An analysis of the likelihood of meteorological conditions suitable for downburst thunderstorms over Tasmania using the BARRA reanalysis

By
Dongye Zha

Supervisor: Stuart Corney, Paul Fox-Hughes, Nick Earl and Peter Love
Bachelor of Marine and Antarctic Science (with Honours)
University of Tasmania

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Declaration

I declare that this thesis contains no material which has been accepted for the award of any other degree or diploma in any tertiary institution, and that, to the best of the my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of this thesis.

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Dongye Zha
10th July 2020

Abstract

This project will determine the downburst thunderstorms over Tasmania from the Severe Storms Archive, investigate the atmospheric condition during those downburst thunderstorms and determine the probability of meteorological conditions suitable for downburst thunderstorms over Tasmania during 1990-2019. This project will use the recently completed Bureau of Meteorology Atmospheric high-resolution Regional Reanalysis for Australia (BARRA) dataset, which offers more than 100 atmospheric model variables at higher resolution in space and time than existing global reanalyses (Jakob et al. 2017). The hourly temporal resolution, 70 levels vertical resolution and 1.5 km horizontal resolution, which has been developed specifically for Tasmania and other three regions, makes it particularly powerful in comparison to larger scale reanalyses for analysis of short-term phenomena like thunderstorms and their environments in Tasmania.

High resolution atmospheric regional reanalysis datasets can provide temporally and spatially continuous weather data so that we can determine the reliability of the weather conditions.

The atmospheric conditions of the dry downburst thunderstorms are mainly concentrated in the development of steep low-level lapse rates and hot sub-saturated surface level. In general, the milder thunderstorms are not accompanied with strong gusts, but there are sometimes powerful destructive thunderstorms in Tasmania. These thunderstorms can produce the high-speed gusts, which is in the driving of the dry downburst structure. This kind of thunderstorm with destructive gusts, although it appears in Tasmania, is still relatively low (20% AEP). These devastating downburst thunderstorms pose a greater threat to people's daily lives than the less severe thunderstorms.

Because frequent strong west winds in Tasmania and the surrounding sea are unobstructed, gusts are very likely to occur. However, because the annual temperature change in Tasmania is not very large, it is not easy to form a very severe downburst thunderstorm. In addition, Tasmanian westerly winds combined with the undulating terrain are also prone to form very severe downhill winds. Simply using Downdraft Convective available potential energy (DCAPE) has a great limitation to fully reflect the occurrence of downburst thunderstorms. Expect the DCAPE we need to WINDEX, and GUSTEX to assess the potential for the damaging wind gusts and can test their intensity. The values of DCAPE> 900 J / kg, WINDEX[2]> 20 m · s and GUSTEX[3,4]> 27.8 m · s-1 can be used as the criteria for identifying downburst thunderstorms. Overall, I expect this project will help governments and residents prepare for storm events in advance to reduce the loss of life and property.

Key word: Downburst thunderstorms; meteorological conditions; likelihood.

Acknowledgments

First of all, I would like to sincerely thank my dear supervisors, Dr. Stuart Corney, Dr. Paul Fox-Hughes. Dr. Nick Earl and Dr. Peter Love. I deeply appreciate them for the valuable help and instructive guidance throughout this year. Their professional advice and patient guidance have been the direction of my efforts throughout the past years.

Then, I would like to express my sincere gratitude to go to Dr. Louise Newman for her wonderful proof-reading.

Special thanks to The Bureau of Meteorology high-resolution atmospheric reanalysis for Australia (BARRA) and link to Bureau's Data Catalogue (http://www.bom.gov.au/metadata/catalogue/view/ANZCW0503900566.shtml?template=full). They did a great job in the high-resolution reanalysis data and that why this project is existing.

Last but not least, my thanks would go to my beloved family for their unwavering support and love for the longest time.

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Part One: Literature Review

1 Background

A severe thunderstorm swept through Melbourne's downtown and its surrounding areas on November 21, 2016 (Thien et al. (2018). The area covered by the thunderstorm system had a strong downdraft and gust front. Because thunderstorms occurred in urban areas with high population density, asthma caused by high rye grass pollen particles in the air caused 9 deaths, and more than 8,500 people were hospitalized for treatment (Grundstein, Shepherd, Miller, & Sarnat, 2017). The sudden asthma incident has brought great panic to residents' lives and has brought significant pressure on Melbourne's local medical system. This time, Melbourne's asthma thunderstorms are the most serious in the global record (Billings, 2017). The severity of the thunderstorm asthma in Melbourne and its geographical proximity to Tasmania have raised significant concerns about the possibility of epidemic thunderstorms breaking out in Tasmania (Campbell et al., 2019). Conditions that caused thunderstorm asthma in Melbourne were moving south and passing through northern Tasmania (Burnie and Launceston) without increasing the rate of asthma-related illnesses, which is in contrast to the severe asthma outbreak in Melbourne (Campbell et al., 2019). This may because the pollen overload doesn’t coincide with thunderstorms in Tasmania (Billings, 2017). The Tasmanian government issued its first thunderstorm asthma alert on November 15, 2017.On the day of the test, high pollen count and forecast thunderstorm had the potential for epidemic thunderstorm asthma occur in southern Tasmania (Billings, 2017). But there had been no increase in asthma-related incidents across the state (Billings, 2017) and A previous study by Campbell et al. (2019) showed that the asthma happened from 2002 to 2017 in Tasmania had no relationship with local thunderstorm weather. Although no casualties are a good thing, we have to think about the key factors that thunderstorm asthma does not occur in Tasmania under the same high pollen conditions. In the context of climate change, better understanding of the meteorological conditions suitable for downburst thunderstorms over Tasmania and the potential risk is important for directing public health policy. Finding the downburst thunderstorm meteorological environment that causes thunderstorm asthma is the key to eliminate the worry that Epidemic thunderstorm asthma may happen in Tasmania. This can be done through Bureau of Meteorology high-resolution Regional Reanalysis for Australia (BARRA) data in over the past three decades. Such an analysis will allow us to determine the likelihood of thunderstorms asthma may occur in Tasmanian and help the improvement of the thunderstorm asthma alert.

Downburst can do harm on people by the Epidemic thunderstorm asthma, but the associated wind gusts may be dangerous in their own right. As sudden and small-scale event, the Downburst thunderstorm will bring severe gusts which is also very destructive. Downburst thunderstorms also caused numerous air crashes, such as the plane crashed in 30 November 1961 happened in Botany Bay caused 15 people died. Wind gusts can reach about 185 km/h during a downburst thunderstorm (Brian & Australian Bureau of Statistics, 2008). The Server thunderstorm frequency in Tasmania is not low. In general, thunderstorms are most common in northern Australia, the most damaging thunderstorms, in terms of wind gusts, occur in the eastern halves of Australia. Some parts of eastern Tasmania receiving about five thunderstorms per year. The storms impact us on Cutting power, uproot large trees, make damage to houses, cars and people and fallen trees closing roads. Severe gusts of wind can put people's lives at risk. At Bureau of Meteorology (BOM) website we can see that there have been a number of unclassified severe storms over the past 30 years. There have strong wind and had made lot of damage and even killed people’s life. Those storms may be downburst thunderstorms, is very impotent to determine and understand the frequency of such event in Tasmania and understanding its formation mechanism in Tasmania, so that we could better prevent such event will bring us more harm. Tasmania is chosen as a testcase, but the methods and results apply nationally.

2 Atmosphere areological diagrams (Sounding)

Profiling the atmosphere is the best way to observe atmospheric stability, using tools such as atmosphere areological diagrams (also known as Sounding). Take the Soundings on 21 November 2016 from Melbourne Airport at 0000 UTC as example to see the stability of atmospheric. According to reports, some people need asthma treatment before the rains caused by thunderstorms (Nasser & Pulimood, 2009). This is because strong gusts of thunderstorm outflows may spread respirable-sized allergic pollen particles to surrounding areas before thunderstorm-induced rainfall occurs (Taylor & Jonsson, 2004). These respirable-sized allergenic particles are wrapped in raindrops and carried away from the high altitude along downdrafts. Small particles are exposed to air in the subcloud dry-adiabatic layer as precipitation evaporates. This concentration of small particles, which can trigger asthma, is concentrated in densely populated areas. They can spread out as the storm flow out. This showed the storm in thunderstorm asthma events is a downburst with a significant thick dry layer.

We can see the atmospheric soundings before the thunderstorm to determine the characteristics for the strong downdraft's potential. The spacing between the environmental temperature and the dew point temperature in the same level is directly related to the dryness of the atmosphere. We can see there have two dry adiabatic layers in the sounding. one is the in the high altitude (8500m-6000m above the ground level) and another is the Medium altitude (3500m-500m above the ground level). When the humid ascending airflow enters the higher dry layer, the density becomes larger due to the disturbance, which forms a preliminary downdraft. When this down flow moves downwards, the three kilometres (From 1000 to 700 hPa) of subcloud dry-adiabatic layer under the high cumulonimbus cloud, which is extremely consistent with the dry adiabatic layers of the dry downburst. So, we can find that the weather conditions of thunderstorm asthma in Melbourne and other areas are very similar to the dry Downburst in the thunderstorm.

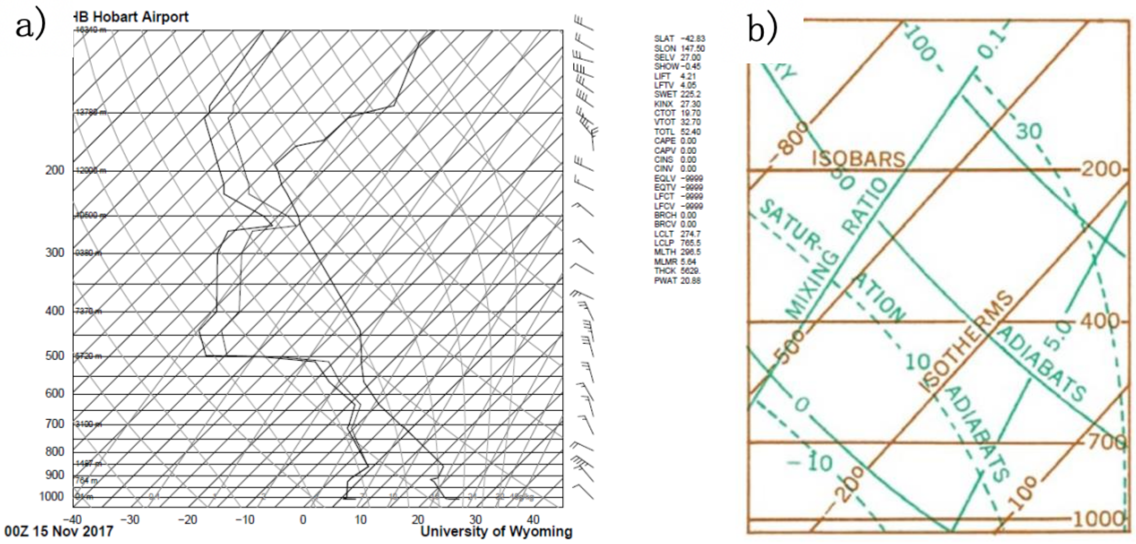

Figure 1 (a) Soundings on 21 November 2016 from Melbourne Airport at 0000 UTC (data source: (University of Wyoming, 2019)). Thin straight lines: isotherms °C, horizontal axis; thick lines: ambient temperature (Left) and dewpoint temperature (Right); and thin bending curves: dry adiabatic and saturated adiabatic lines. Pressure levels and Heights are show on the left vertical axis. The numbers inside the figure represent the mixing ratio of water vapour (gkg$_{-1}$). Wind barbs are given on the right; half barb: 5ms$_{-1}$ and full barb: 10ms$_{-1}$ (De Meutter et al., 2015); (b) The background for the Soundings, with the dry adiabatic lapse rate; saturated adiabatic lapse rate. mixing ratio of water vapour; isobars; isotherms and air pressure.

