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Probability of cyclone strike on specific regions of the Queensland coast, given current cyclone position and movement

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Tropical cyclones in the Queensland region generally travel away from the Queensland coast. The probability of offshore cyclones affecting selected Queensland coastal cities is calculated. This probability is much greater if the cyclone has a component of westward motion rather than eastward. If a cyclone is in a certain offshore position and has a component of motion eastwards, the probability of that cyclone ever affecting the chosen city in the lifetime of the storm is very low, in some cases negligible. This may give some forecast guidance beyond the typical forecast period of tropical cyclone movement.

Introduction

Many methods are used to forecast the tracks of tropical cyclones, from statistical techniques based on climatological tracks and persistence of current cyclone movement (e.g. CLIPER; Aberson 1998), to barotropic models (Aberson and DeMaria 1994) and full primitive equation models (Bender et al. 1993; Davidson and Weber 2000). The output of these and other models is combined to obtain a current best forecast track. If the storm may possibly reach land, probability of strike estimates for various locations on land may be compiled from the best forecast track and the past distribution of forecast errors (Jarrell 1978; Templeton and Keenan 1982; Neumann 1987). The US National Hurricane Center issues probability of strike forecasts to the public for individual Atlantic tropical cyclones, with forecasts issued out to 72 hours. The Australian Bureau of Meteorology issues similar forecasts, but only to registered users.

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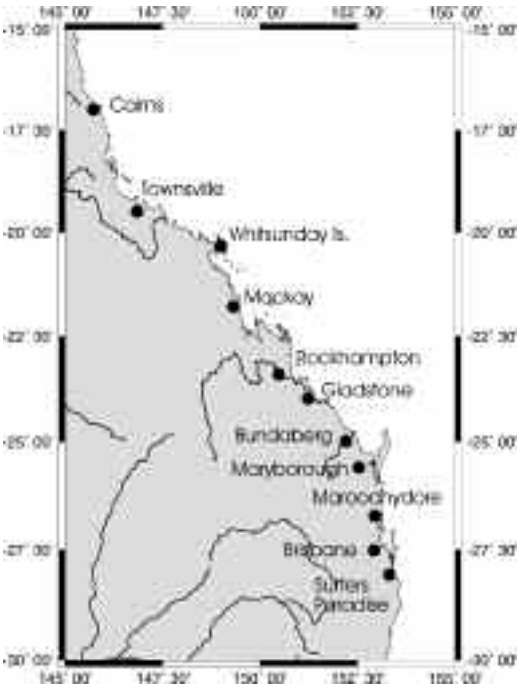
In the Australian region, the climatological track of tropical cyclones off the east coast of Queensland is directed away from the coast, with a pronounced eastward component of motion even for storms in the tropics (Elsberry 1995). Storms that travel on eastward paths would not usually strike the east coast of Queensland. This is unlike the situation in the Caribbean, where the climatological track is westward and may at least permit the possibility of landfall in the US for most storms. Given the orientation of the coast of Queensland (approximately northwest to southeast; Fig. 1), only those storms with a westward component of motion or those whose motion is more southward than eastward would have a chance of reaching the coast.

This suggests that for storms located in certain offshore positions and travelling towards the east, it may be possible to dismiss them as threats to particular coastal locations very early in their lifecycles. Accordingly, this note examines the past movement of tropical cyclones off the coast of Queensland, and associates their direction of movement with a probability that they will ever strike the coast at some time during their lifetimes.

Fig. 1 Map of Queensland, with locations mentioned in the text.



Data analysis methods

Tropical cyclone track data are taken from the Joint Typhoon Warning Center best-track data for the period 1967-1996. The year 1967 represents the start of reliable satellite observations of tropical cyclone location. The region off the Queensland coast is divided into a number of grid boxes 5° on a side, with the exception of those east of 160°E, which span 10° of longitude, and the boxes between 5° and 15°S, which encompass 10° of latitude. The probability that a cyclone will strike a particular location during its entire lifetime once it reaches these grid boxes is then calculated. Probabilities are calculated for the region east of 145°E, south of 5°S, and west of 170°E.

