National Meteorological Library and Archive

Fact sheet No. 14 – Microclimates

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 amalgam 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, and 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, and as far as the UK is concerned they include the following:

- Upland Regions
- Coastal Regions
- Forest
- Urban Regions

Upland Regions

Figure 1. Winter scene in the Brecon Beacons.

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 1000 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.

Occasionally, a temperature inversion can make it warmer above, 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 and Teignmouth.

If we compare the climate statistics for two locations in Devon, one upland and the other coastal, namely Princetown and Teignmouth, at only 20 miles apart you would think that the climate of these two 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 of these locations. Princetown, high up on Dartmoor, is at an altitude of 453 metres above mean sea-level, whereas Teignmouth is only 3 metres above mean sea-level.

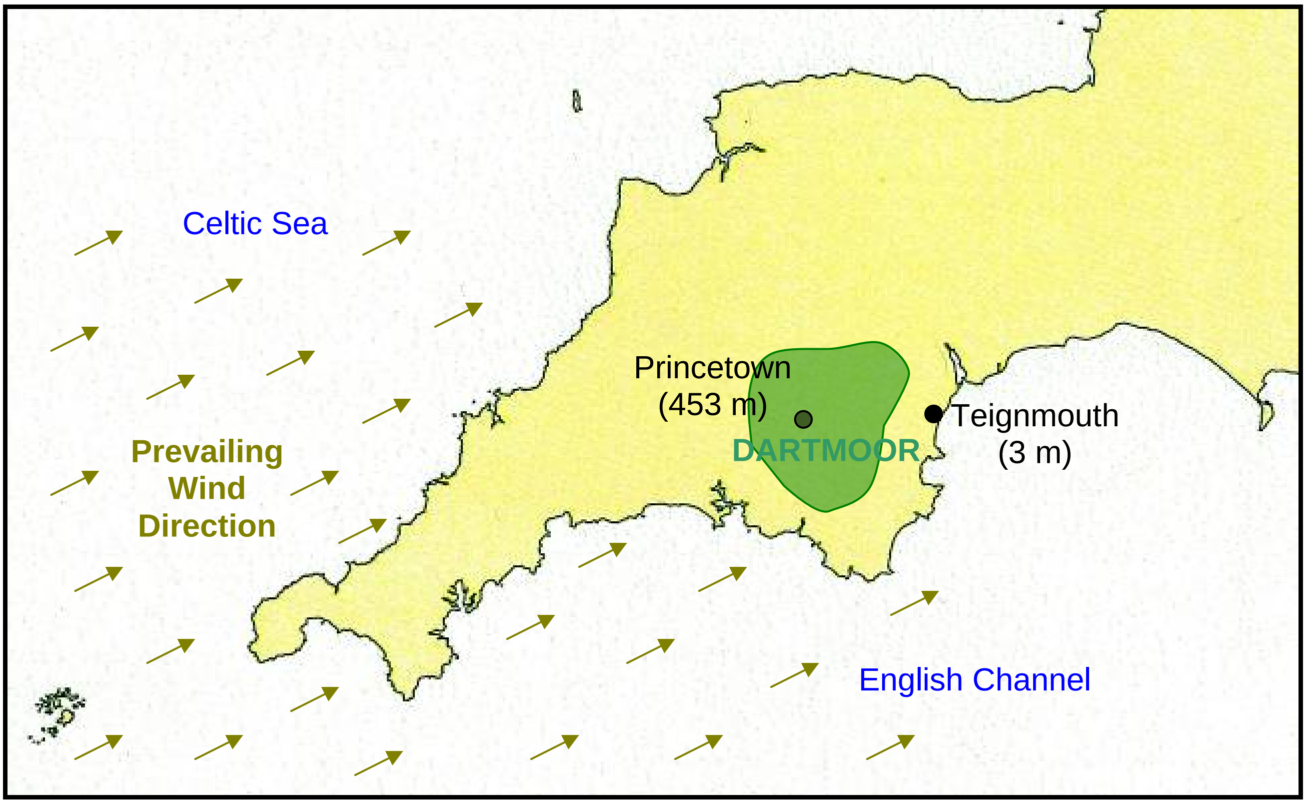


Figure 2. Location and altitudes (in metres) of the stations used in the text in Southwest England.

- Rainfall

The distribution of rainfall across the southwest of England, as in the United Kingdom as a whole, is very much influenced by topography with the largest values occurring over the more highland regions and the smallest values in the low-lying 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 a 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 both Princetown (in yellow) and Teignmouth (in blue).

	Maximum Temperature /°C		Minimum Temperature /°C		Days of Air Frost /days		Rainfall /mm	
	Princetown	Teignmouth	Princetown	Teignmouth	Princetown	Teignmouth	Princetown	Teignmouth
January	5.8	9.0	1.0	3.7	10.7	4.3	218.5	101.8
February	5.7	8.9	0.8	3.5	10.5	4.2	168.4	82.7
March	7.3	10.5	1.9	4.6	7.3	1.6	161.8	68.1
April	9.7	12.2	3.0	5.7	4.5	0.6	109.4	54.8
May	12.9	15.3	5.9	8.6	0.6	0.0	100.2	52.0
June	15.6	18.2	8.5	11.2	0.1	0.0	115.5	51.0
July	17.7	20.6	10.8	13.5	0.0	0.0	111.5	36.4
August	17.5	20.4	10.9	13.4	0.0	0.0	133.1	56.9
September	14.9	18.1	9.0	11.4	0.1	0.0	156.0	66.5
October	11.6	14.8	6.4	8.9	0.7	0.1	215.3	83.2
November	8.4	11.7	3.8	6.0	4.0	1.5	233.6	83.8
December	6.8	9.9	2.1	4.8	7.23	2.9	250.9	112.8
Annual	11.2	14.2	5.4	8.0	45.7	15.2	1974.2	850.0

Table 1. Comparisons of monthly climate statistics between 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.