Downward Convective Available Potential Energy (DCAPE) is proportional to the energy of a sinking saturated air parcel when it arrives to the surface, which provides an estimation for the maximum energy of the downdraft, outflow wind, supposing that it was caused only by thermodynamic processes. The starting level is the pressure level between 800 and 500 hPa with the lowest equivalent potential temperature (which is often the driest mid-level). Theoretical air descending parcel plot line is used to determine the DCAPE. Essentially what this does is takes a parcel of air at the 700 mb and ascends it into the atmosphere to tell us what the temperature of that parcel of air is (in theory) if we put it to a certain level. It is supposed that the sinking air parcel remains saturated all along parcel's path (until it reaches the surface).

Firstly, follow the Dry Adiabatic Lapse Rate at 700 mb for the air temperature and follow the mixing ratio of water vapour line at 700 mb for the dew point temperature. Where these two lines meets is the Lifted Condensation Level (LCL) for the 700 mb. At this point the air contains 100% humidity and is saturated and will now ascend up through the atmosphere at the Saturated Adiabatic Lapse Rate. After that the air mass is sinking and it is supposed that the sinking air parcel remains saturated all along its path (until it reaches the surface). Such as the figure 4(b) in the part two, Theoretical air descending parcel plot line is from this LCL point following the moist adiabat on sounding down to surface (solid rad line). The area between the Theoretical air descending parcel plot line and environmental temperature curve equals DCAPE.

Parcel cooler than environment means high DCAPE and instability of air which will result in outflow. With high DCAPE values larger than 1000 J/kg, damaging winds easily transported downward and spread out at the surface level. Evaluation of DCAPE is an important way to test if downdraft wind happened. And to determine the downburst thunderstorm Environmental conditions must be considered. Then we need to
Wind Index (WINDEX) designed by McCann (1994) to estimate the maximum strength of the divergent wind near the surface adjacent to a microburst and wind gust index (GUSTEX) is a modified index upload Geerts (2001) by that combines the WINDEX with upper-level (in 1-5 km above the ground) wind speed. We will show the details in the method of the part

two. Use the indexes to find and determine the downburst thunderstorm is also a limitation, of course, because they can sometime miss important but unusual information or find some event that not the downburst thunderstorm. So, we need to test the event we find by the method above by seeing the BOM's radar data and satellite images.

3 Cold trough and Cold pool

A trough is an extended region of relatively low atmospheric pressure area, often associated with fronts. Troughs may be at the surface, or aloft, or both under various conditions. Most troughs bring clouds, showers, and a wind shift, particularly following the passage of the trough (Deguara, 2004). This results from convergence or "squeezing" which forces lifting of air behind the trough line (Holton, 1973). A trough is marked as a dashed line extended from a low-pressure centre or between two low pressure centres. a cold trough is like the dashed line in the Figure 4c in the part two. Ryan and Wilson (1985) suggested that prefrontal troughs were responsible for convective initiation in southeast Australia because 50% of thunderstorms cause by the prefrontal cold troughs.

Cold pools represent the collective outflow of individual convective cells and the negative buoyancy of parcels within or beneath the convection. Sublimation and/or melting and evaporation of precipitation falling through unsaturated air, precipitation drag, and vertical perturbation pressure gradients are all factors that may enhance downdraft development and cold-pool strength (Corfidi, 2003). The periphery of a cold pool, that is, the gust front or outflow boundary, is marked by low-level convergence and ascent (Charba, 1974; Craig Goff, 1976). As a result, gust fronts are often the site of new cell development.

Dry air is associated with the formation of a strong cold pool, which can cause the developing convective system and evolved into storm. Johns (1990) noted the presence of large dewpoint depressions at 700 and 500 hPa in the vicinity of downburst thunderstorm, and the ingestion of dry air from the pre-storm environment can assist in the formation and maintenance of downdraft wind by enhancing storm-scale buoyant pressure fields and their associated gust-front (Corfidi, 2003).

4 Bureau of Meteorology Atmospheric high-resolution Regional Reanalysis for Australia (BARRA)

The Bureau of Meteorology Atmospheric high-resolution Regional Reanalysis for Australia (BARRA) is a high-resolution multi-decadal atmospheric reanalysis. The reanalysis provides 100 output variables and is available at hourly time steps, which contains information about surface conditions (such as temperature, precipitation, wind speed and direction, humidity, evaporation and soil moisture), information at pressure and model levels, and information on solar radiation and cloud cover. The reanalysis suite is based on the Australian Community Climate Earth-System Simulator (ACCESS) and extends 70 levels in vertical direction (up to 80 km) into the atmosphere. It is nested within the required boundary and/or initial conditions provided by ERA-Interim reanalysis, Operational SST and Sea Ice Analysis, and the Bureau offline soil moisture reanalysis (Bureau of Meteorology, 2019b).

The produce contains 5 datasets. The "regional" dataset BARRA-R with approximately 12-km resolution. And 4 "subdomain" datasets area contains South-West Western Australia, South Australia, Eastern New South Wales and Tasmania (Bureau of Meteorology, 2019b). BARRA-R provides a realistic depiction of the meteorology at and near the surface over land as diagnosed by temperature, wind speed and precipitation. It shows closer agreement with point-scale observations and gridded analysis of observations, than leading global reanalyses. In particular, BARRA-R improves upon ERA-Interim global reanalysis in several areas at point-scale to 25 km resolution. BARRA-R shows reduced negative biases in (point-scale) 10 m wind speed during strong wind periods, reduced biases in (5 km gridded) daily temperature maximum and minimum, and higher frequency of very heavy precipitation days at 5 km and 25 km resolution. Few issues with BARRA-R are also identified; some of which are common in reanalyses, such as biases in 10 m wind, and others that are more specific to BARRA such as grid point storms. Some of these issues could be improved through dynamical downscaling of BARRA-R fields using convective-scale (1.5-km) models (Su et al., 2019).

The dataset we used in this project is one of the ‘subdomain’ datasets BARRA-TA is dynamically downscaled analyses at 1.5-km resolution. These have been developed using multiple convective-scale (1.5-km) downscaling analyses driven by the 12-km system (Bureau of Meteorology, 2019b).

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Part Two: Manuscript

An analysis of the likelihood of meteorological conditions suitable for downburst thunderstorms over Tasmania using the BARRA reanalysis

Dongye Zha[a], Stuart P. Corney[a, c], Paul Fox-Hughes[c], Nick Earl[a,d] , Peter T. Love[a,b]

[a] *Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia*

[b] *Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania, Australia*

[c] *Bureau of Meteorology, Hobart, Tasmania, Australia*

[d] *School of Earth Sciences, The University of Melbourne, Melbourne, Victoria, Australia*

Abstract:

This project will determine the downburst thunderstorms over Tasmania from the Severe Storms Archive, investigate the atmospheric condition during those downburst thunderstorms and determine the probability of meteorological conditions suitable for downburst thunderstorms over Tasmania during 1990-2019. This project will use the recently completed Bureau of Meteorology Atmospheric high-resolution Regional Reanalysis for Australia (BARRA) dataset, which offers more than 100 atmospheric model variables at higher resolution in space and time than existing global reanalyses (Jakob et al. 2017). The hourly temporal resolution, 70 levels vertical resolution and 1.5 km horizontal resolution, which has been developed specifically for Tasmania and other three regions, makes it particularly powerful in comparison to larger scale reanalyses for analysis of short-term phenomena like thunderstorms and their environments in Tasmania.

High resolution atmospheric regional reanalysis dataset can provide temporally and spatially continuous weather data so that we can determine the reliability of the weather condition. The atmospheric conditions of the dry downburst thunderstorms are mainly concentrated in the development of steep low-level lapse rates and hot sub-saturated surface level. In general, the milder thunderstorms are not accompanied with strong gusts, but there are sometimes powerful destructive thunderstorms in Tasmania. These thunderstorms can produce the high-speed gusts, which is in the driving of the dry downburst structure. This kind of thunderstorm with destructive gusts, although it appears in Tasmania, is still relatively low (20% AEP). These devastating downburst thunderstorms pose a greater threat to people's daily lives than the less severe thunderstorms.

Because frequent strong west winds in Tasmania and the surrounding sea are unobstructed, gusts are very likely to occur. However, because the annual temperature change in Tasmania is not very large, it is not easy to form a very severe downburst thunderstorm. In addition, Tasmanian westerly winds combined with the undulating terrain are also prone to form very severe downhill winds. Simply using Downdraft Convective available potential energy (DCAPE) has a great limitation to fully reflect the occurrence of downburst thunderstorms. Expect the DCAPE we need to WINDEX, and GUSTEX to assess the potential for the damaging wind gusts and can test their intensity. The values of DCAPE> 900 J / kg, WINDEX,2> 20 m · s and GUSTEX3,4> 27.8 m · s-1 can be used as the criteria for identifying downburst thunderstorms. Overall, I expect this project will help governments and residents prepare for storm events in advance to reduce the loss of life and property.

Key word: Downburst thunderstorms; meteorological conditions; likelihood.

1 Introduction

1.1 Downburst thunderstorm and gust front

1.1.1 formation of the Downburst thunderstorm

A Downburst is a strong downdraft from high altitude with the wind rapidly flowing out of a thunderstorm on or near the ground (Doswell, 2001; Fujita, 1990). Downburst in thunderstorm originates from the convection structures of air. Initially, the warm and moist air masses rise in the atmosphere. Like the figure 1, During the ascent these rising air masses cool rapidly until they are saturated. Further uplift leads to condensation, an instability that causes precipitation in the high air (Bluestein et al., 1989; Holton, 1973). Air masses with high airborne density will enter the next stage of storm formation: convective downdraft. The downdraft completes the convective overturning loop by cooling and drying the boundary layer during the descent. Once the downdraft reaches the ground, it expands and creates a gust front on its leading edge (Charba, 1974; R. M. Wakimoto, 1982). As the gust front spreads around, the warm, humid air at the bottom is lifted to its level of free convection, triggering new convection to support the maintenance of the thunderstorm(R. Wakimoto, 2001; R. M. Wakimoto, 1982).

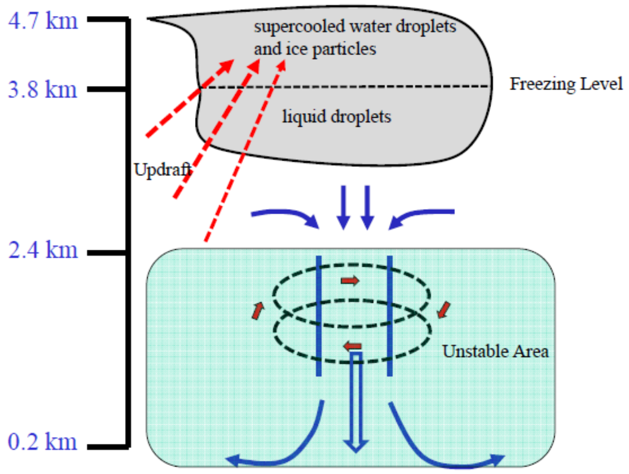


Figure 1 Schematic of the formation of the downburst (right) (Wang, Chandrasekar, He, Shi, & Wang, 2018).

The downdraft is initially nearly saturated, but as it falls into the lower troposphere and mixes with drier air, strong evaporational cooling may occur. This cooling accelerates the downdraft (because of negative buoyancy), which spreads out horizontally as a cold pool (gust front) on reaching the surface. If the diverging outflow winds reach severe levels (greater than about 50 km), the event is referred to as a downburst or microburst. This life cycle (min to complete, and generally severe weather such as high winds or hail tends to be short-lived. Also, should mention rapidly moving air masses contribute momentum to gusts, so in many cases damaging wind gusts result from the vector sum of the downdraft and the airmass movement. These downdrafts are referred to as macro-bursts or microbursts, depending on their size. A macro-burst is more than 4 km (2.5 miles) in diameter and can produce winds as high as 60 metres per second, or 215 km per hour (200 feet per second, or 135 miles per hour). A microburst is smaller in dimension but produces winds as high as 75 metres per second, or 270 km per hour (250 feet per second, or 170 miles per hour) on the ground.

