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Local climate processes in the Illawarra

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Abstract

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LOCAL CLIMATIC PROCESSES IN THE ILLAWARRA

E. BRYANT

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This paper is concerned with the air circulation processes which set the climate of the Illawarra apart from that found in Sydney or on the far south coast. Global air circulation is generated by the necessity to balance the heat surplus at the equator with the deficit at the poles caused by the differential heating effect of the sun with latitude. Superimposed on this general circulation are secondary circulation effects such as high and low pressure cells, cyclones, and fronts. These effects are generated by regional heating or cooling effects over land and water and are controlled in position seasonally by the apparent migration of the sun. On a local scale, air circulation patterns can be generated by differential heating and cooling caused by topographic effects such as mountains, valleys, land-sea boundaries and the works of man. Local climatic processes in the Illawarra can be discussed under 5 headings as follows:

1. Sea breezes
2. Gravity or katabatic winds
3. Slope or anabatic winds
4. *Foehn winds*
5. Industrialization effects

SEA BREEZES

Sea breezes are caused by the daytime heating of a land surface adjacent to a cooler ocean on warmer days of the year. Ocean temperatures off the Illawarra coast lag by 2-3 months behind air temperatures. In summer, water temperatures may be 17-20°C while air temperatures over land might range from 25-40°C. The warm air over the land, heated from below, rises convectionally and is replaced by cooler air lying in contact with cooler ocean waters. This exchange produces a breeze whose speed depends upon the temperature difference between the land and the sea. The breeze can only be generated during the day in warmer seasons when intense heating of the land surface is possible. In the Illawarra a temperature gradient usually becomes sufficiently established by 10.00 o'clock in the morning for a sea breeze to strengthen (Figure 1). A weak front defining the change in temperature between land and ocean air masses develops at the shoreline. This front extends to a height of 500-700m and is often capped by a line of clouds. As heating of the land continues, this front moves progressively landward. By noon it may reach the base of the escarpment and by 1.00 p.m. it usually has reached the top of the escarpment. The sea breeze is rarely followed by return land breezes at night. Instead the sea breeze will gradually die towards midnight and be replaced by calm conditions.

KATABATIC WINDS

In winter time, especially on cloudless still nights, the ground surface rapidly loses heat as outgoing longwave radiation escapes from the earth's surface. Above the escarpment where temperatures are cooler to begin with, because of elevation, a layer of