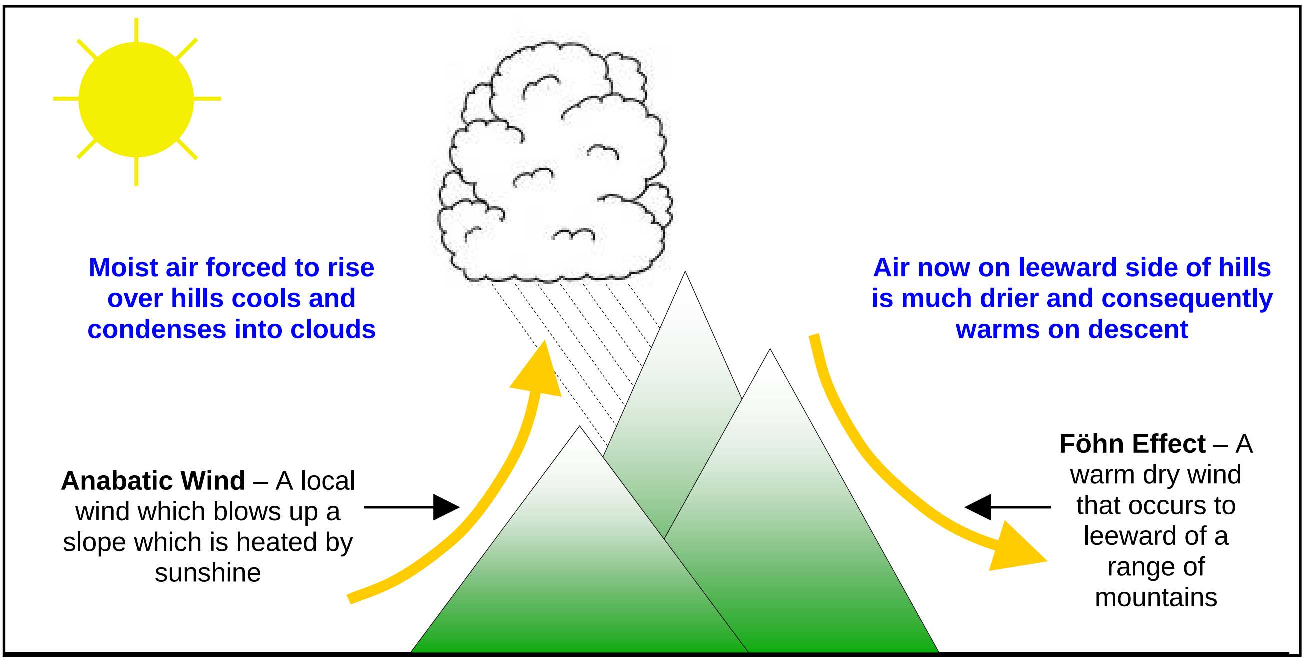


Figure 3. Diagram showing an anabatic wind and the föhn effect.

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.

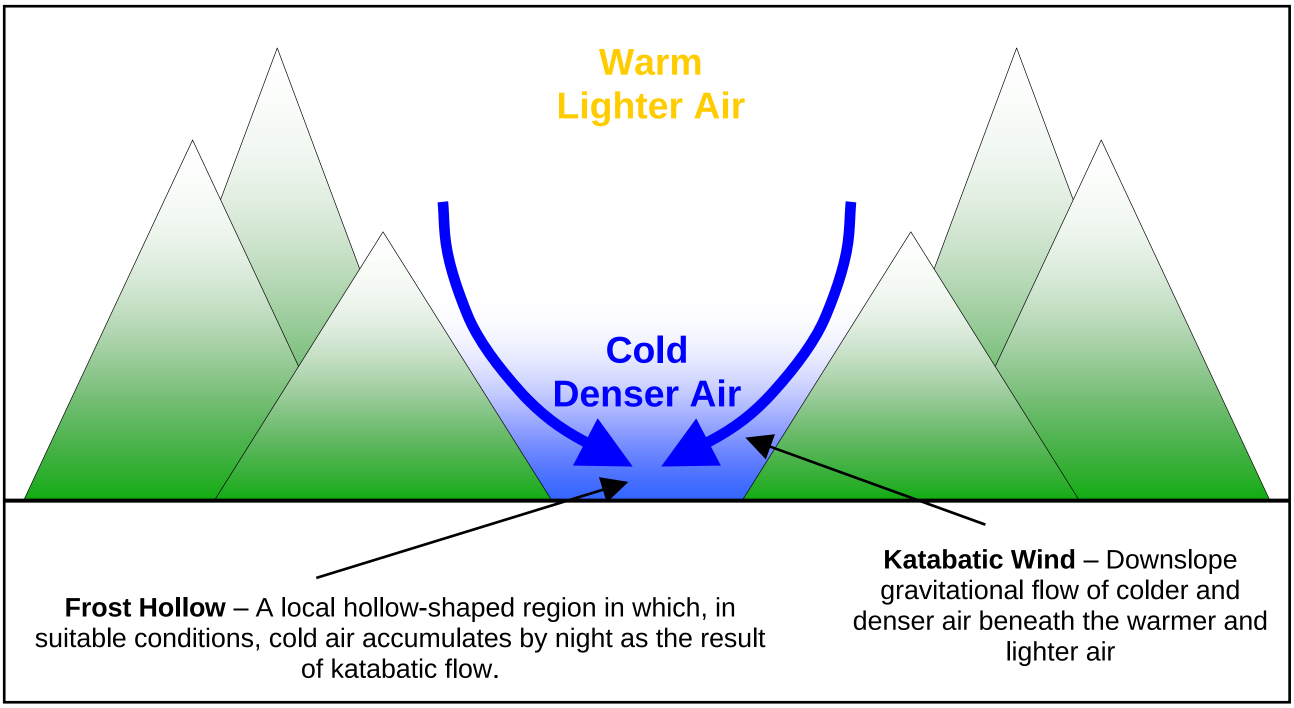


Figure 4. Diagram showing the effect of a katabatic wind.

