ROYAL METEOROLOGICAL SOCIETY: AUSTRALIAN BRANCH MEETING

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Tropical Cyclones as Natural Hazards:
An Evaluation of Queensland Experience in its Meteorological Context

J. Oliver

The chairman, Dr Dyer, opened the meeting by paying tribute to the late Dr F. Loewe, both as a founding Fellow of the Branch and as a stimulating force in Australian meteorology for many years. In introducing the speaker he said that it was most appropriate that Prof. Oliver was to be the first speaker to address the Branch as he had been a foundation member and second chairman of the Welsh Branch of the Society.

Professor Oliver drew attention to the general belief that scientific knowledge and technological capabilities afford sufficient protection against extreme natural conditions. Where these extremes are relatively infrequent a sense of security develops and the dangers are perceived as of low probability and significance. When a natural event of catastrophic proportions occurs, life and property are seriously endangered or destroyed and a considerable stress is solicited from the individual or the community. The level and nature of natural hazards depend on a number of sociological factors, such as the sophistication of community organisation, the nature of the activities at risk, the density and mobility of the population, the frequency and perception of past experiences, *etc*. All these factors make it difficult to assess an objective rating of the nature and severity of natural hazards and to formulate appropriate protective or precautionary planning.

Since tropical cyclones are natural hazards, it is obvious that their worst effects can be alleviated or avoided by acting upon meteorological advice. But the application of advice is achieved through a double filter related to uncertainties in the details and interpretation of the advice and to a somewhat unpredictable evaluation of the advice by all those who have to act upon it.

Tropical Queensland was lulled into a sense of security by the relative quiescence of tropical cyclone development in the 1960s but was widely shaken by 'Ada', which ravaged the Whitsunday Islands in January 1970; 'Althea', which struck Townsville in December 1971; by the threats of 'Daisy' and 'Emily' in February and April 1972 respectively and by the floods in the Brisbane area caused by 'Wanda' and 'Zoe' in January and March 1974. The impact of these storms on areas where material goods and population are concentrated served to regenerate interest in the tropical cyclone hazard and to stimulate a whole series of responses and actions in terms of attention to building codes, mapping of storm surge risk areas and re-examination of flood protection insurance policies.

The damaging effects of a tropical cyclone come from the furious winds around its centre, floods and storm surges. The greatest potential loss of life and damage to property arises from flood and water damage, whether the floods are of terrestrial runoff or marine origin. At a price, engineering and architectural knowledge is adequate to protect buildings and other structures effectively against wind damage; but the problems of floods, especially storm surges, are more intractable.

Sensible planning at various levels based on intelligent use of meteorological information can do much to minimise or even eliminate adverse consequences of a tropical cyclone. Insurance offers an effective solution to problems of material losses, but in many cases active rather than passive response is required.

These human social or economic responses depend on an adequate understanding of the origin, behaviour and frequency of tropical cyclones. The conditions needed for a tropical disturbance to develop into a tropical cyclone are known. They are strong horizontal wind shear on the poleward side of the equatorial trough and consequential lower level convergence, little vertical shear to 200 mb, concentration of convective instability associated with cloud clusters, a sea surface temperature exceeding 26 to 27^{o}C, upper level divergence overlying the surface and middle tropospheric low. But there are still loose ends to be tied in modelling the full story of tropical cyclogenesis.

Using data from Coleman's (1972) work, Prof. Oliver showed that, of all storms that affected the east coast of Queensland, 76% originated in the latitudinal band 10^{o} to 17.5^{o}S with a marked preference for 12.5^{o} to 15^{o}S, whilst 63% originated in the longitudinal band 147.5^{o} to 157.5^{o}E.

If the position of a developing storm is not accurately determined, its subsequen trajectory is difficult to predict. A tropical cyclone is steered by the compounded gradient wind component between the surface and 9,000 to 12,000 m. The 500 mb wind streamlines give an approximate indication of the resultant wind but the actual steering may be different since the effective steering level tends to rise with more intense cyclones. As the system moves, the influence of deep tropical easterlies changes to that of a circulation pattern which varies with height as it is associated with the jet stream and the wave patterns of the tropospheric westerlies. So, as the systems move to higher latitudes they frequently recurve under the influence of the upper level westerlies. Coleman's tracks indicate that less than half of east Queensland storms follow a conventional parabolic path, whilst the tracks of many others are erratic in nature, with loops and unexpected kinks.

The preferred latitude for tropical cyclones to cross the east Queensland coast from the Coral Sea was found to be in the band 16^{o} to 20^{o}S, although shifts do occur with time.

Tropical cyclones in the Australian region are generally smaller in diameter and weaker than those in the North Atlantic. Cyclones with small diameters are more difficult to detect and track. Few Australian cyclones have had central pressures below 950 mb: the minima recorded are a reputed 914 mb at Bathurst Bay in 1899 and 933 mb at Mackay in 1918. The highest measured gust in northeast Australia was 109 kn at Willis island in 1957. At Townsville the strongest gust (106 kn) was recorded at the airport during the passage of cyclone 'Althea' in 1971.