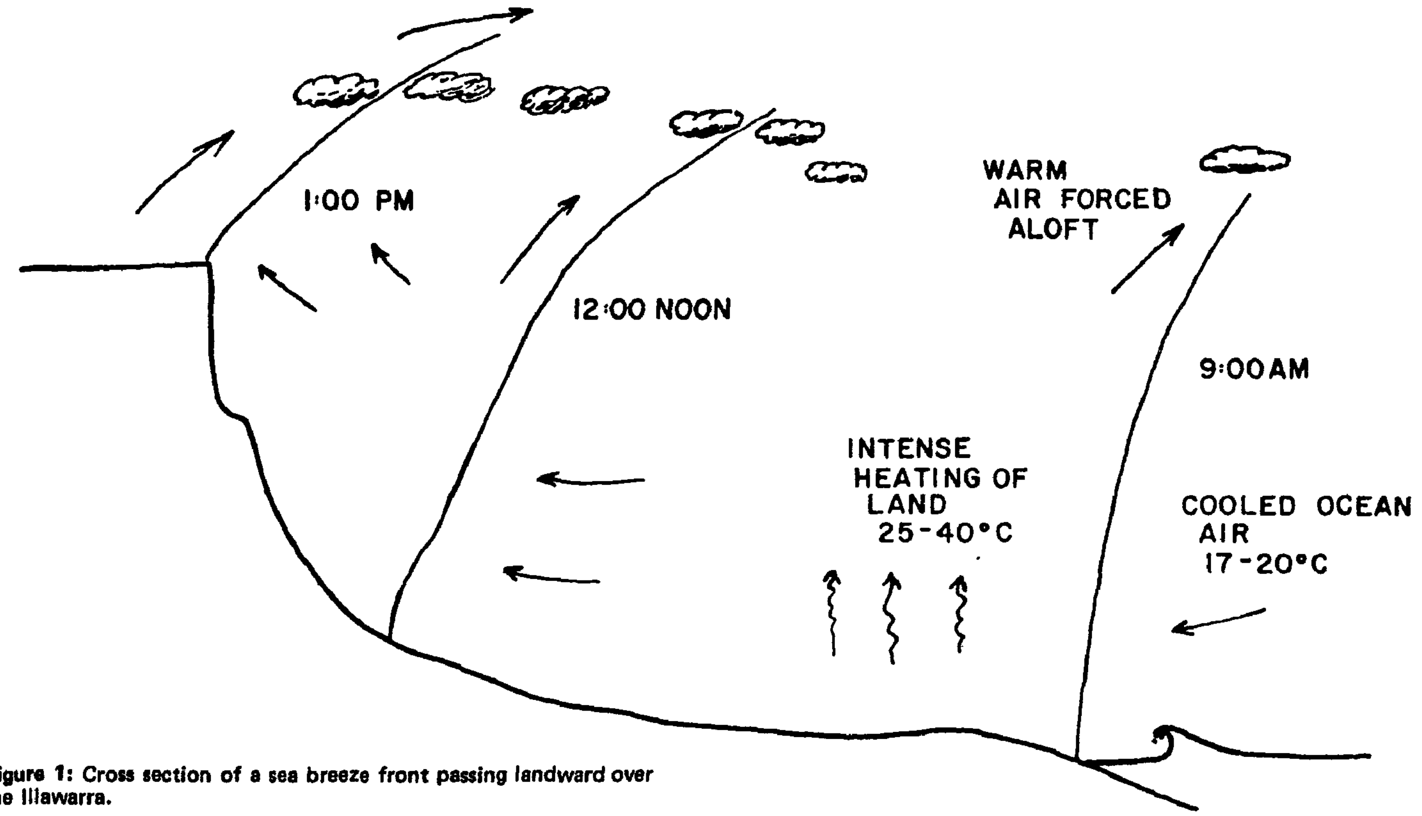


Figure 1: Cross section of a sea breeze front passing landward over the Illawarra.

cold dense air begins to accumulate above the ground surface. This air behaves exactly as a fluid and flows downslope into nearby drainage courses and valleys (Figure 2). Because the movement is induced by gravity these winds are termed gravity winds and the steeper the topography, the faster the wind speed. In the Illawarra these gravity winds are often found after 10.00 p.m. at night seaward of valleys cutting into the escarpment at Stanwell Park, Coalcliff, Macquarie Pass and other scattered locations. Katabatic winds are restricted to the lower 100-200 metres of the atmosphere and are not to be confused with regional westerly winds which will destroy gravity winds by overturning air through turbulence. In this latter situation it becomes impossible for cool air to accumulate near the ground. Gravity winds, once they leave the valleys or reach the ocean, rapidly spread out. Because these winds move downslope they force upwards the warmer air they replace and create local inversion conditions. Inversions, which occur when warm air overlies cooler air, are very stable, prevent any upward movement of air and hence trap pollutants in the lower atmosphere.

ANABATIC WINDS

Anabatic winds are the opposite to gravity winds. Because the sun is positioned to the north, the Illawarra is never directly under the rays of the sun (Figure 3). Instead incoming radiation reaches flat ground at a noon-time angle varying from 11-57 degrees from the vertical. This angle increases towards morning, evening and winter. The slope of land in the Illawarra is not flat but increases progressively westwards up to the vertical face of the escarpment. Many of the footslopes have angles greater than 5-10°. If these slopes face the morning sun, the degree of sun declination is reduced, more radiation is received per unit area, and air temperatures can increase more rapidly than over adjacent flat or southfacing topography. This warm air may rise with sufficient strength to aid and abet seabreeze development. The local wind generated is called an anabatic wind. The process in the Illawarra is very localized. More commonly south-facing slopes receive less radiation than north facing ones and all east-facing slopes receive less radiation in the afternoon. These slopes may be considerably cooler than adjacent areas for part of the day. Along certain sections of the escarpment near Minnamurra Falls, Macquarie Pass and Mt. Keira, shadows are so prevalent that the air remains cool and moist most of the time. These slopes are sheltered from drying westerlies and permit luxuriant growth of rain forest (Bywater, 1979).