Figure 5. Valley or radiation fog.

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

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.

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.

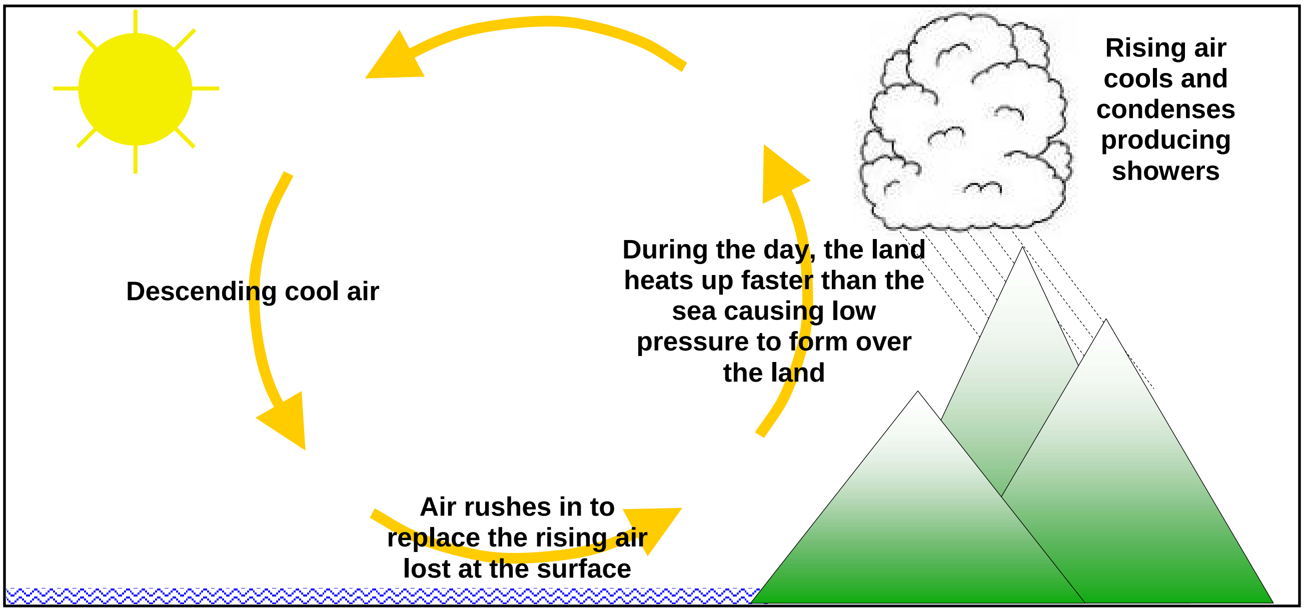


Figure 6. Development of a sea breeze during the day.

Figure 7. Towering cumulus associated with a sea breeze front.

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.