1.1.2 The type of downburst thunderstorm

In general, downburst can be divided into two types (Figure 2): dry and wet microburst: Downburst events are classified as wet downburst and dry downburst depending on the amount of precipitation in downburst events. The dry downburst is usually produced in high-basis rain clouds or altocumulus clouds (R. M. Wakimoto, 1985), while wet downburst are usually associated with thunderstorms that extends through the depth of the troposphere (Atkins & Wakimoto, 1991; Straka & Anderson, 1993).

As the right of the figure 2, Dry downbursts occur when the ambient temperature lapse rate below the cloud base is close to dry adiabatic or even super adiabatic in the layer of air of order tens of meters thick adjacent to the ground (R. M. Wakimoto, 1985). As the downdraft going down in the relatively dry environment, the temperature first increases following the moist-adiabatic lapse rate until all raindrops evaporate, after which the temperature follows the dry-adiabatic lapse rate, which can be seen in the sounding for the dry downburst. And the sounding of the wet downbursts is different (the figure 2 left), which have the shallower subcloud dry-adiabatic layer and the moister surface boundary layer (Billings, 2017; Proctor, 1989).

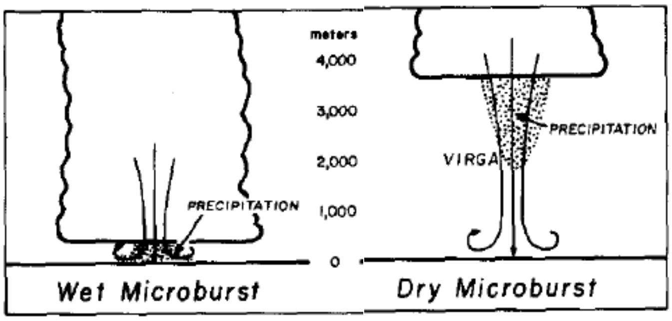


Figure 2 The two types of the microburst clouds (Fujita, 1990)

1.1.3 Thunderstorm in Tasmanian

According to the thunderstorms recorded in the state, destructive gusts may occur (Allen & Karoly, 2014). Tasmanian topography and predominantly westerly flowing air masses affect the occurrence and location of thunderstorms throughout the state. When these westerly flowing air masses are lifted by the terrain as they blow from the ocean to the land, this kind of air masses rising can promote the formation of thunderstorms under some conditions (Campbell et al., 2019). But as these westerly winds over the Tasmanian Mountains and descended along the terrain to the South-eastern part of Tasmania, the formation of thunderstorms became difficult, making thunderstorms less common in the area (Campbell et al., 2019; Kuleshov, De Hoedt, Wright, & Brewster, 2002). Although the relevant thunderstorms are less common, they can cause great harm to people once they occur. And more likely to affect people in the more densely populated areas of southeast Tasmania. Exploring the recent record of strong thunderstorm events in the Tasmanian region (Table 2) will benefit us to better determine whether there will be a thunderstorm in the region similar to the severe thunderstorm event that occurred in Melbourne on November 21, 2016. Although the relevant thunderstorms are less common, they can cause great harm to people once they occur. So, explore the recent record of strong thunderstorm events in the Tasmanian region (Table 2) is benefits for us to better determine whether there will be a downburst thunderstorm in the region. And this project will quantitatively document the frequency of atmospheric conditions that permit formation of dry microburst storms.

Understanding the frequency with which Downburst Events have occurred in Tasmania over the past 30 years gives us a better idea of how we can detect and prevent the many types of damage caused by sudden thunderstorms. This can provide relevant authorities with information on the frequency and severity of this particular type of thunderstorm. Better planning how to prevent and warn such events the next time they happen.

1.1.4 Impact of the thunderstorms

As sudden and small-scale event, the Downburst thunderstorm will bring severe gusts which is also very destructive. Downburst thunderstorms also caused numerous air crashes, such as the plane crashed in 30 November 1961 happened in Botany Bay caused 15 people died. Wind gusts can reach about 185 km/h during a downburst thunderstorm (Brian & Australian Bureau of Statistics, 2008). The Server thunderstorm frequency in Tasmania is not low. In general, thunderstorms are most common in northern Australia, the most damaging thunderstorms, in terms of wind gusts, occur in the eastern halves of Australia. Some parts of eastern Tasmania receiving about five thunderstorms per year. The storms impact us on

Cutting power, uproot large trees, make damage to houses, cars and people and fallen trees closing roads. Severe gusts of wind can put people's lives at risk. At Bureau of Meteorology (BOM) website we can see that there have been a number of unclassified severe storms over the past 30 years. There have strong wind and had made lot of damage and even killed people's life. Those storms may be downburst thunderstorms, is very impotent to determine and understand the frequency of such event in Tasmania and understanding its formation mechanism in Tasmania, so that we could better prevent such event will bring us more harm. Tasmania is chosen as a testcase, but the methods and results apply nationally.

1.2 Profiling the atmosphere

Profiling the atmosphere is the best way to observe atmospheric stability, using tools such as atmosphere areological diagrams (also known as Sounding). Sounding is measured by balloon-based weather observations, but in many places, these are only released twice daily (00 and 12 UTC). Analysis of short-term phenomena like thunderstorms and their environments require more continuous observational data.

Balloon-based weather observations provide precise measurements of temperature, pressure, humidity, wind speed and direction, and can reach an altitude between 16km – 35km in the upper atmosphere. Released from the ground, radiosondes are devices that are used to measure meteorological elements. A weather balloon filled with hydrogen gas carries the radiosonde into the upper atmosphere. Depending on the size of the balloon, the expansion that takes place as it rises into lower pressure causes the balloon to burst and the instrument will descend back to Earth. During the radiosonde's flight, it constantly transmits atmospheric temperature, humidity and pressure data to receiving ground equipment. This equipment processes and converts the data into meteorological weather messages and is also displayed as areological diagram (Sounding) used by forecasters to assist in forecast and warning services (Bureau of Meteorology, 2018). The Australian Bureau of Meteorology routinely releases radiosondes from Hobart airport (WMO 94975), which is in south-eastern Tasmania. Soundings are routinely released twice daily (00 and 12 UTC) with occasional additional special releases.

Without these vertical profiles we can't understand the stability of the atmosphere, however, radiosondes/weather balloons are only launched from Hobart, and therefore sample a limited atmospheric environment that may not represent conditions in other regions for example, on the north coast of Tasmania. Further, the study of downburst thunderstorms requires weather data to be as accurate and continuous as possible, to make a further judgment on if the Downburst thunderstorm is happened. For this instance, the recently completed Bureau of Meteorology high-resolution Regional Reanalysis (BARRA) dataset (Jakob et al., 2017) provides us with highly accurate, hourly weather data for Tasmania.

Crucially, BARRA also provides a lot of information that are not available from observations. This dataset provides output at hourly time steps for a full suite of atmospheric model variables (such as temperature, precipitation, wind speed and direction, humidity, evaporation, soil moisture, information at pressure and model levels, information on solar radiation and cloud cover) at either 1.5km or 12 km horizontal resolution and 70 vertical levels (Bureau of Meteorology, 2019a; Su et al., 2019).

The produce contains 5 datasets. The "regional" dataset BARRA-R with approximately 12-km resolution. And 4 "subdomain" datasets area contains South-West Western Australia, South Australia, Eastern New South Wales and Tasmania (Bureau of Meteorology, 2019b). BARRA-R provides a realistic depiction of the meteorology at and near the surface over land as diagnosed by temperature, wind speed and precipitation. It shows closer agreement with point-scale observations and gridded analysis of observations, than leading global reanalyses (Su et al., 2019). The dataset we used in this project is one of the 'subdomain' datasets BARRA-TA is dynamically downscaled analyses at 1.5-km resolution. These have been developed using multiple convective-scale (1.5-km) downscaling analyses driven by the 12-km system (Bureau of Meteorology, 2019b).

1.3 Several indices identifying downburst potential

In this study, we will analyse the ambient temperature over the air, dew point temperature and wind data to obtain a series of indices. Downdraft Convective available potential energy (DCAPE) is the maximum energy available to a descending air mass and used to access the intensity of downdrafts potential in thunderstorms. WINDEX and GUSTEX can be used to assess the potential for the damaging wind gusts and can test their intensity. So, we can use those indicators to distinguish between damaging downburst days and non-severe days (Dotzek & Friedrich, 2009). This article will be exploring the determine method of the downburst thunderstorms by DCAPE, WINDEX$_1$, WINDEX$_2$, GUSTEX$_3$ and GUSTEX$_4$.in Tasmania. These indices have been used in previous studies for dry downburst thunderstorms by Dotzek and Friedrich (2009). And the dry downburst thunderstorms are downburst thunderstorms most likely happened over Tasmania. Like the figure of the Soundings (Figure 4b; 6b; 8b；10b), greater (lesser) spacing between the ambient temperature and dew point temperature is indicative of a relatively dry (moist) layer. The dryness of the atmosphere is a key measure incorporated into the indices for predicting downdraft potential. Peak downdraft speeds associated with dry microbursts is a result of negative buoyancy. The evaporation of precipitation during the descent below cloud base will increasing the downburst (Grundstein et al., 2017).

1.4 Aims

- Understand mechanics of downburst storms in Tasmania; Find out the atmospheric conditions and the mechanics associated with the sorts of downburst storms that contribute to damaging wind gusts.
- Categorise storms over the past 30 years as downburst or other; Determine the percentage of storms that are downburst in Tasmania.
- Use examples to further verify and analyse whether DCAPE, WINDEX and GUSTEX are suitable for Tasmanian thunderstorm gale forecast and unusual downwind events. A better understanding of the frequency of severe storms in Tasmania would be valuable.

This research analyzed the weather conditions associated with downburst in Tasmania with high precision and combined the weather data from the BARRA dataset over the past 30 years to analyze the probability of severe downburst storms in different parts of Tasmania. Certain criteria have emerged for predicting severe gusts since 1990, when Fujita (1990) identified and defined strong downbursts and the powerful and destructive gusts they brought to the surface. However, due to the small- and medium-scale range of downburst and gust, follow-up research on downburst needs to be enriched and improved by weather data with higher accuracy. As indicated in the high-precision BARRA dataset used in this paper, the Tasmanian region has seen many destructive gust events over the past 30 years in small and medium-scale areas. These severe gust events will provide samples for our research on downburst, so as to judge the type, intensity and possibility of downburst in specific geographical areas of medium and small scales. This will provide important reference for the prediction and prevention of severe storm weather in the future and help to fill gaps in missing downburst thunderstorm event archive in Tasmania in 1990-2019. Use examples to further verify and analyse whether DCAPE, WINDEX and GUSTEX are suitable for Tasmanian thunderstorm gale forecast and unusual downwind events. Combined with Doppler wind chart, air model-pseudo-soundings calculated from BARRA and Typical MSLP analysis to determine whether downburst thunderstorms have occurred and summarize the air structure characteristics of downburst thunderstorms.

2 Data and Methods

2.1 Data Sources

A list of severe storms over Tasmania between 1990 and 2019 were collated using the BoM severe storms archive (Bureau of Meteorology, 2020b). This archive lists date, place and a description. This archive has the best record of severe storms, but it is very limited in its scope and the information available. Many storms are not recorded if impact occurs in an unpopulated area where either nobody saw and reported it and it was not detected by any observation systems (e.g. radar, AWS). Wind speeds are often estimated, or available by relying on the nearest weather station. There are 52 Severe Storm Events recorded by satellites in Tasmania between 1990 and 2019 as provided by the Australian Bureau of meteorology website. This study aims to fill in the gaps missing downburst thunderstorm event archive in Tasmania in 1990-2019.

