RAINFALL CLIMATOLOGY OF SOUTH EASTERN QUEENSLAND

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1 INTRODUCTION

The weather of southeastern Queensland (SEQ) can be described by a wet season from October through to March and a dry season from April through to September with the highest falls occurring during summer along the coast north and south of Brisbane. The rainfall tends to decrease away from the coast in all months. Rainfall in this area has been declining for the past fifty years and climate projections indicate decreasing trends in annual rainfall and increases in temperature.

As a consequence of these changes the region has experienced water stress. As part of the response to this stress the Queensland Government in December 2006 announced a four-year Queensland Cloud Seeding Research Program (QCSRP) to understand the microphysics of these clouds and to assess the feasibility of cloud seeding in SEQ. This program is a collaboration between national and overseas research groups involving aircraft, radiosonde and radar measurements. During 2008 there have been two field campaigns involving advanced radar and research aircraft observations. The field program has included the selection of more than 60 cloud systems for randomised seeding with salt particles to induce warm rain processes. Statictical analysis of the randomised cases will determine the basic impacts of seeding. This analysis of the local impact of seeding needs to be put into a broader context of the larger-scale environment in which the clouds form. In particular, it will be instructive to determine the synoptic-scale weather regimes associated with specific cloud-scale and micro-scale processes.

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2 RAINFALL CLIMATOLOGY

A comprehensive climatology of the clouds and precipitation is an initial step that underpins the QCSRP. To construct this climatology the spatial and temporal variability of the rainfall was investigated over the SEQ region using daily rainfall data from the Bureau of Meteorology (BOM) spanning the period from 1995 to the present, which is taken to be the area east of 151°E and lying between 29°S and 26°S.

In order to understand the rainfall variability of the region, we first consider the monthly rainfall at Alderley (27.4181S, 153.0025E) situated near Brisbane Airport. This site has a good-quality rainfall record over the period since 1995 and, at an elevation of 153 m above sea level, it is representative of the region near the coast. Figure 1 shows the seasonal variation of the rainfall of the region. The peak rainfall occurs in January and February, with mean values of about 4 mm/day. The lowest rainfall occurs in July, with less than 1 mm/day. However, there is large variability and very high daily rainfalls can occur in winter, as well as in summer. The most rain days occur in January, when there is a 30% chance of rain on any day. This probability falls away so that there is only a 10% chance of rain in the winter months of July and August.

Having considered the temporal variability of rainfall near Brisbane, it is now useful to investigate the spatial variability. Figure 2 shows that monthly total rainfall across the SEQ region averaged over the period from 1995 to 2007. The interpolation between sites is carried out using a simple Kriging algorithm. As found at Alderley, there is a summer maximum in the rainfall across the region, with the highest falls occurring near the coast north and south of Brisbane. The rainfall tends to decrease away from the coast in all months. Significant rainfall over the catchments tends to be limited to the summer months for October through to March, with falls over 100 mm only in the period of November to February.

The reason for the strong gradient in rainfall

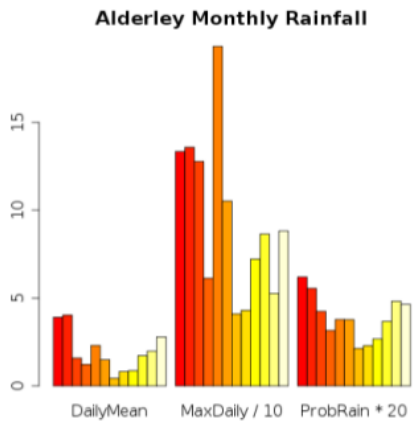

Figure 1: Seasonal variation of monthly rainfall at Alderley averaged over the period from 1995 to the present; bars represent the monthly values of mean daily rainfall (mm), maximum rain (mm/10) over the period, and the probability of rain (x20) on any day of the month.