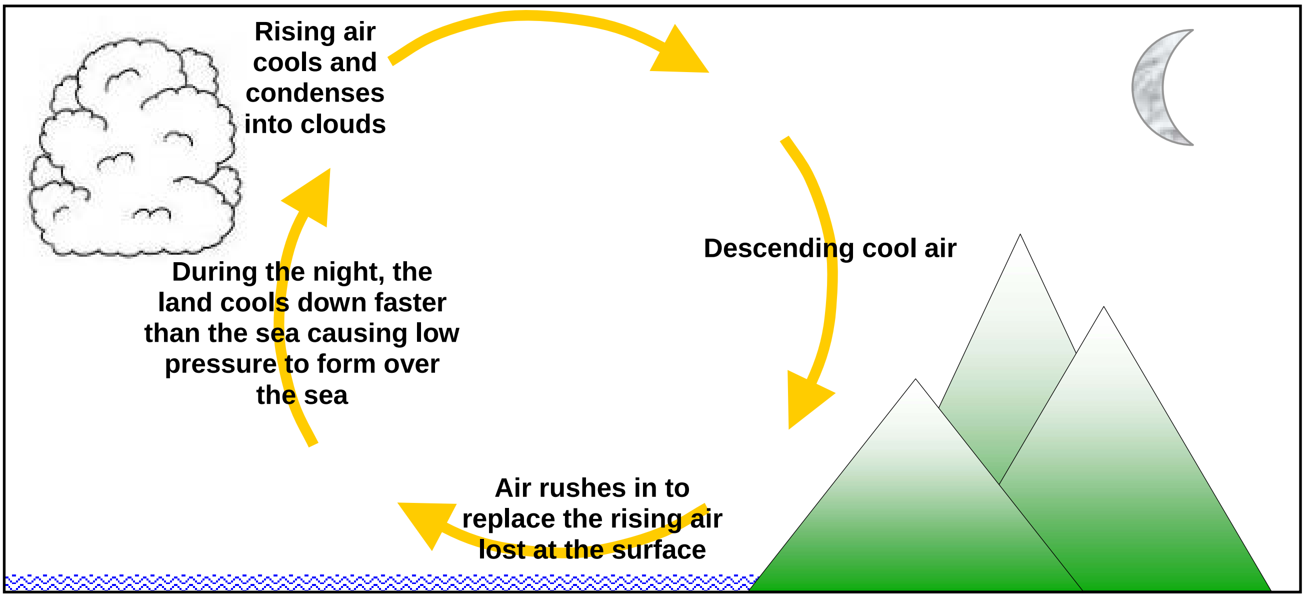
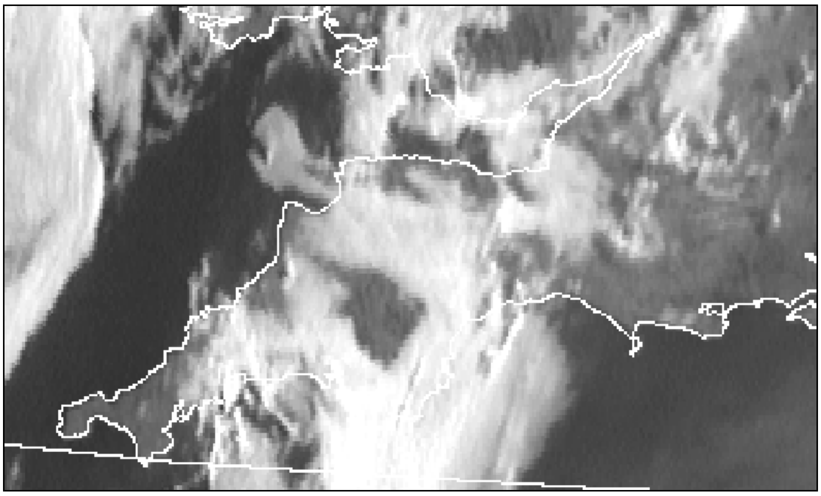


Figure 8. Development of a land breeze during the night.

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.

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.



Extensive early morning fog across Devon and Cornwall. Owing to a temperature inversion, the top of Dartmoor is warmer than the lower land and sea temperature and hence Dartmoor is clear of fog and stands out in this satellite imagery.

Figure 9. 0600z on 30 June 2006 satellite image showing extensive fog across Devon and Cornwall.

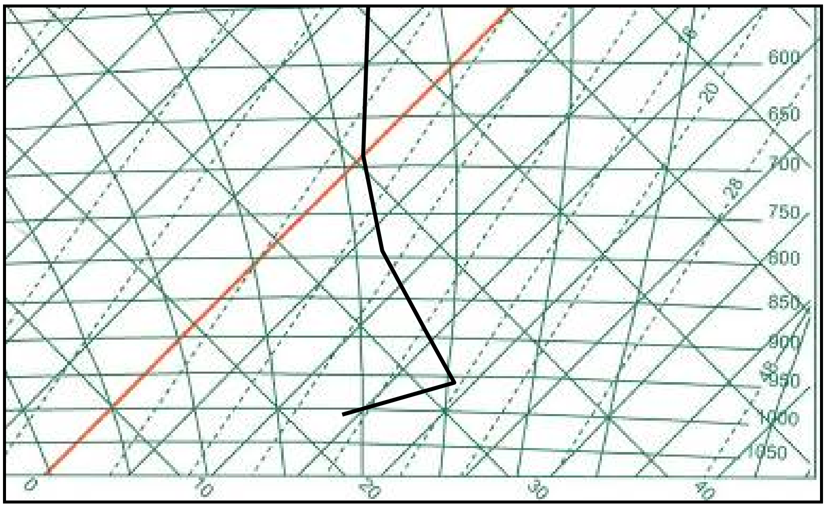


Figure 10. 0000z on 30 June 2006 upper air ascent from Camborne, Cornwall showing a marked surface inversion.

Midnight ascent from Camborne showing the development of a surface temperature inversion. The inversion acts as a lid trapping the cool moist air below it and prevents this air from mixing with the drier air above.

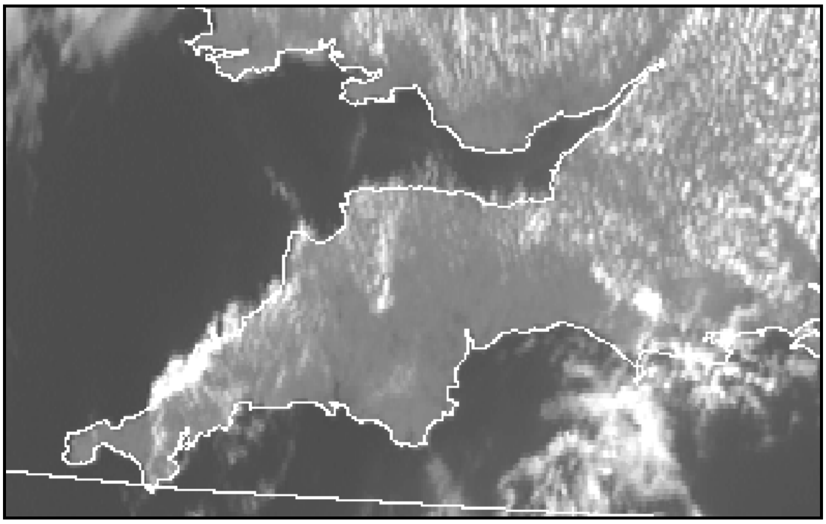


Figure 11. 1200z on 30 June 2006 satellite image showing the clearance of sea fog across Devon and Cornwall.