Bureau of Meteorology high-resolution Regional Reanalysis (BARRA) offers more than 100 parameters atmospheric model variables, such as temperature, precipitation, wind speed and direction, humidity, evaporation and cloud cover, at 1.5 km horizontal resolution, 70 levels vertical resolution and hourly temporal resolution. This kind of high precision data allows us to calculate more important air coefficients (such as Downdraft Convective available potential; Convective available potential; Microburst wind speed potential index; Gust index; Wind index) and combine the three-dimensional graphics of the wind to determine whether the events are downburst gust events or otherwise and thus to analyze the meteorological environmental fields.

In addition to using the BARRA dataset, our research also used the Bureau of Meteorology Satellite meteorological images (http://www.australianweathernews.com/news/2020/00news2020headlines.shtml) to check the meteorological environmental fields to see if the weather process is real and if it is driven by the pressure gradient or the wind that has been generated. The images are 6-hourly output and can be used to validate the air movement trend with the result we get from the BARRA Dataset (Australian weather news, 2020).

Australian Region Mean Sea Level Pressure (MSLP) Analysis from the Bureau of Meteorology (http://www.bom.gov.au/australia/charts/archive/index.shtml) are also used in this project. Its dominant features are the smooth, curving patterns of sea level isobars (lines of equal atmospheric pressure), which show the central elements of our weather systems: highs, lows (including tropical cyclones) and cold fronts. It incorporates the effects of atmospheric processes at higher levels. Forecast (prognostic) maps are also available. These indicate how the weather patterns are expected to develop. The MSLP analysis does not and cannot show all of Meteorology factors, but It is a fairly simple representation of past and probable future locations of surface weather systems (highs, lows, fronts, etc.). it provides a useful guide to analysis the weather (Bureau of Meteorology, 2020a).

2.2 The Air coefficients used to identify the downburst thunderstorms

From the Downburst-producing thunderstorms in southern Germany: Radar analysis and predictability (Dotzek & Friedrich, 2009). The predictability of the downburst potential was further investigated from proximity soundings and their derived indices WINDEX as well as different formulations of GUSTEX. In particular, a new formulation of $\text{GUSTEX}_{3,4}$ is proposed by Dotzek and Friedrich (2009), which shows promising predictive skill for the VERTIKATOR cases and a number of other severe (and non-severe) situations from the same region in southern Germany

The value of indices in that they condense a lot of information into an easily understood number. This is also a limitation, of course, because they can sometime miss important but unusual information. But we can expand the search area by relaxing the screening criteria and then analysing the specific environment (for example, comparing the radar data at that time and analysing the movement of the atmosphere). Then determine if the storm is a downburst thunderstorm.

2.2.1 Downdraft Convective available potential energy (DCAPE)

DCAPE is the maximum energy available to a descending air mass and can be calculated as the area of the region between the descending parcel curve and the environmental sounding, from the parcel's level descending to the surface. DCAPE is used to access the intensity of downdrafts potential in thunderstorms. The larger DCAPE means the stronger intensity of the downdraft potential. DCAPE values over 800 J/kg are decent and over 1000 J/kg they will have the significant downburst and means the steep low-level lapse rates which contribute to downward momentum transfer of higher momentum air to the surface. Values over 1200 J/kg usually cause the wind damage. Even higher values could be associated with long-lived drenches. The drier the air aloft and the steeper the low-level lapse rates, means potential for wind damage along the wind gust front associated with higher the DCAPE. Hot and sub-saturated surface level (large difference between the environmental temperature and the dewpoint temperature) will also advantageous to effective downward momentum transport and strong surface winds. BARRA can be used to map the distribution of DCAPE over the Tasmanian region (like the Figure) during the Specific period to study the movement of the wind. The DCAPE is mostly sensitive to the middle layer of the atmosphere where the satellite gives the most information on the humidity thus it might be a better candidate to be calculated from satellite retrieved profiles. Only sensitive to the level where we start to sink the parcel.

Figure 1: The air sounding of the dry downburst.

$$DCAPE = -\int_{P_f}^{P_s} T_{v,parcel} - T_{v,env}\, d_P \qquad \text{Eq. (1)}$$

where $T_{v,\,parcel}$ and $T_{v,\,env}$ are the specific volumes of the parcel and its environment, respectively. And P_s and P_f are the surface pressure and the pressure of the level aloft of free sink, respectively.

2.2.2 Wind Index (WINDEX) and wind gust index (GUSTEX)

WINDEX and GUSTEX can be used to assess the potential for the damaging wind gusts and can test their intensity. So, we can use those indicators to distinguish between damaging downburst days and non-severe days.

1) The Wind Index can be computed from:

$\mathrm{WINDEX1,2} = 5\left[H_m min\left(\frac{r_1}{12}, 1\right)(\tau^2 - 5.5^2 + r_1 - 2r_m)\right]^{0.5}$ Eq. (3) (Dotzek & Friedrich, 2009; McCann, 1994)

Here, Hm is the height of the melting layer above ground level in km, r1 is the average mixing ratio in the lowest surface level (< 1 km), rm is the mixing ratio at the melting level and τ is (Tm−Ts)/Hm respect the bulk lapse rate between the ground and the freezing layer in ℃ km$_{-1}$ (Dotzek & Friedrich, 2009). Note that depending on the actual lapse rate, the radicand in Eq. (3) may become negative. In these cases, WINDEX is held fixed at zero, as it smoothly approaches zero for smaller and smaller values of τ.

- WINDEX1 uses the raw sounding temperatures at the surface and the freezing layer, that is, Γ1 = (Tm − Ts) / Hm;
- WINDEX2 incorporates an estimate (or a posteriori data) of the actual maximum surface temperatures before the high wind event: Γ2 = (Tm − Ts, max) / Hm.

2) The Gust Index can be computed from:

$\mathrm{GUSTEX}_{1,2} = \alpha \mathrm{WINDEX}_{1,2} + \frac{\rho_{500}}{\rho_s} U_{500}$ Eq. (4) (Grundstein et al., 2017)

Where ρ500 is the air density at the 500 hPa level and ρs is the surface air density. U500 is the wind (in knots) at the 500 hPa level, and α is an empirical constant (0<α<1), which is according to observed high winds at the surface. Dotzek and Friedrich (2009) selected α is 0.60 and replaced ρ500/ρs by its approximate value 0.50, which are used for in GUSTEX$_1$ and GUSTEX$_2$ remained in this project.

Geerts (2001)had made an aside that instead of using the momentum at the 500 hPa-level in Eq. (4), “perhaps a density- weighted mean wind between the 1 and 5 km AGL levels would have been a better choice” — in other words, the average momentum confined between these two levels. Grundstein et al. (2017) confirm that this should indeed be a better choice, in line with the reasoning mentioned above concerning the choice of r1: If vertical advection of high momentum aloft is to be represented in a forecast index, then an average over the depth of the layer likely contributing to the downdraft is preferable compared to any arbitrarily chosen single mid-tropospheric level. The air density can be calculated with a transformation of the ideal gas law

Thus, Grundstein et al. (2017) introduce the density-weighted mean wind 〈U〉 :

$$\langle \mathrm{U} \rangle = \frac{\int_{z=1\ km\ AGL}^{z=5\ km\ AGL} \rho U d_Z}{\int_{z=1\ km\ AGL}^{z=5\ km\ AGL} \rho d_Z} \qquad \text{Eq. (5) (Grundstein et al., 2017)}$$

Simultaneously, they omit the tuning parameter α of Eq. (4), to arrive at a new formulation of GUSTEX as a pure super- position of two terms, measuring (i) the downburst potential from the atmospheric stratification and (ii) the potential that high winds from aloft are brought to the surface:

$$\mathrm{GUSTEX}_{3,4} = \mathrm{WINDEX}_{3,4} + \langle \mathrm{U} \rangle \qquad \text{Eq. (6) (Grundstein et al., 2017)}$$

Operationally in Tasmania, though, because of the commonly higher windspeeds, 27.8m/s. We choose to use 27.8 m s_{-1} as the criterion for damaging downburst winds according to Dotzek and Friedrich (2009). If GUSTEX_3 and GUSTEX_4 are more than the criterion of 27.8 m s_{-1}, a cross-check with WINDEX_1 and WINDEX_2 should be performed. If WINDEX_1 and WINDEX_2 are close or more than to 25 m s_{-1}, the potential for downbursts of the intensity is large. However, if WINDEX_1 and WINDEX_2 are small, the downburst potential is still low.

2.3 Method

1) For the 52 Severe gust events that occur in the Bureau of Meteorology Severe Storms Archive, we will calculate the air coefficients used to identify the downburst thunderstorms according to the data in the BARRA dataset when the event occurs.

2) To Search BARRA for severe storms that may have occurred over Tasmania that are not picked up in severe storms archive. According to the characteristics of the severe downburst, large vertical wind moves than usual, we will find the severe downburst in the BARRA dataset in the past 30 years. And calculate the air coefficients as step 1.

3) Looks at Bureau of Meteorology satellite data (Satellite meteorological images, Mean Sea Level Pressure (MSLP) Analysis map and Doppler Wind) and Atmospheric Sounding the to see if there is evidence of activity on days we have identified in BARRA and Severe Storms Archive.

4) Compare events on both lists to compile list of downburst storms over Tasmania

5) Determine the percentage of storms that are downburst in Tasmania.

6) Establish a working procedure for the determine of strong gusts that cause by the thunderstorm downburst in Tasmania.

BARRA offers higher resolution in space and time than existing global reanalyses and has been developed specifically for Australia.
This project will use the recently completed Bureau of Meteorology high-resolution Regional Reanalysis (BARRA) dataset (Jakob et al. 2017). This dataset provides output at hourly time steps for more than 100 parameters atmospheric model variables (such as temperature, precipitation, wind speed and direction, humidity, evaporation and cloud cover) and 70 vertical levels. For the data analysis in Tasmania, we would need to use the 1.5 km horizontal resolution BARRA-TA dataset, which is the highest resolution dataset cover the Tasmania. And because the rapid onset of the event, it would be worth checking the hourly soundings to see what the peak of the event showed. Which can be only get in the BARRA.

Because the Severe Storms Archive in the Bureau of meteorology comes from records distributed in different parts of Tasmania, there may be some downburst events that have not been recorded. Therefore, according to the characteristics of the severe downburst and the severe gust spreading around, we will screen the severe downburst in the BARRA dataset in the past 30 years and combine the 3D wind diagram to get the second downburst list. Once we have these two lists we will ccalculate the important air coefficient (Downdraft Convective available potential; Convective available potential; Microburst wind speed potential index; Gust index; Wind index)， to identify which of the possible events are likely to be genuine downburst storms. Using the screening requirements of the coefficients mentioned above.

Air Sounding images and satellite cloud images will be plotted to further determine whether the weather is a serious downburst event. We will compare it with the events selected in the Severe Storms Archive of the Meteorological Bureau in the previous step. Look at the overlap between these two lists. For events in both lists we will use them as standard storm events. For the remaining events we will continue to analyse its satellite cloud image.

Comparative analysis of the two lists of downburst gust events and combined with satellite images to get a final downburst events list. For these events, we will subsequently calculate their CAPE; MWPI; WINDEX; GUSTEX; Surface Pressure; Surface Relative humidity; Surface Temperature; Height of 1000 hpa and Pressure gradient across Tasmania before the downburst event and make statistics. And from the BARRA we can get the Max Gust speed. And compare with the strong wind event in the Severe Storms Archive and the strong downdraft wind in the BARRA dataset. Then judge the reliability of these important air coefficients with the occurrence of downburst gust events.