For maximum utility, the probability of a cyclone affecting several coastal Queensland cities or locations is given (Fig. 1). These are Cairns, Townsville, Whitsunday Is., Mackay, Rockhampton, Gladstone, Bundaberg, Maryborough, Maroochydore, Brisbane and Surfers Paradise. It is assumed that a cyclone 'affects' a location if the centre of the storm travels within 200 km of that location. This distance is somewhat arbitrarily chosen, as the geographical extent of tropical cyclone effects varies greatly from storm to storm, but it provides a reasonable estimate of the maximum distance of significant impact. Note that large cyclones can affect the coastline at greater distances than 200 km. We divided the calculation of probabilities of strike into two simple cases, depending on whether the storm's zonal component of motion is eastwards or westwards during the previous six hours (most storms of course also have substantial northward/southward movement at any one time, usually more southwards than northwards in this part of the world). In this way, knowing the current or likely future zonal movement of a cyclone, we can give an estimate of the probability that it will affect a particular location at some point in its entire lifetime, not just within the next 72 hours.

The results are summarised in Table 1 which shows the percentage of all cyclones located in a particular grid box that eventually travel within 200 km of a specified location. This is termed the probability of strike. In some grid boxes, no storms located there have ever affected the location in question. In this case, the maximum probability is calculated by assuming that the probability must be less than one strike for all of the cyclone occurrences in that grid box. For example, if there were 100 cyclone occurrences in a grid box and none of these cyclones had ever affected the location in question, the percentage probability would be specified as <1.

Results

The results of percentage probability of strike, for storms with either westward or eastward components of motion, are contained in Table 1. The probability of strike for each city is discussed in turn.

Cairns

At a longitude of about 145°E, Cairns is at the western edge of the analysed grid boxes. Therefore, there is a clear difference between the likelihood of cyclone effects in Cairns depending upon whether the storm is moving eastward or westward. Storms are generally more likely to strike Cairns if they are moving westwards. The difference is greatest between 150°E and 155°E. As expected, the overall probability of storm strike on Cairns decreases for storms located further east and south of Cairns. For instance, very few storms have ever affected Cairns once they are east of 155°E and south of 20°E. Conversely, a storm that was between 15°S and 20°S and west of 150°E, travelling westward, would have a better than even (54%) chance of affecting Cairns.

Table 1. Probability in % of cyclone eventually travelling within 200 km of the specified location given its current position, delineated by latitude and longitude boxes. Probabilities are calculated based upon whether the cyclone is moving west or east. Bold figures show where no cyclone in that position has ever affected the location in question.

Cairns (16° 57'S 145° 54' E)– cyclone moving west

Lat./Long.	145-150	150-155	155-160	160-170
5-15	29	30	16	10
15-20	54	29	13	2
20-25	24	11	**<2**	**<2**
25-30	Land	**<5**	**<3**	**<3**

Cairns – cyclone moving east

Lat./Long.	145-150	150-155	155-160	160-170
5-15	7	11	10	3
15-20	34	9	4	2
20-25	**<5**	**<2**	**<1**	2
25-30	Land	**<3**	**<2**	**<1**

Townsville (19° 15S 146° 45' E)– moving west

Lat./Long.	145-150	150-155	155-160	160-170
5-15	18	27	22	11
15-20	68	32	14	3
20-25	43	11	**<2**	**<2**
25-30	Land	**<5**	**<3**	**<3**

Townsville -- moving east

Lat./Long.	145-150	150-155	155-160	160-170
5-15	11	12	10	1
15-20	41	11	4	1
20-25	25	**<2**	**<1**	**<0.5**
25-30	Land	**<3**	**<2**	**<3**

Whitsunday Is. (20° 15'S 149° 4' E) – moving west

Lat./Long.	145-150	150-155	155-160	160-170
5-15	4	19	25	11
15-20	37	51	24	10
20-25	71	28	8	**<2**
25-30	Land	**<5**	**<3**	**<3**

Whitsunday Is – moving east

Lat./Long.	145-150	150-155	155-160	160-170
5-15	14	12	10	0.5
15-20	34	27	9	0.5
20-25	70	7	3	**<0.5**
25-30	Land	**<3**	**<2**	**<3**

Mackay (21° 8'S 149° 11' E)– moving west

Lat./Long.	145-150	150-155	155-160	160-170
5-15	4	16	15	11
15-20	24	46	24	10
20-25	71	27	4	**<2**
25-30	Land	**<5**	**<2**	**<3**

Mackay – moving east

Lat./Long.	145-150	150-155	155-160	160-170
5-15	11	13	10	0.5
15-20	24	16	9	0.5
20-25	95	3	**<1**	**<0.5**
25-30	Land	**<3**	**<2**	**<3**

Table 1. Continued.