The early morning fog across Devon and Cornwall had largely dispersed by midday as the surface air temperature was now higher than the fog point.

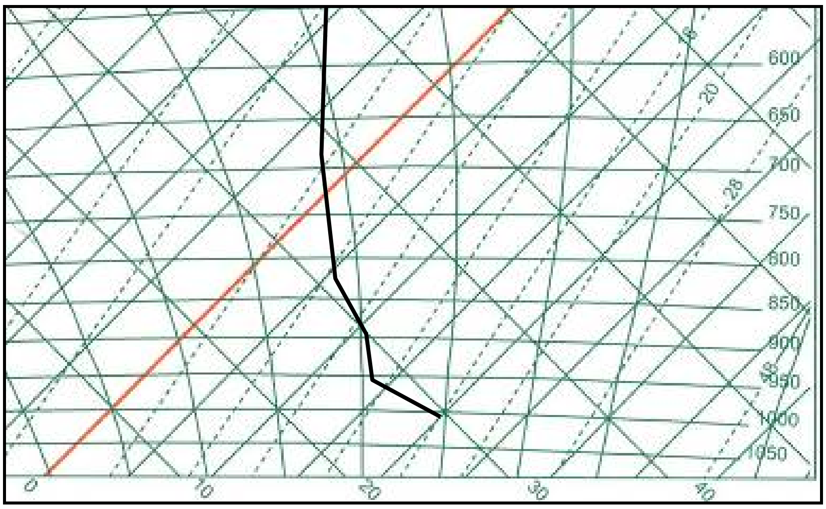


Figure 12. 1200z on 30 June 2006 upper air ascent from Camborne, Cornwall showing no surface inversion.

Midday ascent from Camborne showing no surface inversion. Consequently, the cool moist layer at the surface can now freely mix with the drier and warmer layer above. This mixing has the effect of lifting and dispersing the fog.

Forests

Tropical rainforests cover only about 6% of the 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 13. Temperate forest in Romania.

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 2. 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

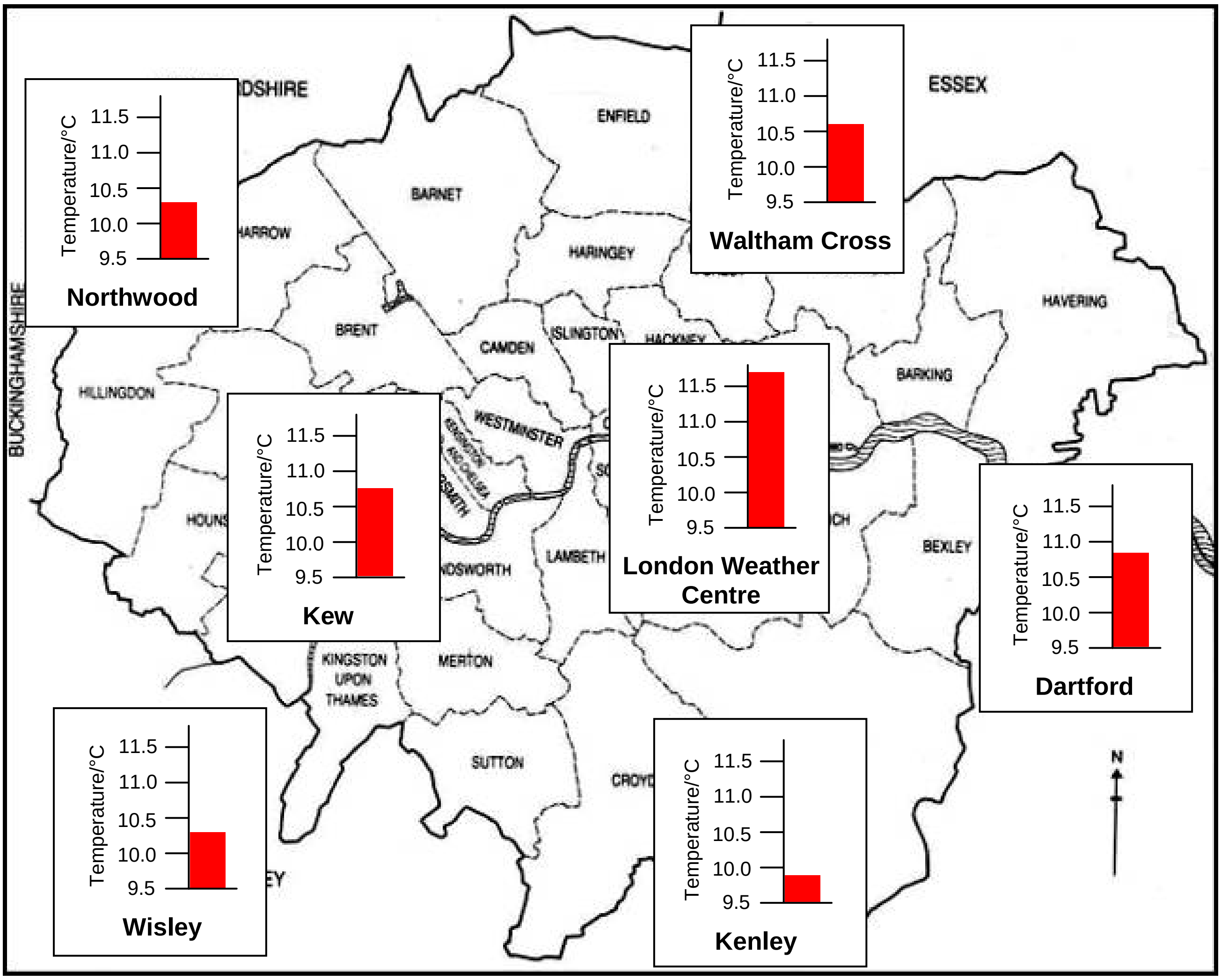


Figure 14. Mean annual temperatures for a number of stations around London.