Based on the final list of downburst gust events in Tasmania over the past 30 years, a preliminary statistical analysis of the occurrence probability in different regions was made by analysing the intensity and occurrence area of the wind gust events. The statistical probability and relative gust intensity of downburst in different regions and months were obtained.

For the final confirmed list, we will conduct a final data analysis in an attempt to find a reference range of air coefficients for Tasmanian downburst prediction. And make statistics on the occurrence frequency of the downburst and the judgment of the degree of harm.

3 Results

3.1 The downburst thunderstorms over Tasmania from the Severe Storms Archive and BARRA.

52 Severe Storm events were chosen from the Severe Storms Archive with the strong wind damage from 1990-2019. And get an Anomalous downdraft wind events list from the BARRA dataset, which including 318 events. To do this, we ranged the downdraft wind in the near surface air layer (bigger than 900 hpa) from 1990-2019 and the maximum downdraft wind is about 10 m/s downdraft to the ground. Then, considering the max downdraft wind in the near surface air layer for the 52 Severe Storm events were chosen from the Severe Storms is about 4 m/s. To determination of Anomalous downbursts that not be observed and recorded by the Severe Storms Archive and We choose events that have the downdraft wind near surface air layer larger than 6 m/s and get the Anomalous downdraft wind events list.

From the relative humidity, temperature, pressure, height, and wind we calculated the pressure gradient in/between? Launceston and Hobart (hpa/KM), DCAPE (J/kg), CAPE (J/kg), MWPI (m/s), WINDEX$_1$ (m/s), WINDEX$_2$ (m/s), GUSTEX$_3$ (m/s), GUSTEX$_4$ (m/s). Considering that the descending wind needs to be driven by strong downward potential energy in downward motion, we made a preliminary screening of the events and selected those where the DCAPE was greater than 800 J/Kg at the location when the event occurred, according to the DCAPE value.

As shown in Table 1, we found a total of 24 suspected downburst events, including 6 events (blue cell) relating to events recorded by the Severe Storms Archive, and 18 events that were screened again in BARRA with abnormal downdraft wind. 15 events occurred over land and

9 events occurred over the sea (the orange cell). 7 of the 16 events occurred in forested regions in the south Huon Valley (43.516 °S,146.4965 °E, gray cell). As shown in Table 1, the south Huon Valley has the largest number of downburst events in the past 30 years and is a region with no permanent human populations.

Considering that the air above the sea is fully exposed to westerly winds and winter fronts, a lot of windspeed would be associated with the airmass speed rather than the thermodynamics of the atmosphere (the downburst). This can result in severe storms with big wind speeds. In this case, we need to combine the satellite meteorological images, MSLP map and Doppler Wind to determine downdraft events.

*Table 1 The list of the event that like the Downburst thunderstorm and Basic parameters; （a）Downburst events list in Tasmanina in 1990-2019 with the sources, time(UTC), Latitude, Longitude, DCAPE (J/kg), CAPE (J/kg), MWPI (m/s) , WINDEX$_1$ (m/s), WINDEX$_2$ (m/s), GUSTEX$_1$ (m/s), GUSTEX$_2$ (m/s), GUSTEX$_3$ (m/s), GUSTEX$_4$ (m/s), Max Gust speed in BARRA above the ground (m/s), surface Pressure (*10hpa), surface Pressure gradient between Launceston and Hobart (hpa/Km), Surface relative humidity (%), Temperature at the 1000 hpa(C°);* 6 events determined based on the events recorded by the Severe Storms Archive (blue cell); 9 events happened in the sea (the orange cell); 7 events are happened in the forest of the south Huon Valley (grey cell); WINDEX$_{1,2}$ bigger or Close to 25m · s^{-1}(red cell); GUSTEX$_{3,4}$ bigger than 27.8 m · s^{-1} (yellow cell).

ID	Method	Time UTC	Latitude	Longitude	DCAPE	CAPE	WINDEX$_1$	WINDEX$_2$	GUSTEX$_3$	GUSTEX$_4$	Max Gust speed	Pressure surface	Pressure gradient	Relative humidity	Temperature
1	Large vertical wind in BARRA	13-Oct-1991 04:00:00	-43.516	146.4965	2749.31	0	0	0	0	0	16	98.22	-0.042	76.25	8.98
2	Severe storm Archive	20-Dec-2015 04:00:00	-42.7	147.252	2593.1	0.9	12.61	46.67	40.62	74.68	23	99.2275	-0.055	43.75	19.475
3	Large vertical wind in BARRA	10-Oct-2006 07:00:00	-43.516	146.4965	2524.7	0.96	0	0	0	0	13.125	98.67	-1.56	73.38	9.85
4	Large vertical wind in BARRA	25-Sep-2007 19:00:00	-43.475	146.591	2361.9	0.22	0	0	0	0	13.125	97.43	2.39	71.5	11.98
5	Large vertical wind in BARRA	30-May-2003 08:00:00	-43.516	146.4965	2102.1	0.02	0	0	0	0	19.625	98.17	-2.16	74.75	11.23
6	Severe storm Archive	15-May-2016 04:34:00	-40.99	148.35	1671.2	29.02	17.17	26.45	48.31	57.59	14.5	100.92	-0.54	53.5	12.1
7	Large vertical wind in BARRA	08-May-2007 18:00:00	-42.895	147.266	1640.4	0.22	0	0	0	0	25.75	96.59	-2.70	68.25	11.35
8	Large vertical wind in BARRA	19-Aug-2007 16:00:00	-43.516	146.4965	1633.4	0.11	0	0	0	0	14.125	99.27	-0.14	90.38	6.85
9	Large vertical wind in BARRA	30-Aug-2006 06:00:00	-43.516	146.4965	1422.3	0.1	0	0	0	0	14.75	98.76	-0.49	77.88	9.98

10	Large vertical wind in BARRA	08-Mar-1991 08:00:00	-40.9915	149.8175	1232.92	566.13	40.52	40.52	56.95	56.95	29.5	100.93	1.942	21.63	32.85
11	Severe storm Archive	01-Jul-2004 12:36:00	-41.15	145.152	1169.6	49.14	15.97	22.7	46.5	53.24	19.38	98.29	-2.61	64.38	8.85
12	Large vertical wind in BARRA	31-Dec-2007 16:00:00	-41.018	150.182	1061.7	165.3	0	0	0	0	16	100.83	4.16	77	20.6
13	Severe storm Archive	27-Sep-2013 12:30:00	-41.11	147.11	1059.4	277.8	14.22	18.85	29.53	34.16	3.13	99.68	0.50	95.75	9.85
14	Large vertical wind in BARRA	22-Feb-2015 00:00:00	-42.976	147.6035	1016.86	371.18	41.81	41.81	53.19	53.19	9.25	101.08	-0.348	16.75	32.98
15	Large vertical wind in BARRA	27-Apr-1992 23:00:00	-43.529	146.6585	1016.44	2.02	0	0	0	0	21.75	97.46	5.732	70.5	13.35
16	Large vertical wind in BARRA	18-Jul-2005 10:00:00	-42.895	147.266	1015.7	11.41	0	0	0	0	21	97.6	-0.30	62.38	10.48
17	Large vertical wind in BARRA	17-Jan-2014 04:00:00	-43.934	149.8175	1000.0	151.6	0	0	0	0	12	100.53	2.34	70.75	21.6
18	Severe storm Archive	26-Jan-2005 07:10:00	-43.117	147.736	917	558.2	32.82	44.16	45.7	57.04	8.5	100.34	0.43	60.25	23.6
19	Severe storm Archive	09-Feb-2014 04:02:00	-42.89	147.33	914.32	77.07	24.72	42.35	51.26	68.89	18.38	100.58	-0.35	55.25	15.97
20	Large vertical wind in BARRA	03-Jan-1991 10:00:00	-42.233	150.047	887.36	96.58	3.19	3.19	22.88	22.88	19.25	100.58	1.46	56.5	23.85
21	Large vertical wind in BARRA	20-Feb-1997 01:00:00	-39.709	150.128	863.51	114.75	9	9	29.34	29.34	11	100.89	4.175	69	22.98
22	Large vertical wind in BARRA	22-Feb-2015 06:00:00	-44.272	148.6565	855.63	579.7	44.53	44.53	55.78	55.78	11.125	100.98	0.66	21.5	32.48
23	Large vertical wind in BARRA	13-Oct-1991 17:00:00	-43.516	146.4965	852.09	0.1	0	0	0	0	17.625	97.6	-3.072	83.13	9.98
24	Large vertical wind in BARRA	31-Dec-2009 11:00:00	-43.111	148.994	835.25	2454.67	35.69	44.24	60.92	69.47	16.875	99.99	-0.628	75.75	25.85
25*	Large vertical wind in BARRA	08-Mar-1991 09:00:00	-40.613	149.3045	798.8	431.82	42.22	42.22	56.21	56.21	30.25	101.21	2.25	22	31.73

* The wind with ID 25th is DCAPE a bit less than 800J/kg and it happened in the Tasman Sea, but it is showed a downdraft wind formation and expansion.

3.2 Analysis of weather conditions in several specific cases:

Using BARRA dataset reproduces 15 events happened in the land by mapping of DCAPE and drawing the atmosphere areological diagrams (Sounding) before and after the events to see the instability in vertical direction of airmass. Using satellite meteorological images, MSLP map and Doppler Wind map reproduce the movement of air in the atmosphere before and after those events. As the Doppler Wind map (from West Takone Radar & Hobart Radar) can only provide data from 128km surrounding the Radar from 2012 (expect 2014) to now, the satellite meteorological images and Mean Sea Level Pressure (MSLP) Analysis map are from 2005 to now. tall of them are keyways to help us find if strong winds and downburst weather conditions have occurred. Examining 15 events happened in the land, by the method above, we can initially determine the number of downbursts that occurred.

For the 15 events happened in the land, We found the events that have large potential for downbursts of the intensity is large, by test the events both satisfied the DCAPE is larger than 1000 J/kg and with GUSTEX$_3$ and GUSTEX$_4$ are more than 27.8 m s$_{-1}$, WINDEX$_1$ and WINDEX$_2$ are close or more than 25 m s$_{-1}$. According to the above conditions, we found that it was too harsh. We found two cases of downburst thunderstorm that occurred in the waters around Tasmania, but we could not find a downburst thunderstorm that occurred on the land of Tasmania. This may indicate that these coefficients are not very suitable for testing downburst in Tasmania, or that most of the strong winds caused by downburst thunderstorm in Tasmania have not reached the very serious level we want to detect. In order to better determine whether the weather driving mechanism that cause strong winds. Finally, we get the event that have the large potential for downbursts 2nd, 6th, 11th, 13th ,18th and 19th events in the list above because they satisfied two of the three conditions above. They are the six events that most likely to be the downburst events. Because using coefficients (DCAPE >1000J/kg) for screening downburst events can help us narrow down the range of downburst events, but at the same time, may be because the BARRA database is not the actual observed data but the simulated predicted values of multiple data, which leads to the selected events have never happened in reality. So, we check whether these events have actually experienced strong winds. And in the Australian weather news (2020), we can find the Highest wind gusts above 89km/h (storm force) or mean wind above 62km/h (gale force) in the Australia from the 1997 to now. And the events 4th, 8th, and 9thnot be recorded maybe the intensity of wind of those events did not reach the standard of the strong storm force wind. So, I picked them of the list. What is more events 1st and 15th are far away from now and we couldn't check the Australian weather news (2020), Doppler Wind map or Mean Sea Level Pressure (MSLP) Analysis to determine the real situation in the atmosphere at that time or whether there were storms or strong winds.

So, except the events that we are not sure if strong winds occurred at that time the we got the 2nd, 3rd, 5th, 6th, 7th ,11th, 16th, 18th and 19th events.

