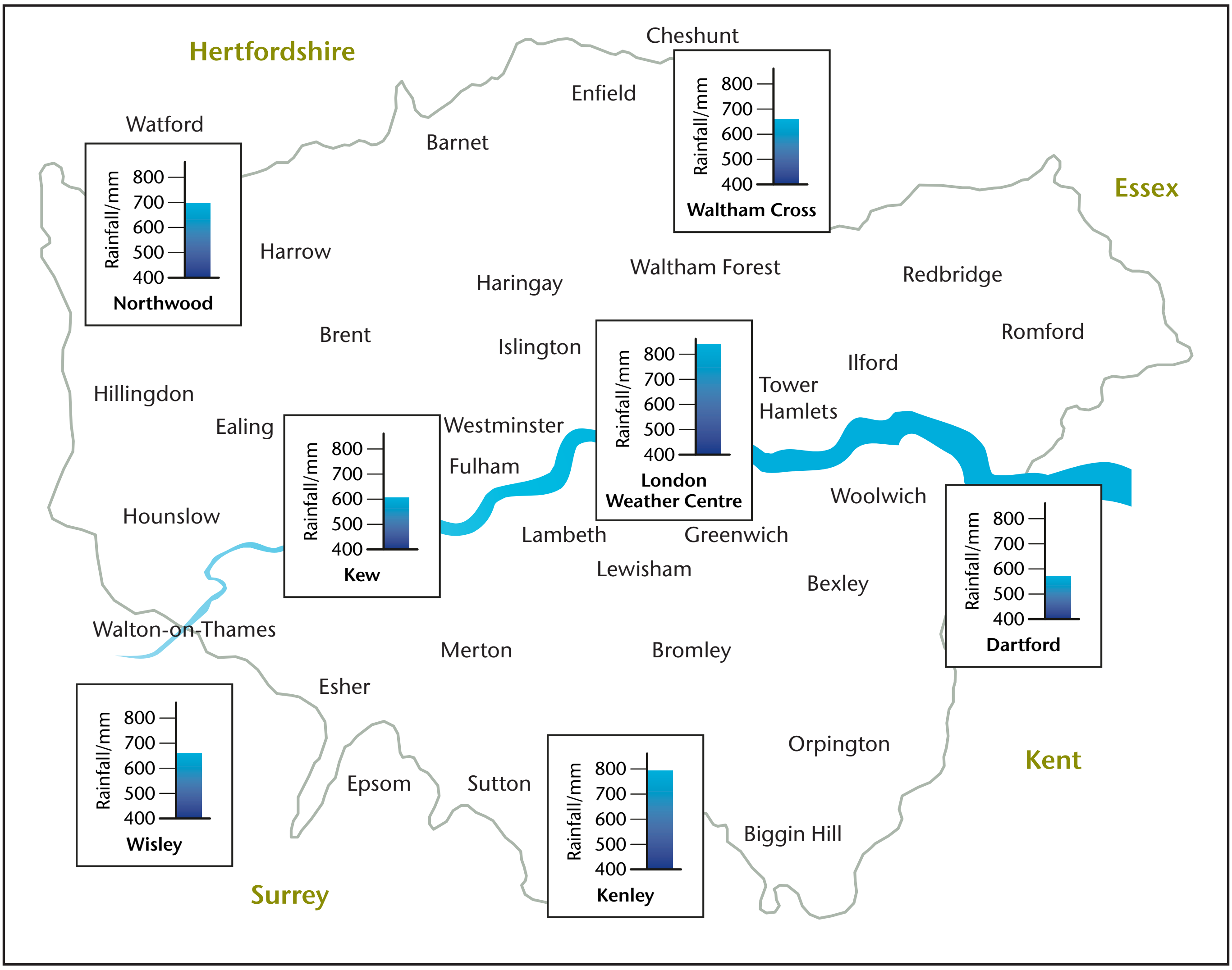


Figure 16. Mean annual rainfall totals for a number of stations around London.

Smog

Smogs were common in many British cities in the late 19th and early 20th centuries, when domestic fires, industrial furnaces and steam trains were all emitting smoke and other hygroscopic pollutants by burning fossil fuels. The smogs were particularly bad during the winter months and when temperature inversions built up under high pressure, causing the pollutants to become trapped in the lower atmosphere and for water vapour to condense around these particles. One of the worst of these 'pea-soup fogs' was the London smog of the winter of 1952/53. Approximately 4,000 people died during the smog itself, but it is estimated that 12,000 people may have died due to its effects. As a result, the Clean Air Act of 1956 was introduced to reduce these emissions into the lower atmosphere. Taller chimney stacks and the banning of heavy industry from urban areas were just two of the measures introduced and, consequently, fewer smogs were recorded in the United Kingdom during the 1960s and 1970s.

Research in the 1990s has shown, however, that another type of smog — photochemical — is now occurring in some urban areas as a result of fumes from car exhausts and the build up of other pollutants in the lower atmosphere which react with incoming solar radiation. The presence of a brown-coloured haze over urban areas is an indication of photochemical smog, and among its side effects are people experiencing breathing difficulties and asthma attacks.