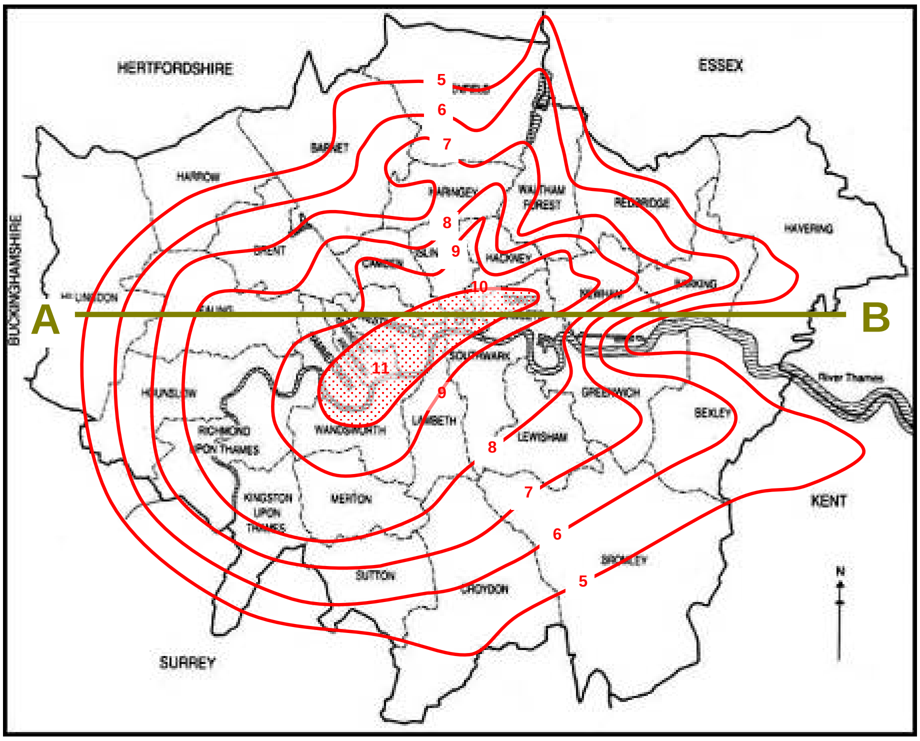


Figure 15. London 'heat island' (minimum temperatures in °C) *[mid-May: clear skies and light winds].*

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.

Indeed, the term urban heat island is used to describe the dome of warm air that frequently builds up over towns and cities.

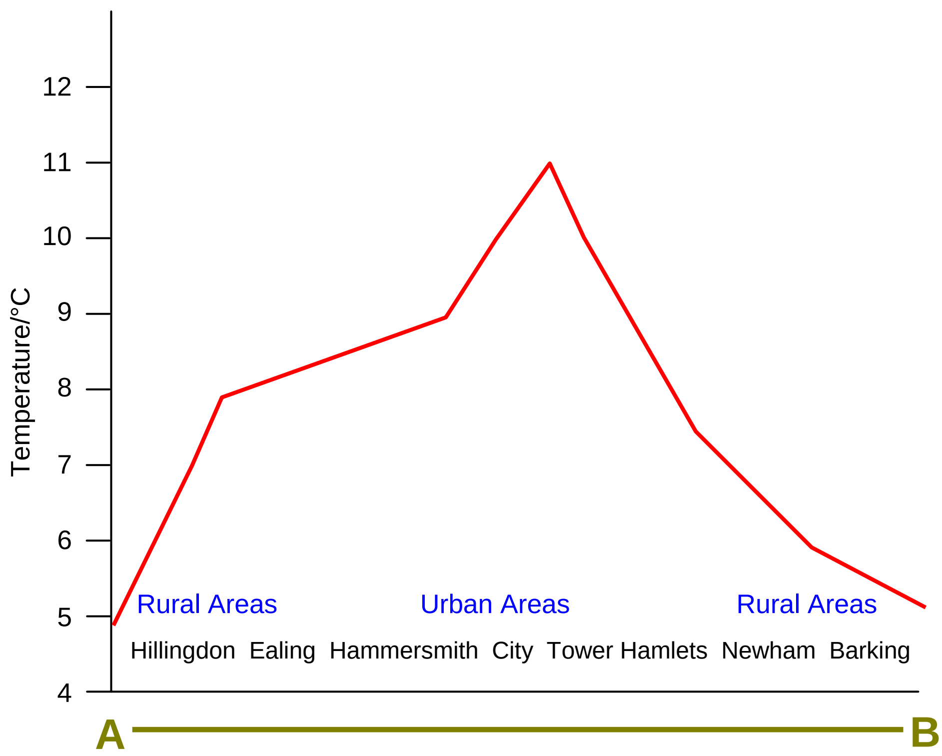


Figure 16. Temperature profile for London.

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 on Figure 11 above).

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. Storms 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.