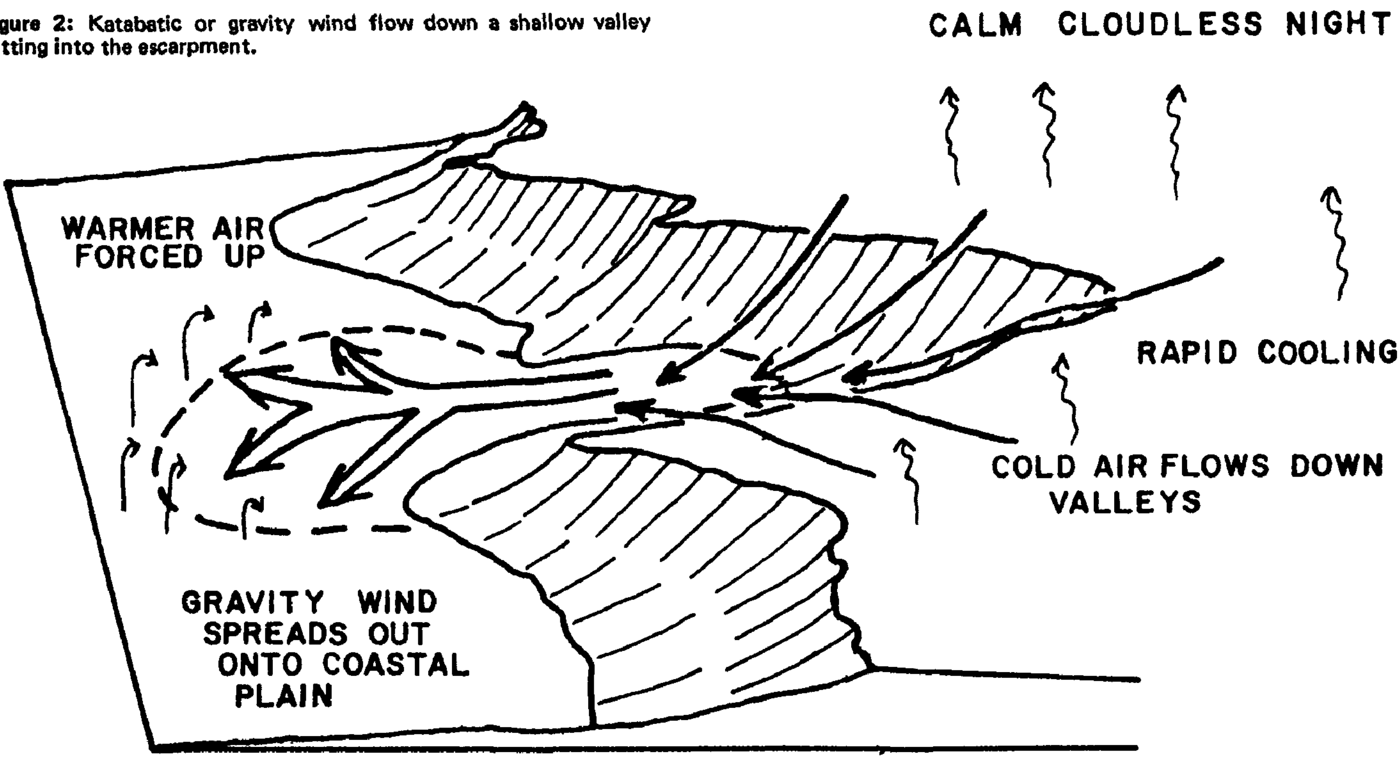
FOEHN WINDS

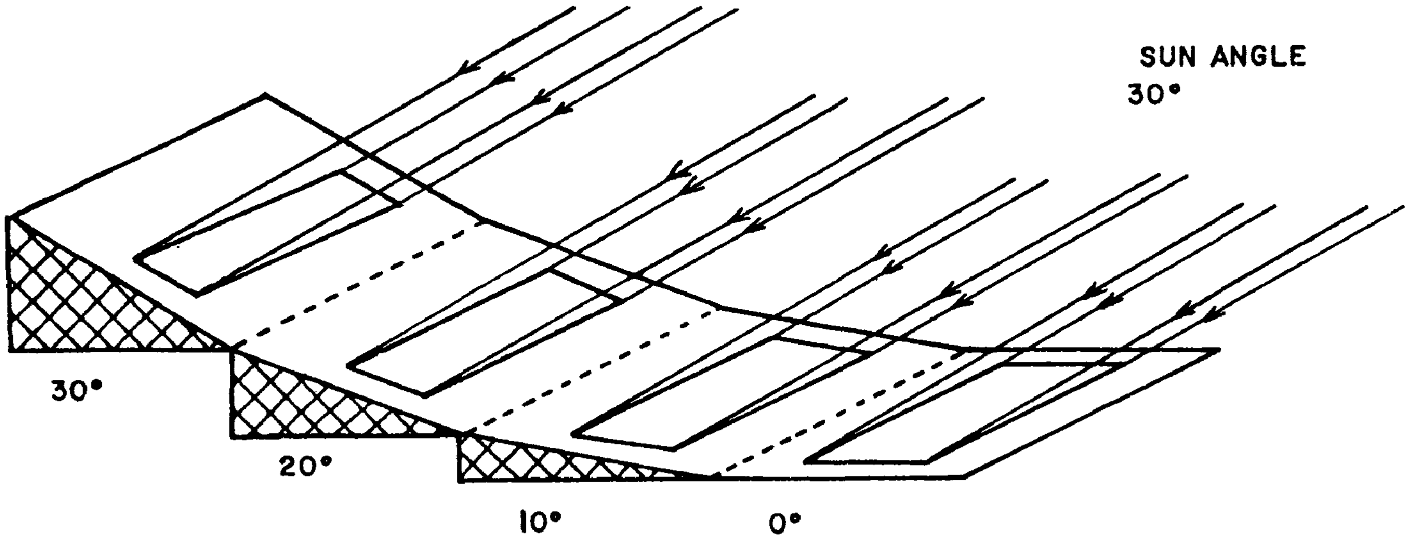
Air generally cools with increased elevation. The average rate of cooling is -10°C/1000 metres elevation. Thus if the air temperature is 20°C at Nowra and Wollongong it will, other things being equal, be 10°C at Mt. Cambewarra and 17°C at Mt. Keira as these points are higher in elevation by 700 and 300 metres respectively. The reverse process also holds. Air warms with decreased elevation. If the air above the escarpment and tablelands is moved down to the coast by regional westerlies, it will warm at the rate of 10°C/1000 metres. This process is called the foehn effect. The tablelands and mountains backing the Illawarra rise from 500-1000 metres above sea level. If air heated over this topography is forced rapidly to the coast it must increase in temperature by 5-10°C. One of the characteristics of the south coast in summer is for temperature to increase southwards under regional northwest winds (Figure 4). The cause can be attributed directly to the foehn effect. In other parts of the world the foehn effect is most noticeable in winter. Even in Sydney the foehn wind operates under winter westerlies. However in the Illawarra the wind is most effective under hot, strong, summer northwesterlies. In winter there is not a dramatic warming of westerlies as they descend the escarpment because turbulence is continually mixing the air vertically. In winter the foehn effect may operate on katabatic winds especially in the northern suburbs of Wollongong. Here gravity forces cold air down the valleys but the air is warmed to such an extent as it moves downslope that it may be 2-3° warmer at the base of the escarpment than air temperatures in adjacent suburbs. This warming may be aided by compression of air down valleys.