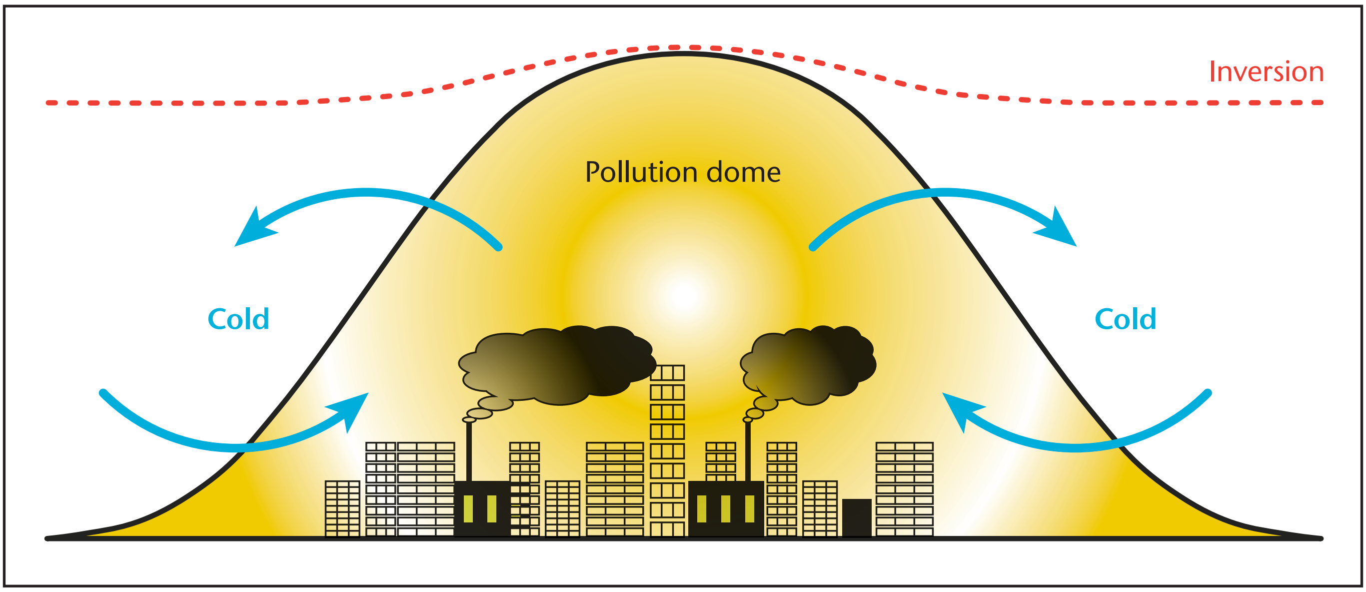


Figure 17. Pollution dome over a city.

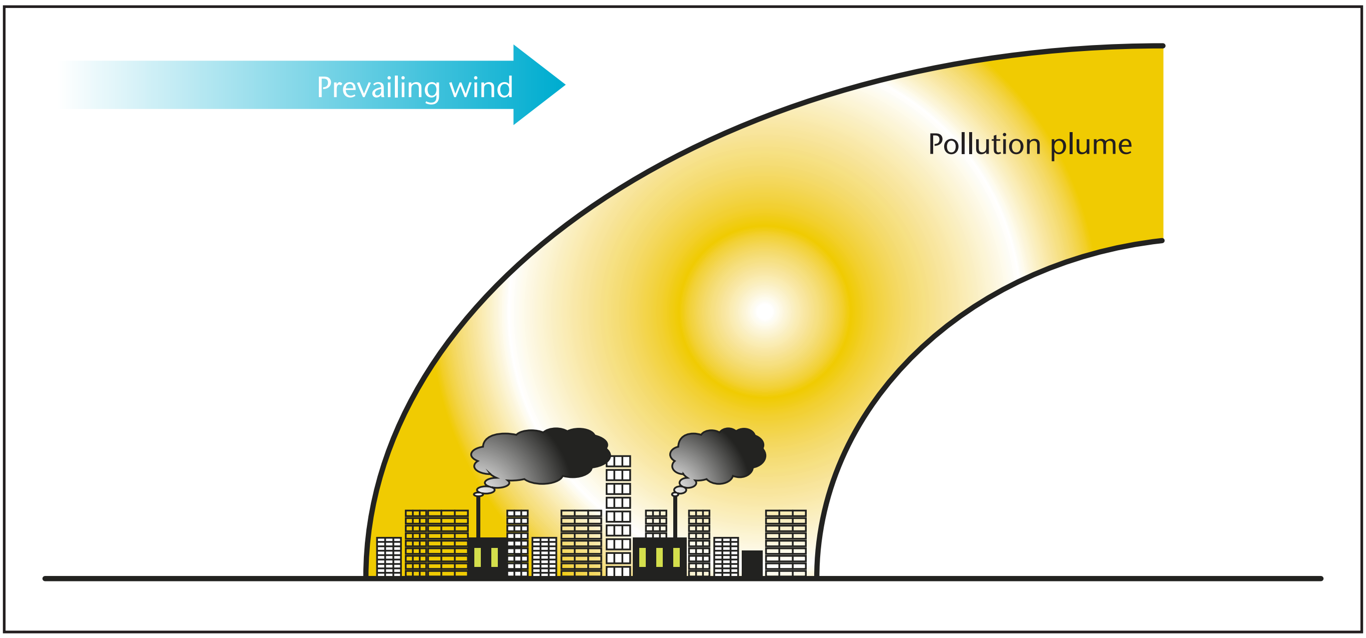


Figure 18. Pollution plume over a city.