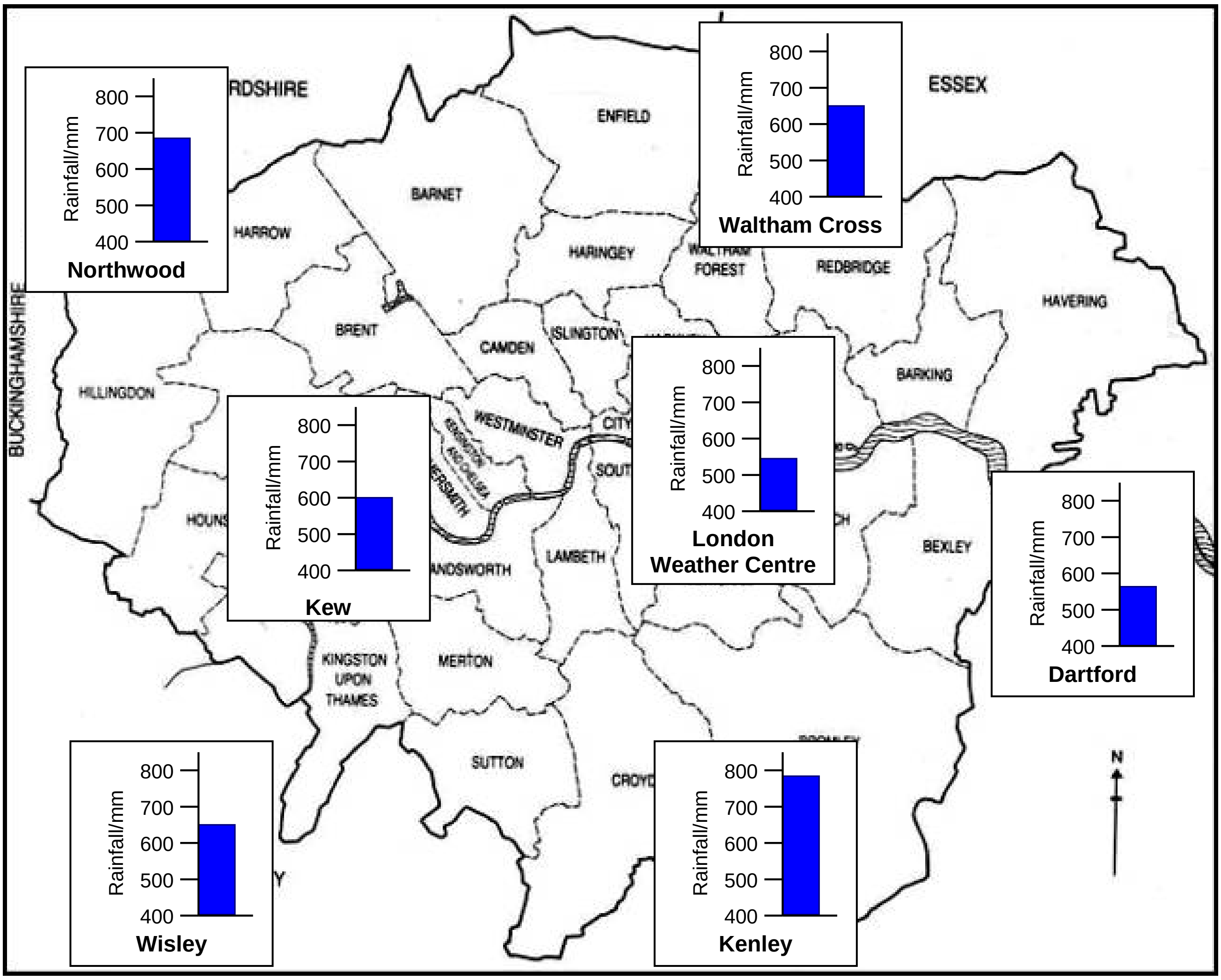


Figure 17. Mean annual rainfall totals for a number of stations around London.

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.

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 UK 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.

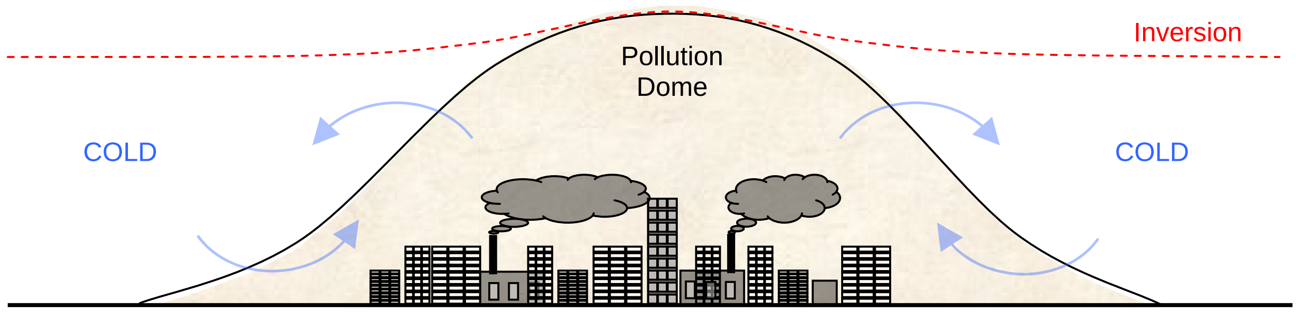


Figure 18. Pollution dome over a city.