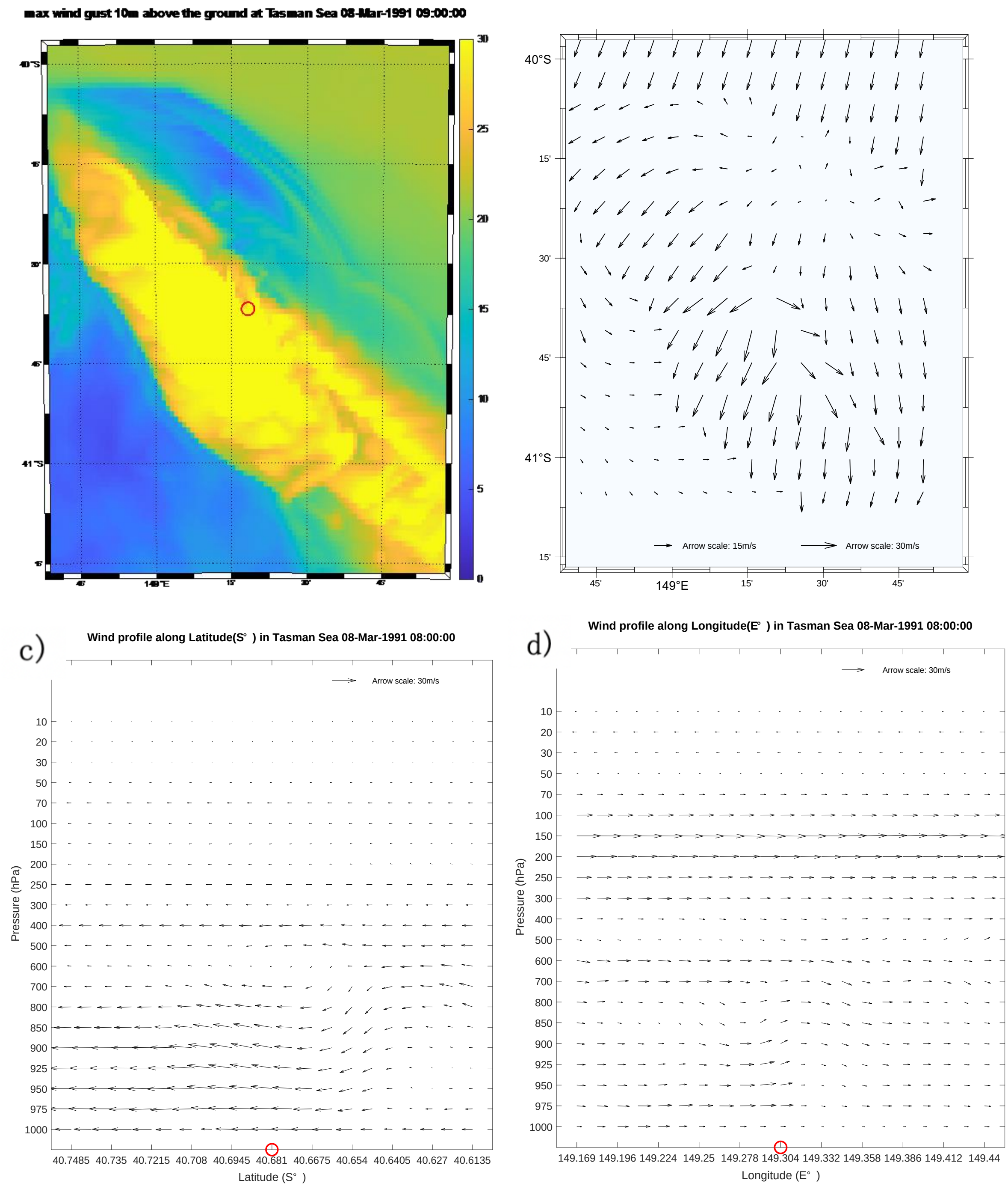
- Tasmania's southern and eastern regions are densely populated. Because of the frequent westerly winds in Tasmania, the area is on the leeward side. 2nd, 18th and 19th. we choose the 2nd (Brighton) events as representative case to analyse these events.
- In the 6th, 11th and 13th events happened in the windward side on the western and northern of Tasmania. There are flat and no obstruction. we choose the 6th (Eddystone Point) events as representative case to analyse these events.
- The large DCAPE events (3rd, 5th, 7th, 16th) occurring in the eastern foothills of the Wellington Mountains or the eastern foothills of the South Huon Valley. Because the above events are similar, we choose the 16th (Wellington Mountains) events as representative case to analyse these events.
- What is more, the 25th events, is happened in the Tasman Sea, it is showed a downdraft wind formation and expansion. The DCAPE at the during the strong downdraft is not as larger as the number before and after the strong downburst happen (figure 4). we choose the 25th (Tasman Sea) events as representative case on the sea.

3.2.1 Weather conditions at 08-mar-1991 09:00:00 in Tasman Sea (ID 25)

Although we do not have more data to verify whether this event actually happened. However, we can see that in this event, figure 3a, 3b downburst at the centre of the drop point spread to the south in all directions. The maximum speed of the gust is close to 30m/s. We can see the rise in this air mass in figure 3c, 3d Before it was 08:00, the air mass rose from 900 hpa to 600 hpa. At this time, the air temperature at 1000hpa on the surface of figure 4b at 07:00 to 08:00 is increased by four degrees Celsius. The surface air temperature continued to increase by 5 degrees Celsius from 8 to 9 o'clock. This increase in surface temperature raises the originally relatively humid air on the surface. As a result, the difference between dew temperature and temperature at sounding 1000hpa at 09:00 is getting bigger and bigger. It creates a dry air environment for the lowest floor. After the saturated gas rises, we can see that it becomes saturated in the 400hpa-600hpa section of sounding. The two temperature lines are stuck together. It is this oversaturated gas that becomes unstable when it reaches a certain height (500hpa). Under the disturbance of the upper atmosphere of the atmosphere, the highly saturated high-density gas with water droplets moves downward due to gravity and dissipates heat into the air. And a cold pool is formed at the bottom atmosphere, and the air mass diffuses to the surroundings after hitting the ground. When the surface air diffuses to the surroundings at close to 1000hpa, it continues until 10:00. Just as the sounding in figure 4b is at 11: At 00 o'clock, the bottom dew temperature and temperature converge to a point and the bottom temperature drops by 10 degrees Celsius compared to 09:00. This is because some of the saturated gas or air bubbles with water drops are evaporated by the high-temperature drying gas in the lower layer. The gas in the lower layer will become saturated. We can see in figure 3e, because the wind from the south is pushed by the southward wind, the front of the cold pool also moves southward. In contrast, the wind on the surface (900hpa-1000hpa) in the east-west direction is not strong, so the gust of wind spreads freely in the east-west direction on the basis of the southward direction. However, when the shear stress at 500hpa at the east of the wind is received, more wind will spread to the southeast. The yellow range in figure 3a is the scope of this downburst. Of course, the downburst environment that occurs at sea is too ideal, and there are no obstacles on the ocean and no relief. So, this time the cold direction of the cold pool spreads evenly to one side. We can see that the downburst that occurred in the Tasman waters is around Tasmania, and the wind volume has reached the level of the destructive wind. Because the terrain in Tasmania is undulating and is subject to strong westerly winds all year round. So, the weather is more complicated, and similar events should happen, but the downburst wind will be much larger than the land level because there are no obstacles at sea.

a)

b)


max wind gust 10m above the ground at Tasman Sea 08-Mar-1991 09:00:00
40°S
15'
30'
45'
41°S
15'
45'
149°E
15'
30'
45'
30
25
20
15
10
5
0
40°S
15'
30'
45'
41°S
15'
45'
149°E
15'
30'
45'
Arrow scale: 15m/s
Arrow scale: 30m/s
c)
Wind profile along Latitude(S°) in Tasman Sea 08-Mar-1991 08:00:00
Arrow scale: 30m/s
Pressure (hPa)
10
20
30
50
70
100
150
200
250
300
400
500
600
700
800
850
900
925
950
975
1000
40.7485
40.735
40.7215
40.708
40.6945
40.681
40.6675
40.654
40.6405
40.627
40.6135
Latitude (S°)
d)
Wind profile along Longitude(E°) in Tasman Sea 08-Mar-1991 08:00:00
Arrow scale: 30m/s
Pressure (hPa)
10
20
30
50
70
100
150
200
250
300
400
500
600
700
800
850
900
925
950
975
1000
149.169
149.196
149.224
149.25
149.278
149.304
149.332
149.358
149.386
149.412
149.44
Longitude (E°)

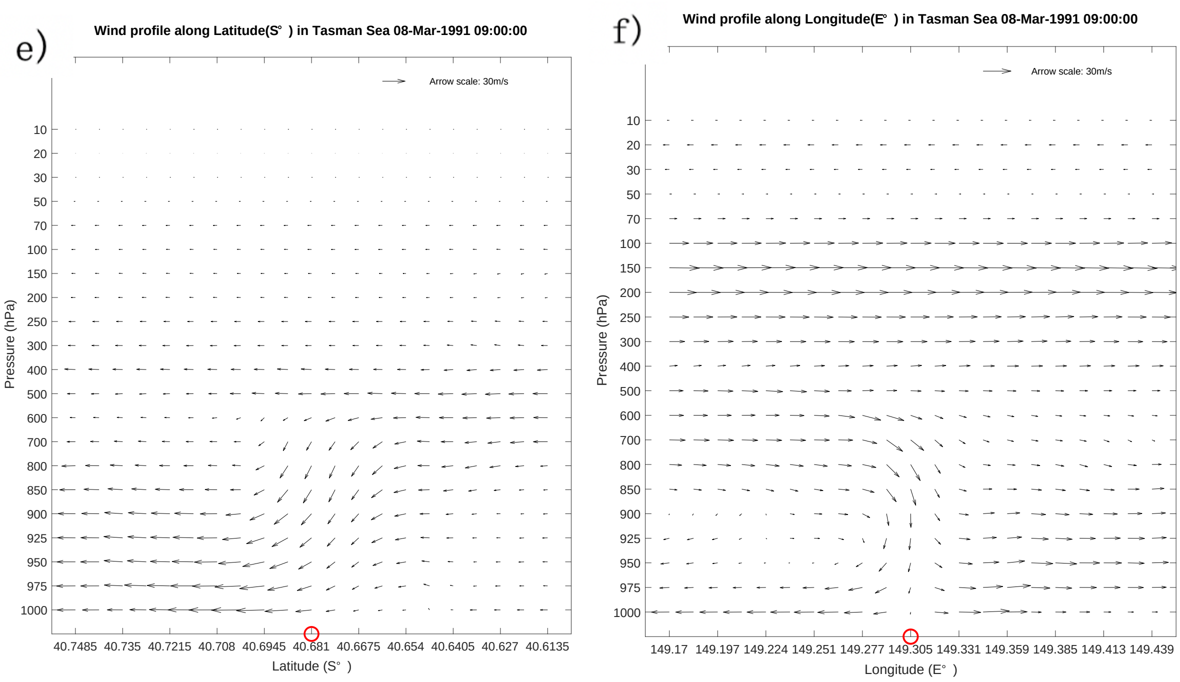
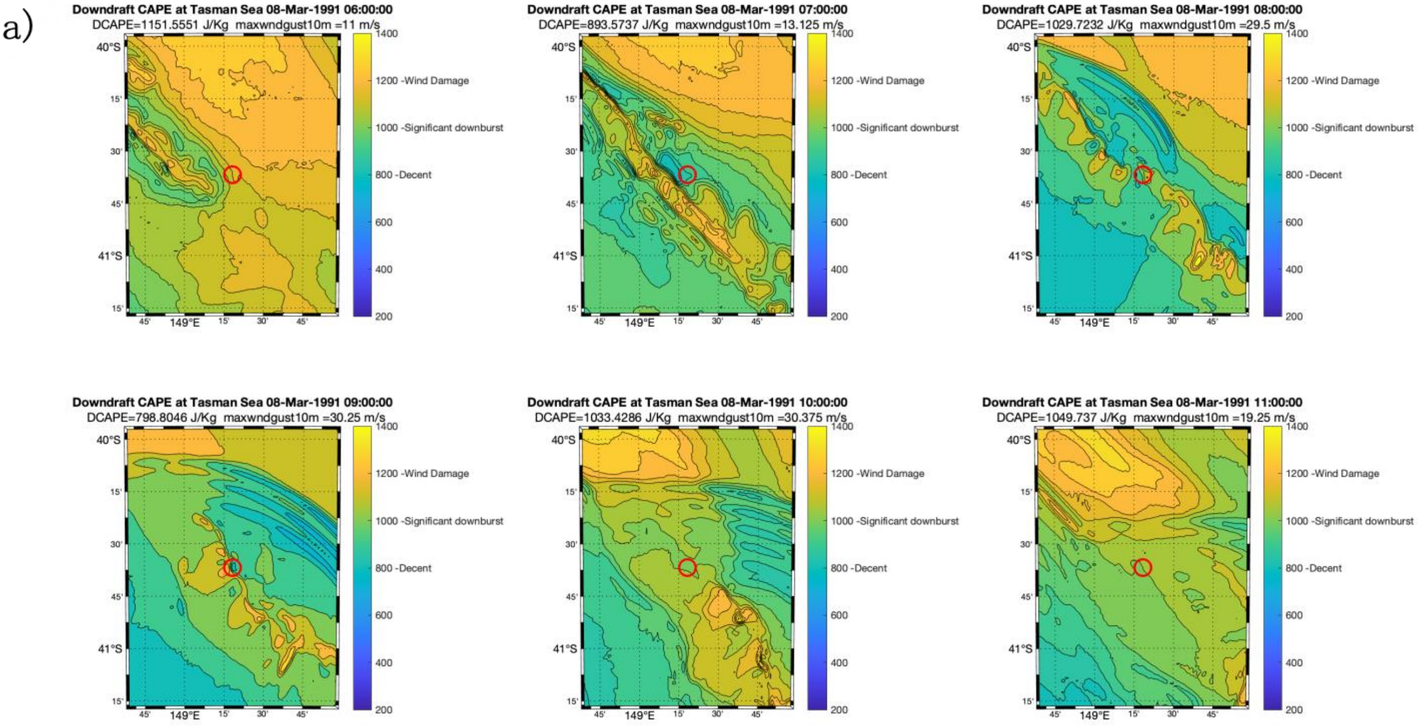