Urban winds

Tall buildings can significantly disturb airflows over urban areas, and even a building 100 metres or so high can deflect and slow down the faster upper-atmosphere winds. The net result is that urban areas, in general, are less windy than surrounding rural areas.

However, the 'office quarter' of larger conurbations can be windier, with quite marked gusts. This is the result of the increased surface roughness that the urban skyline creates, leading to strong vortices and eddies. In some cases, these faster, turbulent winds are funnelled in between buildings, producing a venturi effect, swirling up litter and making walking along the pavements quite difficult.

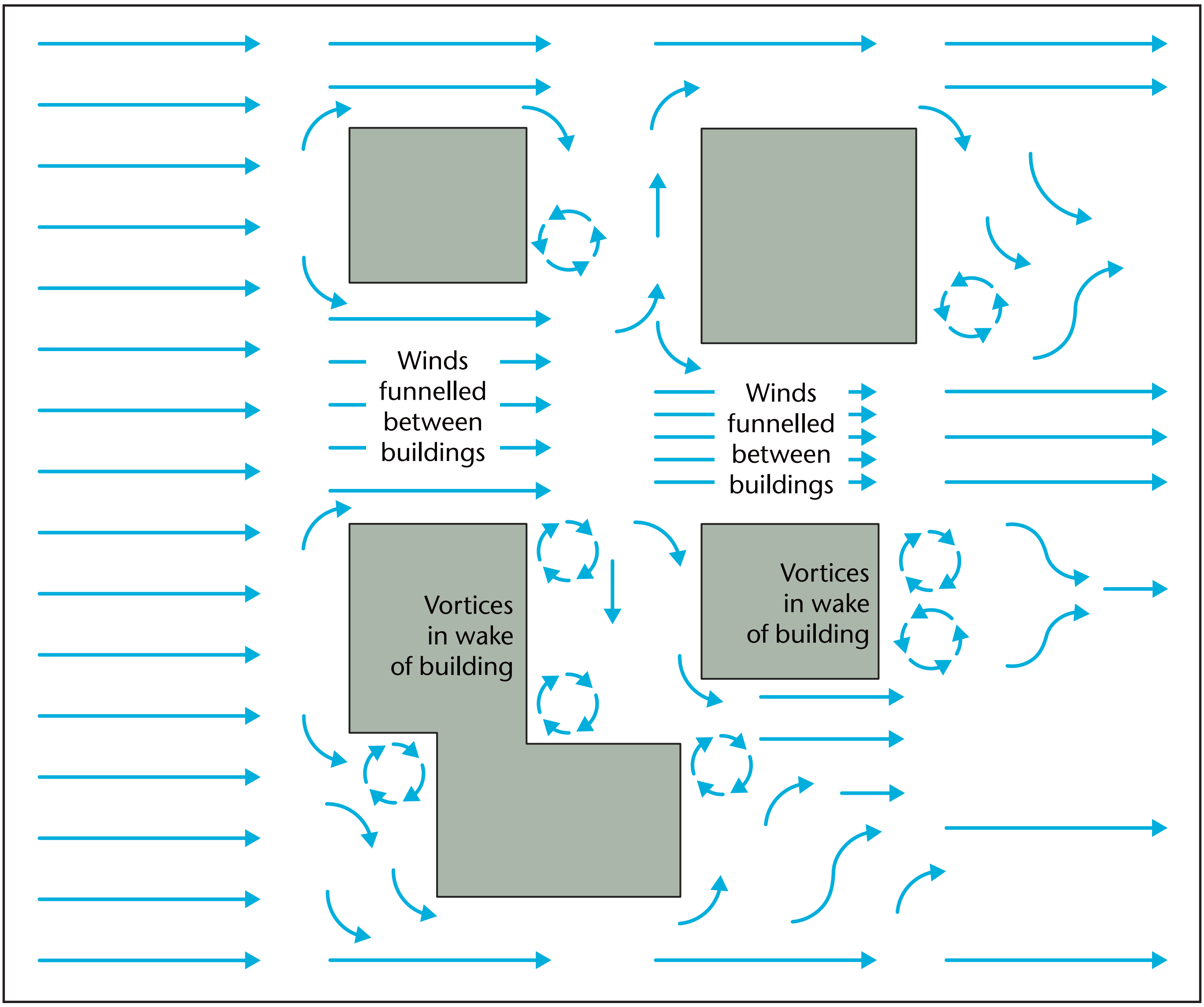


Figure 19. Winds around offices in a city showing the vortices created by the buildings.

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