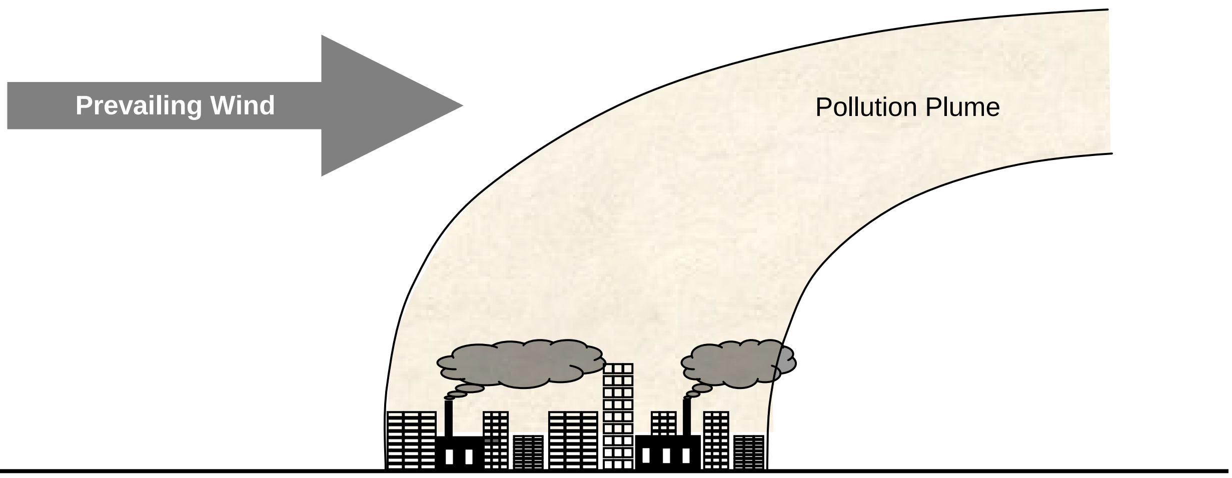


Figure 19. Pollution plume over a city.

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.

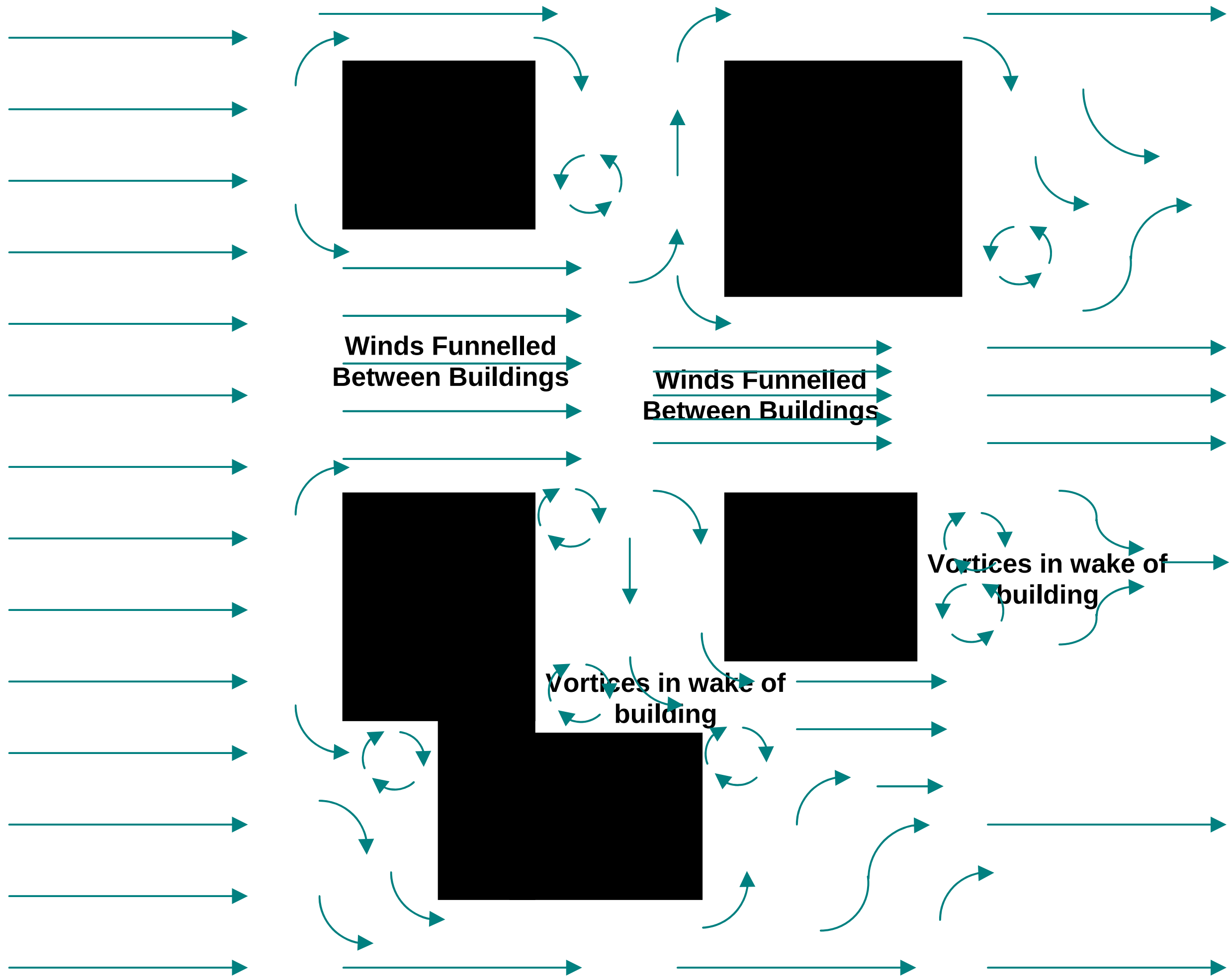


Figure 20. Winds around offices in a city showing the vortices created by the buildings.

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