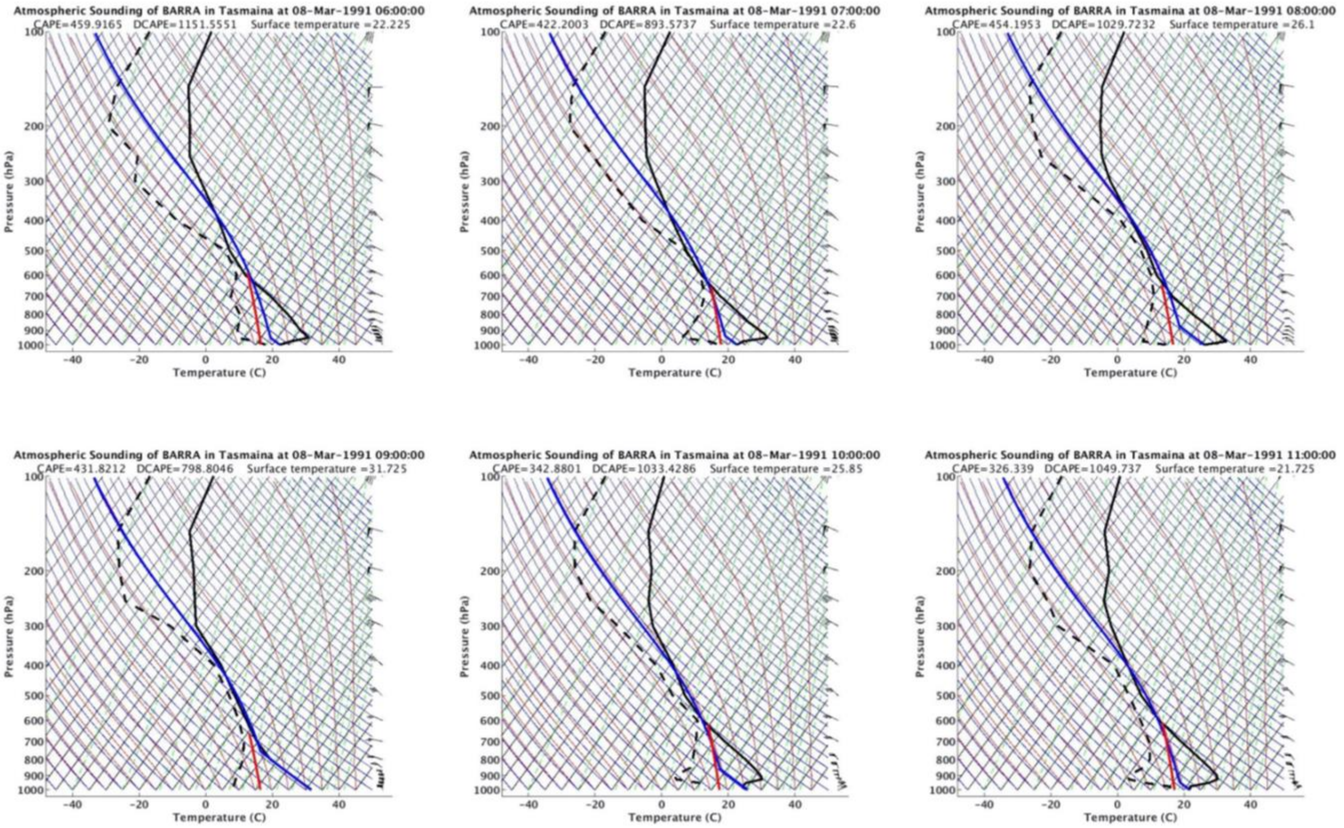
Figure 3 (a) Max wind gust at 10 m above the ground in Tasman Sea (40.6135 S°,149.3045 E°) in 08-mar-1991 09:00:00; (b) Wind gust with direction at surface in Tasman Sea (40.6135 S°,149.3045 E°) in 08-mar-1991 09:00:00; (c)Wind profile along Latitude (S°) in Tasman Sea (40.6135 S°,149.3045 E°) in 08-mar-1991 08:00:00; (d)Wind profile along Longitude (e°) in Tasman Sea (40.6135 S°,149.3045 E°) in 08-mar-1991 08:00:00; (e)Wind profile along Latitude (S°) in Tasman Sea (40.6135 S°,149.3045 E°) in 08-mar-1991 09:00:00; (f)Wind profile along Longitude (E°) in Tasman Sea (40.6135 S°,149.3045 E°) in 08-mar-1991 09:00:00; The red circle is the gusty position.

As we can see in the figure 4a, after the DCAPE of this point comes to 1029 J/kg at 08:00, the lifting if the airmass is began. And the at 09:00 this point showed that there have a strong wind and the cold pool forms in the lower atmosphere. After the downburst the wind at the middle layer of air blown away the saturated water vapor of this layer, and the previous unsaturated air condition was restored. Without the relatively dry air of 800hpa-900hpa brought by downburst, the air at 1000hpa only flows in same horizontal layer, and the contact interface between the ocean and the atmosphere continuously provides water vapor to restore the humidity of the underlying atmosphere to the previous saturation. This also shows that the downburst dissipated. At this time, although there is still a DCAPE area greater than 1000J/kg in the air, there is no sudden change in the surface air temperature. The downburst will not happen again.

Under the premise that the environmental water content is unchanged, the higher the temperature, the lower the relative humidity. So, before the downburst happed the surface temperature rises, the surface layer is the easiest place to be heated. We can see that the distance between the temperature of the middle and lower parts of the atmosphere and the dew temperature in sounding becomes larger. This is also because there is initially no vertical water vapor exchange. Therefore, the increase in the temperature of the bottom layer of the atmosphere causes the relative humidity here in the upper and middle layers to become smaller (the spacing becomes larger）.



b)


Atmospheric Sounding of BARRA in Tasmaina at 08-Mar-1991 06:00:00
CAPE=459.9165 DCAPE=1151.5551 Surface temperature =22.225

Atmospheric Sounding of BARRA in Tasmaina at 08-Mar-1991 07:00:00
CAPE=422.2003 DCAPE=893.5737 Surface temperature =22.6

Atmospheric Sounding of BARRA in Tasmaina at 08-Mar-1991 08:00:00
CAPE=454.1953 DCAPE=1029.7232 Surface temperature =26.1

Atmospheric Sounding of BARRA in Tasmaina at 08-Mar-1991 09:00:00
CAPE=431.8212 DCAPE=798.8046 Surface temperature =31.725

Atmospheric Sounding of BARRA in Tasmaina at 08-Mar-1991 10:00:00
CAPE=342.8801 DCAPE=1033.4286 Surface temperature =25.85

Atmospheric Sounding of BARRA in Tasmaina at 08-Mar-1991 11:00:00
CAPE=326.339 DCAPE=1049.737 Surface temperature =21.725

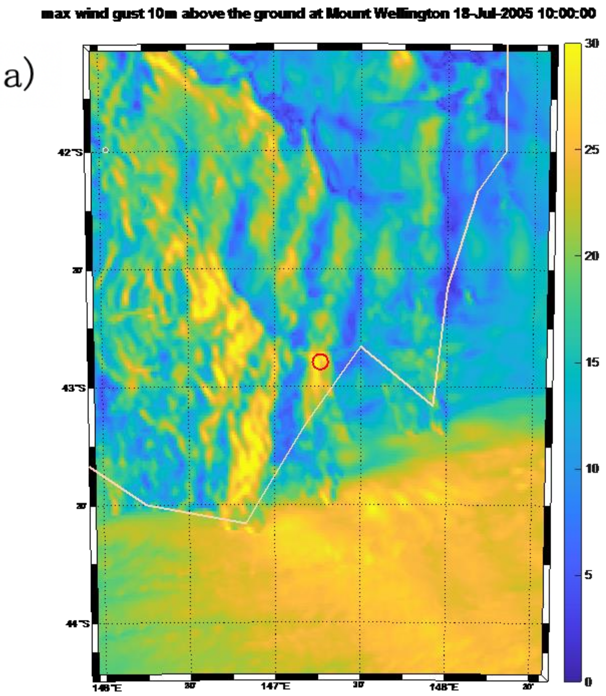
Figure 4 (a) The hourly maps of the Downdraft Convective available potential energy (DCAPE) over the Brighton at from 00:00- 06:00 December 20, 2015 UTC (Brighton is in the centre of the map); (b) The hourly Atmospheric Sounding of Brighton, with the index of CAPE, DCAPE, surface temperature at from 00:00- 06:00 December 20, 2015 UTC; The red circle is the gust position.