INDUSTRIAL EFFECTS

In many large cities, including Sydney, noticeable heating of air over the urban centre occurs relative to adjacent suburban and rural areas at night, particularly in winter. This effect is maximized with high density building within city centres and creates a 'heat island' (see Davey, 1976, 148). Cities also have decreased wind speeds, lower humidities, and greater cloudiness and precipitation. Most of these effects are minor in Wollongong because of the low density of development and the narrowness of the built-up area. There may be a 1-2°C temperature increase towards the centre of Wollongong on calm winter nights and air temperature certainly rises towards the steel works at Port Kembla. However these effects are very localized.

Figure 2: Katabatic or gravity wind flow down a shallow valley cutting into the escarpment.





INCREASE IN SOLAR RADIATION	SLOPE
25%	10°
54%	20°
100%	30°

Figure 3: The effect of heating on slopes. Morning sun angle is 30°. The slopes shown have equal areas. Packets with equal amounts of energy are shown intercepting each slope. This energy is concentrated into smaller areas as slope increases. The higher angle slopes receive more energy in the morning.

The Port Kembla industrial complex also produces water vapour and particulate matter in large quantities. The particulate matter forms nuclei for water vapour condensation such that cloud formation is often generated over the steel complex. If the regional air mass is unstable and rain-producing, then rainfall downwind of the steelworks will be increased. No available precipitation data has been collected to prove this point, but the increased rainfall effect is noticeable at times when one travels through areas adjacent to the steel complex.

