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Severe Thunderstorms over northeastern Queensland on 19 January 2000

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1. INTRODUCTION

On 19 January 2001 a band of severe thunderstorms moved through the Burdekin (Ayr-Home Hill) area of northern Queensland just after 0800 GMT (6 pm local time) causing widespread damage More than 26,200 lightning strikes were recorded in one hour, which is an Australian record. This was an unusual event as severe thunderstorms are almost unheard of in this area. This paper investigates the meteorological circumstances leading to the formation of the storms and, in particular, the possible role of an upper-level trough and an inland heat low.

The first echoes appeared over the Dividing Ranges to the west of Townsville at 0230 GMT. By 1130 GMT the cells had developed further and merged to cover a large region inland from the coast and a second storm complex had formed to the south of the Gulf of Carpentaria (Fig. 1).

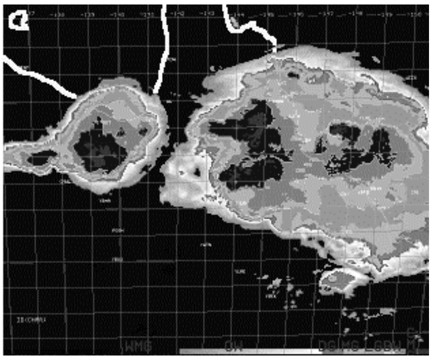

Fig. 1. Enhanced GMS satellite imagery for 1130 GMT on 19 January 2001.

The study is based on an analysis of data obtained from the European Centre for Medium Range Weather Forecasts (ECMWF), complemented by satellite imagery and other observational data. The distribution of Convective Available Potential Energy (CAPE) and Convective Inhibition (CIN) are calculated to examine the utility of these quantities as indicators of storm genesis and severity**.** The possible influence of an upper-level trough on the storms and on the distribution of CAPE is examined also. Theoretical calculations by Juckes and Smith (2000) indicate that the approach of an upper trough can significantly enhance the CAPE and also decrease the CIN.

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2. Data Source and Analysis

Our study is based on ECMWF operational model data sets with 60 vertical layers in σ-coordinates and 1°×1° horizontal resolution, interpolated from spherical harmonics into latitude and longitude grid points. We define a region zonally from 130° E to 170°E and meriodinally from 0° S to 40° S, which includes the east part of the Australian continent and part of the southwest Pacific Ocean. Pressure level data are used to calculate the ageostrophic wind at 925 mb and to plot the vertical velocity at 850 mb. We examine the Mean Sea Level Pressure (MSLP) analyses, orography. The CAPE and CIN are calculated using model data and appropriate values are compared with the sounding at Townsville at 2300 GMT on 18 January. Forecasts of accumulated convective precipitation, based on 3 GMT and 12 GMT analyses and produced every 3 hours, are used to estimate how well the thunderstorms were captured by the ECMWF model. Hourly Japanese Geostationary Meteorological Satellite (GMS) imagery and Bureau of Meteorology radar data provided information on the evolution of the thunderstorms.

3. Synoptic situation

The MSLP distribution at 0600 GMT over eastern Australia showed a low over the continent and one over the Tasman Sea (Fig. 2). These systems were separated by a ridge located over the Dividing Range just inland from the coast. Fandry and Leslie (1984) found that surface heating and orography are important in the formation of the trough over northeastern Queensland and the ridge formation over the Dividing Ranges.

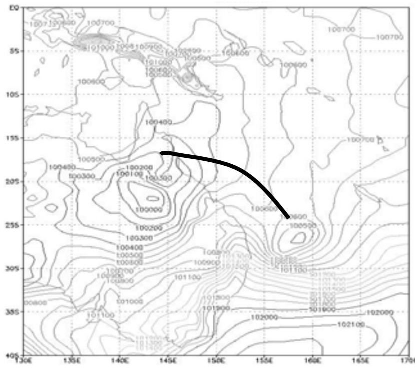

Fig. 2. Mean Sea Level Pressure over the Eastern Australia (with unit of Pa) at 0600 GMT. The contour level is 1 mb. The thick solid line corresponds to a frontal trough.