Professor Oliver also noted some tendency for tropical cyclones to follow longer straight paths towards the south or southeast, hence remaining over oceans, in December, January and April, and for a longer westerly track in February and March, hence with a greater probability of crossing the coast in these two months. There is also a tendency for some apparent shift of landfall to higher latitudes as the season progresses.

The speed of movement is also highly variable. In general the speed, 5 to 10 kn in their earlier life, may increase up to 35 kn in their mature or degenerative phase. In other cases storms can become stationary or even reverse for short periods. Strong winds at a given locality may persist for several hours as the storm moves in and passes on, but the duration of destructive winds may be prolonged if the system is slow moving or is curving back on itself.

Apart from these uncertainties in the genesis and subsequent behaviour of a tropical cyclone there are also possibilities when a tropical cyclone, threatening a locality as it approaches the coast, changes within an hour or two into a cold core rain depression with a sharp decrease of the maximum winds. Among factors that can contribute to a sudden decline of the storm are detachment of the upper-air anticyclone from the main axis of the vortex centre, movement over a land surface, and inflow of cold or dry air into the lower levels. At that stage, however, the depression still retains considerable potential as a natural hazard. Uplift of moist air over high ground near the system's path encourages large rainfalls. Whilst the rainfall rate for many tropical cyclones is 125 to 200 mm/day, that for rain depressions can be 500 to 750 mm/day or more.

Another element contributes to the difficulties of forecasting and civil defence planning. A fully grown cyclone has a well developed banded structure; a number of relatively narrow cloudbands spiral in towards the centre. Beneath these bands, rainfalls are heavier and winds stronger than between them. On either side of the clam eye of the storm the strong winds reverse in direction within 10 to 40 km. Also the wind profile and the extent of gales to the left of the direction of motion differs appreciably from those on the right. This asymmetry takes on different forms for storms over the sea and for those approaching the coast in different directions. Thus marked contrasts can exist over short distances and local topographic conditions introduce still further complexity in producing shelter effects or local wind accelerations.

Problems of planning evasive or precautionary action to deal with tropical cyclones must also be viewed with respect to the more complex possibilities of short term climatic oscillations. An average of 19 cyclones per 10 year period crossed the Queensland coast for the period 1940-1959 as opposed to 8 and 5 in the periods 1920-1939 and 1960-1969 respectively. The increase in cyclone activity in 1940 occurred when the zonal circulation of the extra tropical latitudes was replaced by a more meridional circulation. Changes in the circulation index are related to energy transfer in the troposphere, to the extent of invasion of higher latitude air into the equatorial region and the consequential increase of the horizontal wind shear, and to trans-equatorial flow. In the North Atlantic, whilst the frequency of hurricanes was well above the long-term average from the 1930s to the 1960s, there was a brief interlude about 1940.

Trends for a small area however, differ from those for a larger area of which it it a part. Coleman's data show that, whilst in 1960-1969 few storms crossed the Queensland coast, a higher number occurred in the Gulf area. We cannot therefore expect precisely similar changes within one hemisphere in the long wave patterns in different ocean areas and perhaps less so between hemispheres.

Professor Oliver also noted that in the period 1910-1939, 22% of the cyclones crossed the Queensland coast south of 20^{o}S, whilst of the larger number of storms in 1940-1959, 42% crossed the coast south of this latitude. This pattern suggests yet other steering influences of importance.

Thus the nature and behaviour of tropical cyclones call for more research in order to forecast risk areas with greater certainty and to indicate the magnitude of the immediate threats to the affected areas. The probabilities of different scales of damage require careful analysis so that planners can make rational decisions about the methods of dealing with hazard situations. It may be appropriate to choose one or a number of possibilities - taking a chance, insurance, protective or ameliorative measures, avoidance policies such as evacuation or non-use of seriously threatened localities, modification of the intensity of the cyclone to reduce its impact or attempting to change its development in the initial stages of growth or subsequent movement. The objective scientific analyses of the meteorologist are not always adequately utilised. The decision makers need guidance in the interpretation of the meteorological knowledge; both that which reveals the general situation and that involved in forecasts. Without this knowledge, perception of and response to hazard situations range from panic action to complacency.

In the subsequent discussion, Dr Pittock suggested that, because of their important role in tropical cyclogenesis and maintenance, changes in sea surface temperatures over the various areas could have some relationship to the frequency trends shown. Although he had not looked at this aspect, Prof. Oliver agreed that it could have an important bearing. Dr Smith inquired as to the relative statistics of tropic cyclone eye size in the northern and southern hemispheres. In reply, the speaker said that they were probably comparable, although southern hemisphere data were less plentiful. Prof. Morton commented that satellite and radar observations should eventually give a more precise picture of southern hemisphere storms. Dr Gibbs amplified on these aspects and then went on to outline the role of the Bureau of Meteorology in advice and assistance to authorities in planning for cyclone mitigatio

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REFERENCE

Coleman, F. 1972. *Frequencies, tracks and intensities of tropical cyclones in the Australian region 1909 to 1969.* Meteorological Summary. Bur. Met. Australia.