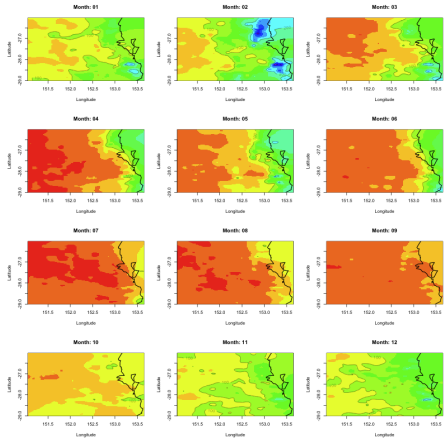

Figure 2: Maps of mean monthly total rainfall across SEQ averages over the period from 1995 to 2007; contours are 25 mm apart and the 100-mm contour is labelled.

away from the coast is explained at least in part by the orography of the region. As along all the eastern coast of Australia, the terrain rises to the ridges of the Great Dividing Range, with a maximum elevation of about 1000 m in the south of the region. The areas of maximum monthly rainfall correspond to the areas of steepest topography. The monthly rainfall tends to decrease to the west of the ridges around 152°E.

3 SYNOPTIC REGIMES AND RAINFALL

In order to understand the rainfall variability of SEQ, it is useful to consider the impact of the different weather patterns or synoptic regimes on the regional rainfall. Conner and Bonnell (1998) show that radiosonde data can be used to classify rainfall regimes along the Queensland coast, and a similar approach is taken here.

Radiosonde measurements from Brisbane airport for the same period were analysed to determine the influence of some key air mass variables on precipitation. The air mass variables chosen for inclusion were inversion height, total-totals, 850mb winds, wind shear between 850mb and 500mb, moisture flux and total water calculated from the standard-level sounding data at Brisbane Airport. The wind vector (U,V) at 850 hPa provides information on the basic dynamical flow, particularly whether the flow in onshore (easterly) or offshore (westerly). The Shear variable indicates whether raining systems are likely to be susceptible to shearing forces, and the Total-totals variable is a simple measure of the stability of the atmosphere. The water flux vector (QU, QV) is expected to be important in determining the amount of moisture available for rainfall in the region, and the total water is a measure of the water in the atmosphere at a given time.

Before analysing the different regimes, it is useful to consider the seasonal variation of each of the variables, and these variations are shown in Figure 3. It is seen that the strongest seasonal cycle is in the amount of moisture in the atmosphere (TW) and in the atmospheric stability variable (TT). In particular, TW and TT are both much lower in the winter; that is, the atmosphere is drier and more stable at that time. While the average stability is greater in the winter, it is apparent that TT values comparable with those in summer can occur in winter. In addition the highest values of TW tend to occur in January and February. Moreover, the wind regime tends to be from the south-east in these months, and more westerly winds in the winter months.

Figure 3 separates the days in 2008 from the earlier years, in order to identify whether the conditions during the first field phase of the QCSRP were normal. It is apparent that January of 2008 was especially moist with higher south-easterly water fluxes than normal. However, by March the environment seemed to be returning to normal conditions. These assessments are confirmed by inspection of Figure 4, which shows the spatial variation of rainfall across SEQ during 2008. Comparison of Figures 2 and 4 shows that January and February were extremely wet months, with the mean rainfall decreasing perhaps below normal by March. The start of the second field phase, October and November, is also drier than normal.

K-means clustering (Hartigan and Wong, 1979) of the upper air and the rainfall identified three dominant rainfall regimes. A westerly winter regime comprising 25% of all rainfall events characterised by westerly winds and widespread rain with a westerly moisture flux; a north-westerly monsoon regime comprising approximately 20% of all events also with a westerly component to the moisture flux accounts and which is associated with average rainfall and occurs most commonly during the first half of summer; and most commonly a south-easterly trade wind regime which accounted for approximately 55% of all events. The south-easterly trade wind regime which can be split into two types. The most common type is associated with low areal rainfall coverage with moderate rainfall, the moisture fluxes being aligned with the wind vectors. The second type is associated with easterly winds, heavy widespread rain and a northerly component to the moisture flux.