Rockhampton (23° 22'S 150° 32' E) – moving west

Lat./Long.	145-150	150-155	155-160	160-170
5-15	1	6	9	9
15-20	13	29	29	9
20-25	24	56	14	5
25-30	Land	10	8	2
30-35	Land	No storms	**<10**	**<5**

Rockhampton – moving east

Lat./Long.	145-150	150-155	155-160	160-170
5-15	7	16	9	2
15-20	13	14	14	0.3
20-25	60	23	3	4
25-30	Land	**<4**	**<2**	**<1**
30-35	Land	**<33 (of 3 storms)**	**<3**	**<2**

Gladstone (23° 50'S 151° 17')– moving west

Lat./Long.	145-150	150-155	155-160	160-170
5-15	1	6	9	9
15-20	13	31	28	2
20-25	19	67	10	5
25-30	Land	15	8	2
30-35	Land	No storms	**<10**	**<5**

Gladstone – moving east

Lat./Long.	145-150	150-155	155-160	160-170
5-15	7	16	9	2
15-20	13	14	14	0.3
20-25	60	36	3	4
25-30	Land	4	**<2**	**<1**
30-35	Land	**<33 (of 3 storms)**	**<3**	**<2**

Bundaberg (24° 54'S 152° 22') – moving west

Lat./Long.	145-150	150-155	155-160	160-170
5-15	1	6	1	1
15-20	8	10	7	2
20-25	<5	59	31	5
25-30	Land	40	8	2
30-35	Land	No storms	**<10**	**<5**

Bundaberg – moving east

Lat./Long.	145-150	150-155	155-160	160-170
5-15	2	15	4	2
15-20	5	12	6	0.3
20-25	55	48	7	4
25-30	Land	35	**<2**	**<1**
30-35	Land	**<33 (of 3 storms)**	**<3**	**<2**

Maryborough (25° 31'S 152° 37' E) – moving west

Lat./Long.	145-150	150-155	155-160	160-170
5-15	1	6	1	1
15-20	8	10	7	2
20-25	**<5**	58	31	5
25-30	Land	55	8	2
30-35	Land	No storms	**<10**	**<5**

Table 1. Continued.

Maryborough – moving east				
Lat./Long.	145-150	150-155	155-160	160-170
5-15	2	15	5	2
15-20	0.9	12	6	0.3
20-25	35	43	7	4
25-30	Land	54	**<2**	**<1**
30-35	Land	**<33 (of 3 storms)**	**<3**	**<2**

Maroochydore (26° 29'S 153° 5' E) – moving west				
Lat./Long.	145-150	150-155	155-160	160-170
5-15	1	6	1	1
15-20	8	11	5	3
20-25	**<5**	44	24	6
25-30	Land	80	16	2
30-35	Land	No storms	**<10**	**<5**

Maroochydore – moving east				
Lat./Long.	145-150	150-155	155-160	160-170
5-15	**<2**	4	0.8	2
15-20	0.9	9	3	0.5
20-25	25	28	5	**<0.5**
25-30	Land	75	**<2**	**<1**
30-35	Land	**<33 (of 3 storms)**	**<3**	**<2**

Brisbane (27° 24'S 153° 9' E) – moving west				
Lat./Long.	145-150	150-155	155-160	160-170
5-15	1	6	1	1
15-20	8	7	4	3
20-25	**<5**	32	29	1
25-30	Land	85	16	**<3**
30-35	Land	No storms	**<10**	**<5**

Brisbane – moving east				
Lat./Long.	145-150	150-155	155-160	160-170
5-15	**<2**	4	0.8	**<1**
15-20	0.9	8	3	0.3
20-25	25	13	5	**<0.5**
25-30	Land	75	**<2**	**<1**
30-35	Land	<33 (of 3 storms)	**<3**	**<2**

Surfers Paradise (28° 0'S 153° 25' E) – moving west				
Lat./Long.	145-150	150-155	155-160	160-170
5-15	1	6	1	1
15-20	4	4	4	3
20-25	**<5**	18	25	1
25-30	Land	80	18	4
30-35	Land	No storms	18	**<5**