A vertical-cross section of potential temperature at 0000 GMT on 19 January shows that the low over the continent has the structure of a heat low, with the

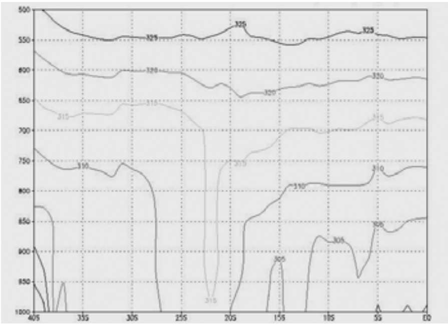

Fig. 3. Meridional height cross-section of potential temperature through the centre of the heat low over northern Queensland, at 0600 GMT on 19 January.

warmest air and deepest mixed layer near the centre (Fig. 3). A weak frontal trough extended from the heat low to the low over the Tasman and was moving slowly northwards. The first thunderstorms formed in the vicinity of this trough. The 925 mb ageostrophic wind (arrows) and 850 mb vertical velocity (shaded) fields showed that there was strong low-level ageostrophic convergence and therefore ascent in the region of the trough and the heat low (Fig. 4).

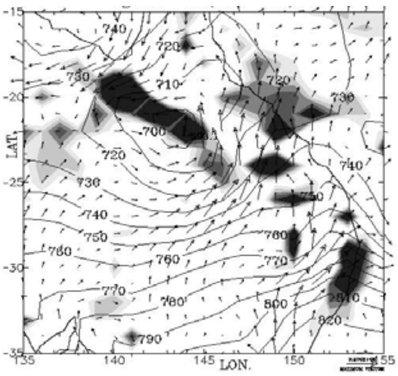

Fig. 4. Ageostrophic wind at 925 mb (in m s^{-1}) and 850 mb vertical velocity (Pa s^{-1}) at 0600 GMT on 19 January. The reference vector corresponds to a wind speed of 20 m s^{-1}. Vertical velocities less than -0.1 Pa s^{-1} are shaded with a contour interval of 0.05 Pa s^{-1}.

During the generation of Burdekin thunderstorm an upper-level trough moved northwestwards into the region of formation. Temperature analyses on isobaric surfaces between 500 mb and 300 mb indicated significant cooling with this trough as exemplified by the 500 mb analysis at 0600 GMT on 19 January.

4. CAPE AND CIN

CAPE values at 0000 GMT on 19 January were generally higher throughout the region of interest as this is mid-morning in eastern Queensland. In particular there were relatively high values (exceeding 2000 J kg^{-1}) over the ranges and the Burdekin area. There was a small region of enhanced CAPE south of the Gulf of Carpentaria also. At higher latitudes, significant values of CAPE were found only within the region of the upper-level trough. The formation of deep convection in regions of high CAPE requires the removal of the CIN. At 1800 GMT on 18 January, values of CIN were significant (greater than 25 J kg^{-1}) over much of the eastern part of the Australian continent, but over the

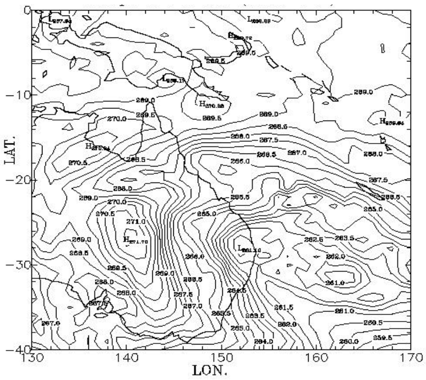

Fig. 5. Temperature at 500 mb (K) with a contour interval of 0.5 K on 18 January to 1200 GMT on 19 January.

ocean to the immediate east of the continent, the values were less than 5 J kg^{-1}. Six hours later, the CIN was almost everywhere less than 5 J kg^{-1} even over the continent, presumably because of strong surface heating over the continent during this period.

The ECMWF forecasts predicted the pattern of convective precipitation over the Burdekin area well, but not that to the south of the Gulf of the Carpentaria. We are unable to compare the predicted precipitation amounts with observations.

4. CONCLUSIONS

A favourable condition for the initiation of the Burdekin thunderstorms was apparently the existence of strong ageostrophic low-level convergence towards an equatorward-moving frontal trough. The trough formed part of a low that developed over the Tasman Sea some 1500 km to the southeast, and it extended into a heat low on the western side of the Dividing Ranges, to which there was also low-level ageostrophic convergence. The ECMWF analyses as well as the morning radiosonde sounding for Townsville indicated little or no CIN in the region prior to the formation of the storms, presumably because of strong surface heating during the morning. The analyses indicated also locally elevated values of CAPE (> 1500 J kg^{-1}) in the region where the storms formed. The mid- to upper-level cooling associated with the temporary equatorward extension of an upper-level trough at the analysis time closest to that of storm formation would have contributed to these high CAPE values and these locally high CAPE values would have contributed to the severity of the storms.

7. ACKNOWLEDGEMENT

This work was supported by the US Office of Naval Research through Grant No. N00014-03-1-0185 and a stipendium to the first author from the Deutsch Akademischer Austauchdienst (DAAD). We are grateful to the ECMWF for providing the analysis data.

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