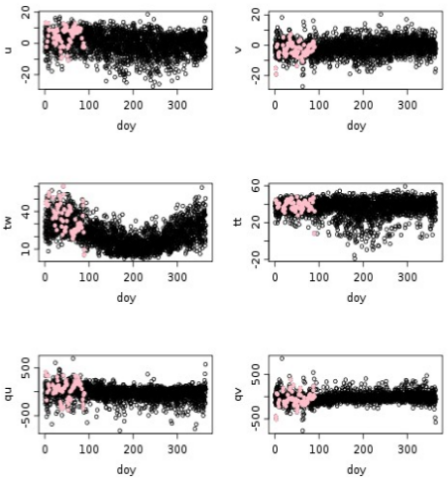

Figure 3: Seasonal variation of environmental variables over the period from 2000; the days for 2008 are coloured pink.

4 SYNOPTIC REGIMES AND CLOUD SEEDING

The QCSRP has so far undertaken two field campaigns during 2008 and 2009 and has collected data for more than 50 randomised seeding cases. Analysis of these cases should provide information on the types of clouds that are best suited to seeding, based on cloud structure. In particular, it is of use to know how many storms in the target area are suitable on each suitable day, and what the seasonal rainfall totals are for these clouds. In this way, a basic assessment of a cloud seeding program over the region can be made. Such cloud-scale analyses will be derived from comprehensive radar data, currently being undertaken by Dr Justin Peter at Monash University and the Bureau of Meteorology.

It will also be useful to extend the cloud-scale analyses to investigate the meso-scale and synpotic conditions associated with clouds suitable for seeding. These investigations will build on the synoptic analysis described in Section 3, and they should enhance the understanding of the physical basis of cloud seeding. Moreover, by linking cloud seeding suitability to predictable synopyic features, the analyses should enhance the operational aspects of a cloud seeding program by providing a means for predicting the occurrence of suitable conditions some hours to days ahead.

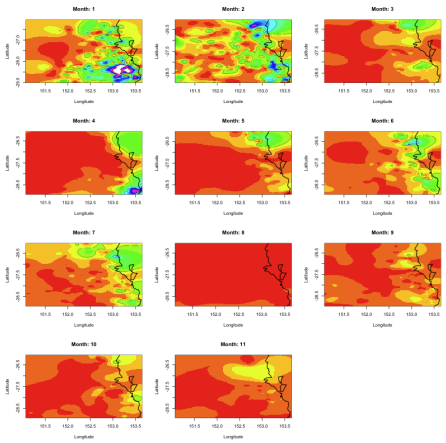

Figure 4: Deviation from mean rainfall across SEQ in 2008; contours are separated by 25 mm

5 POTENTIAL IMPACTS OF CLOUD SEEDING

Analysis of the radar and aircraft data from the field phases of QCSRP should quantify the impact of seeding on clouds at the cloud scale and the mirco-scale. However, the area of seeded cloud is generally only a fraction of a water catchment area, over which rainfall needs to be enhanced. One question to be considered is whether the impact of seeding, detectable at the cloud level, can be detected from the surface network of rain gauges. The second question is the estimation of the amount of seeding that would need to be done to yield a useful increase in rainfall across a catchment, recognising that the definition of useful will vary from application to application.

The results of these analyses will enable statistical studies to be carried out on the probability that seeding effects can be detected in the 'noise' of natural variability and whether seeding could have an economic impact on the overall water balance of the region.

6 CONCLUSIONS

An initial analysis of the climate of the south east Queensland (SEQ) region has been carried out in order to support planning and implementation for the Queensland Cloud Seeding Research Program (QCSRP). It is apparent that the rainfall is largely limited to the coastal strip, with maxima near regions with steep terrain. The main rainfall regime is from November through to February, with peak falls tending to be in February.

The daily rainfall data can be combined with data from the routine radiosondes of the Bureau of Meteorology to identify major weather regimes for SEQ. Useful information can be obtained by only four regimes; in particular, heavy rainfall events associated with easterly flow are separated from the dominant south east trade wind regime. More sophisticated analysis will refine these regimes.

This initial analysis will also provide a foundation for detailed examination of results from the field campaigns of the QCSRP. In particular, it will be necessary to determine the synoptic-scale weather regimes associated with the detailed micro-physical and radar observations of the field campaigns.

REFERENCES

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Hartigan, J. A. and Wong, M. A.: 1979, *Applied Statsitics* **28**, 100