Surfers Paradise – moving east				
Lat./Long.	145-150	150-155	155-160	160-170
5-15	**<2**	4	0.9	**<1**
15-20	0.9	11	3	0.3
20-25	25	7	7	**<0.5**
25-30	Land	64	**<2**	**<1**
30-35	Land	<33 (of 3 storms)	**<3**	**<2**

Townsville
The results for Townsville are similar to those for Cairns. The only major difference is a strongly increased probability of strike for storms moving east that are located between 145° and 150° and south of 20° (<5% vs 25%). This is probably because Townsville is a little further east than Cairns, and thus storms that are west of Townsville's longitude (147°) but east of 145° can still affect Townsville by travelling east.

Whitsunday Is
In the Whitsundays, we see the same effect discussed for Townsville above: west of 150°E, there is little difference between the chance of a cyclone affecting the Whitsundays if it is travelling east or west. Further away from the coast, however, cyclones are considerably more likely to affect the coast in this location if they are travelling westwards. This is especially true for cyclones east of 160°E, where cyclones are 20 times more likely (21% vs 1%) to hit the coast if they have a component of westward rather than eastward motion. No cyclone in the data record examined has ever travelled within 200 km of Whitsunday Is. if it is south of 25°S, or if it is both south of 20°S and east of 160°E.

Mackay
The results for Mackay are similar to those for the Whitsundays. No cyclone in the data record examined has ever come within 200 km of Mackay once it is south of 25°S, or if it is both south of 20°S and east of 160°E (if it is moving west) or east of 155°E (if it is moving east).

Rockhampton
Compared with the results for Mackay, there is a substantially lower probability of storm effect on Rockhampton for storms located between 145°E and 150°E and moving westwards. This is because Rockhampton is located in the next grid box eastwards, being located at 150° 32' E. Compared with Mackay, there is an increased probability that storms south of 25°S and moving west might affect Rockhampton. Accordingly, for Rockhampton and locations further south, another latitude band has been added (30-35°S). In this latitude band, few storms have occurred in the narrow strip of ocean south of 30°S between the coast and 155°E. Of these, none have ever travelled westward, and only three have travelled eastwards. Larger numbers have occurred at these latitudes further east. No storms in the data record examined have ever affected Rockhampton once they are south of 25°S and moving east. In contrast, for storms moving west in the latitude belt 25-30°S, there has been some cyclone strike on Rockhampton.

Gladstone
The results for Gladstone are similar to those for Rockhampton. One difference is that for storms between 150-155°E and 25-30°S and moving east, there has historically been some impact on Gladstone (a still rather low 4% probability).

Bundaberg
Compared to locations further north, at this latitude there is a greatly increased chance of cyclone effect for storms located south of 25°S. Even so, no storm in the data record examined has ever travelled within 200 km of Bundaberg if it is moving east, is south of 25°S and east of 155°E. East of 155°E, it continues to be usually much more probable for a storm to affect this location if it is travelling west rather than east, provided that it is already south of 20°S. North of this latitude, there is less systematic difference in the strike probability on Bundaberg between eastward travelling and westward travelling storms.

Maryborough
The results for Maryborough are similar to those for Bundaberg.

Maroochydore
In common with the analysis for Maryborough and Bundaberg, no storm in the data record examined has ever travelled within 200 km of Maroochydore if it is moving east, is south of 25°S and east of 155° E. This is also true for Maroochydore for storms moving east that are south of 20°S and east of 160°E. South of 20°S, strike probabilities are still considerably higher for storms moving westwards, except very close to the coast.

Brisbane
The results for Brisbane are similar to those for Maroochydore. There is a somewhat reduced probability of strike on Brisbane compared with Maroochydore for cyclones moving east that are in the grid box 20-25°S, 150-155°E (13% vs 28%).

Gold Coast (Surfers Paradise)
The results for the Gold Coast are similar to those for Brisbane and Maroochydore, except that the probability of strike for storms travelling west that are also south of 30°S increases substantially because of the higher latitude of the Gold Coast region.

Conclusion

For many locations along the Queensland coast, once a tropical cyclone is in a certain position offshore and

has a component of motion eastwards, the probability that it will affect that location becomes very low. Strike probabilities can be much higher for storms with a westward component of motion. This may give some forecast guidance beyond the usual 72-hour tropical cyclone outlook period.

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