The increased particulate component is more important in calm stable conditions. It should be pointed out that the pollution in the Illawarra does not necessarily all originate within the region. Sea breezes, building up daily in Sydney and dissipating at night inland, pile up urban pollutants against the Blue Mountains. Some of this pollution drifts southward over the escarpment into the Illawarra. The effect is most pronounced at Albion Park-Minnamurra. Some of the Sydney brown haze (photochemical pollution) also finds its way out over the ocean (Bell, 1981-82, 14) and blows into the Illawarra under subsequent northeast sea breezes developing the following day.

The localized climatic effects already described enhance air stability because they generate inversions by pushing warm air over the top of cooler air. Under these conditions visible pollution and condensation will increase in magnitude because air is not being recirculated or moved from the region. Sea breezes pond cooler ocean air against the escarpment underneath warmer air (Figure 1). Under these conditions, particulate matter from the Port Kembla industrial complex moves landward and is trapped within a narrow coastal plain and increases in concentration. Summer days in the area are often accompanied by increasing haziness during the day because of this process. The inversion only breaks down temporarily in the early morning of the following day. Katabatic winds can also generate inversions by forcing cold air downslope underneath warmer air. The movement of this air stops 1-2 km beyond the coastline, and industrial particulate matter again can be trapped within the narrow confines of the coastal plain. The effect on calm winter mornings produces a heavy concentration of polluted air extending with decreasing concentrations from 1-2 kms distance over the ocean back to the escarpment top. This haze slowly disperses as the inversion breaks down with daytime heating of the land.

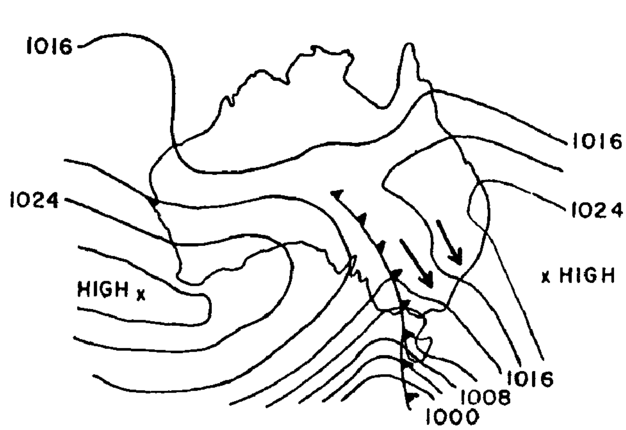


Figure 4: Weather map showing pressure cell pattern generating a foehn wind in the warmer part of the year for the N.S.W. south coast.

SUMMARY

Table 1 compares the localized climatic effects of Sydney and the Illawarra. The Illawarra is often cooled by sea breezes while many parts of Sydney, distant from the coast, are sweltering in summer heat. The escarpment along Wollongong's western edge causes an immediate build-up of pollution under sea breezes which is dispersed daily, while in Sydney pollution may build up progressively to high levels over several days. In summer Wollongong may also be affected more than Sydney by drying northwest winds, and areas near the escarpment on northeast-facing slopes may be warmed more rapidly in the morning. In winter the Illawarra receives katabatic winds which can increase general pollution levels in the area; however, Sydney's katabatic winds are restricted to valleys and may lead to heavy pollution build-up especially along the Parramatta River. Apart from the drying northwest winds in summer, the basic effect of local climatic factors in the Illawarra is for the moderation of climatic extremes. Despite Wollongong's reputation these climatic conditions exacerbate pollution levels less in the Illawarra than in Sydney.

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TABLE 1: COMPARISON OF SYDNEY AND ILLAWARRA WIND REGIMES

CONDITION	SYDNEY	ILLAWARRA
Sea Breeze	- duration decreases with distrance from ocean - movement slowed by topography - causes pollution build-up over several days	- rapid progression across area - often blocked by escarpment - causes daily pollution build-up
Katabatic Wind	- restricted to valleys within Sydney - blocked by heat island over city centre - causes heavy pollution build-up over valleys	- strong localized effect near valleys in escarpment - blocked by air over ocean - causes general pollution over Wollongong area
Anabatic Wind	- very localized (valleys on northeastern and northwestern edges of upland plateaus)	- common along escarpment slopes
Foehn Wind	- winter nighttime phenomenon - restricted to Blue Mountains	- mainly summer daytime phenomenon - affects whole area - affects katabatic wind in northern Wollongong suburbs during winter nights

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