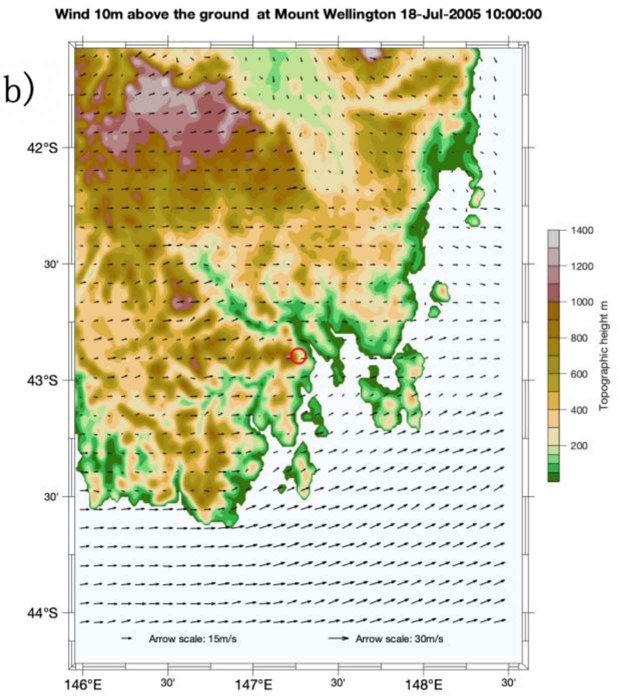
3.2.2 Weather conditions in 10:00:00 July 18, 2005 Mount Wellington (ID 16)

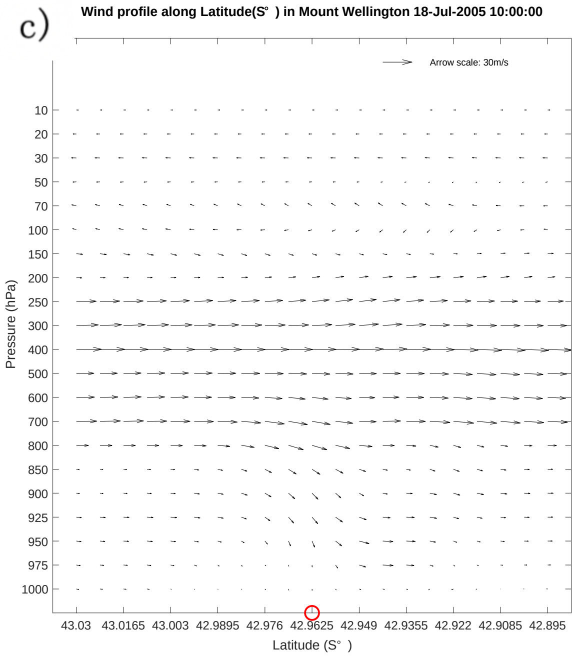
This event is from the from the BARRA. According to the BoM, the Storm force gusts in Mount Wellington is about 126km/h at 10:00 July 18, 2005 in Mount Wellington.

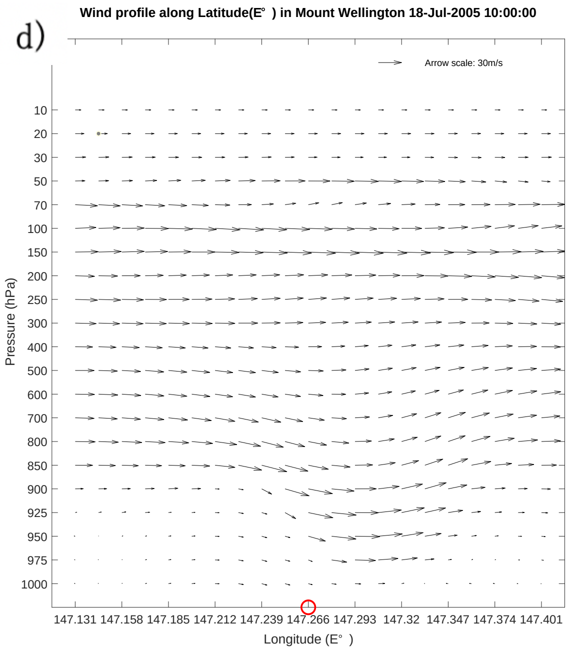
The prevailing west wind in Tasmania and the sinking of wind due to gravity after leafing through the mountains maybe can be used to explain the large DCAPE events occurring in the eastern foothills of the Wellington Mountains and the eastern foothills of the South Huon Valley. Because the above events are similar, we choose the 3th and 7th events as representative cases to analyse these events.

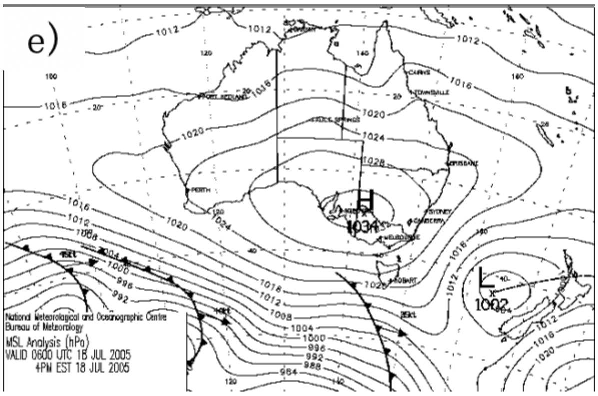
As we can see, the strong wind on the land appears in the form of a band in the place where the terrain is raised, such as hills, peaks and other places. On the left side of the red Circle (figure 9b) where this strong wind events occurred is Mount Wellington, and on the right is the flat estuary area. The average altitude of 850 hPa is about 1400 meters. The elevation of Mount Wellington is 1,271 meters. At this. From figure 9c, d, we can see that the south-west wind that crosses the Wellington Mountains slides down the hillside due to gravity after losing the support of the terrain. We can see that in figure 10b, the air below 900hpa in sounding at 6:00 is relatively saturated. Between 6:00-11:00 a dry air replaced the low altitude (850hpa-1000hpa) air at the location where the gust occurred (ID 16). This may be because the humid air current from the ocean rises and cools along the windward slope when landing and climbing over the mountain. Before the saturated water vapor reaches saturation, the temperature is reduced according to the dry adiabatic process. As a result, when the air mass reaches the top of the mountain, the temperature will drop a lot, and the airflow will saturate before reaching the top of the mountain, and precipitation will occur to further reduce the moisture. When the airmass reaches the top of the mountain, it will be close to saturation, and then the cold air with little absolute moisture will be adiabatic and sink along the leeward slope (direction changed) due to the density of the air and the surrounding air. After the mountain passes, the air sinks along the leeward slope. At this time, the air temperature gradually increasing, and the relative humidity becomes lower and lower. We can see the space between dew point temperature and temperature become lager when sound gusts occur (10:00). It shows that the original 850hpa-1000hpa air is replaced by dry air coming down the mountain. Because of the acceleration of gravity and the sinking wind such as the initial velocity of the previous wind, it will be much faster than the original (such as figure 9d). As this gust reached 126km/h, this is already destructive. But this is not a downburst thunderstorm because it is not caused by the instability of the air in the higher atmosphere.


max wind gust 10m above the ground at Mount Wellington 18-Jul-2005 10:00:00


Wind 10m above the ground at Mount Wellington 18-Jul-2005 10:00:00


Wind profile along Latitude(S°) in Mount Wellington 18-Jul-2005 10:00:00


Wind profile along Latitude(E°) in Mount Wellington 18-Jul-2005 10:00:00



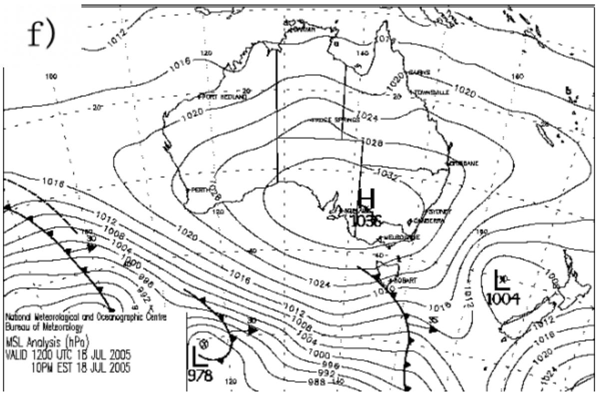
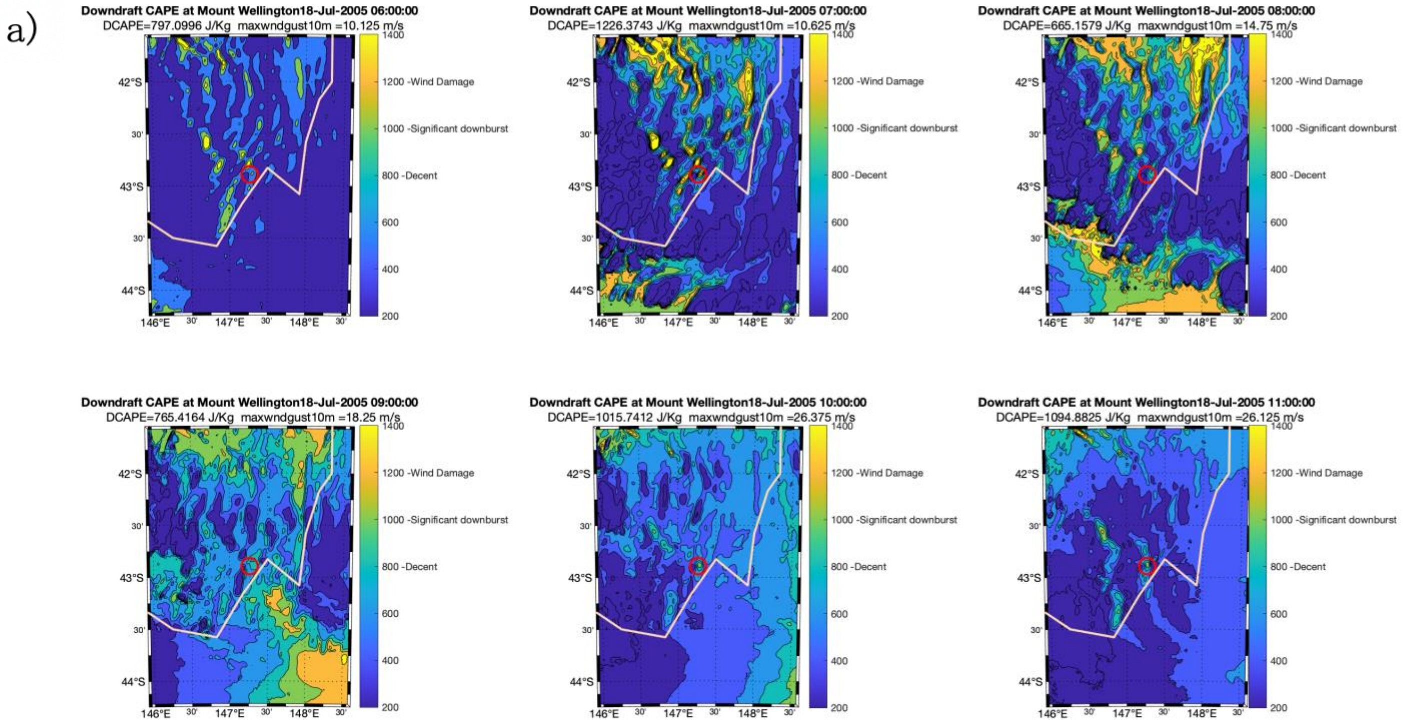


Figure 9 (a) The maps of wind over the Mount Wellington at 04:00 December 20, 2015 UTC (Mount Wellington is in the centre of the map); (b) Geographic height and the Wind direction and volume at 10 m above ground (Mount Wellington is in the centre of the map); ; (c)Wind profile along Latitude (S°) in Mount Wellington at 04:00 December 20, 2015 UTC; (d)Wind profile along Longitude (e°) Mount Wellington at 04:00 December 20, 2015 UTC; (e) & (f) Typical MSLP analysis of 06:00 and 12:00 in July 18, 2005 UTC over the Australia; The red circle is the gust position.

This incident occurred before the cold front and did not cause the large DCAPE area of the whole island to appear as before. In the table we can find the surface pressure at this point is 976hpa. Interestingly in figure 9d, we can see that first the wind sinking to the surface at 967hpa and then trend of eastward and upward movement at 147.347E° (River Derwent).



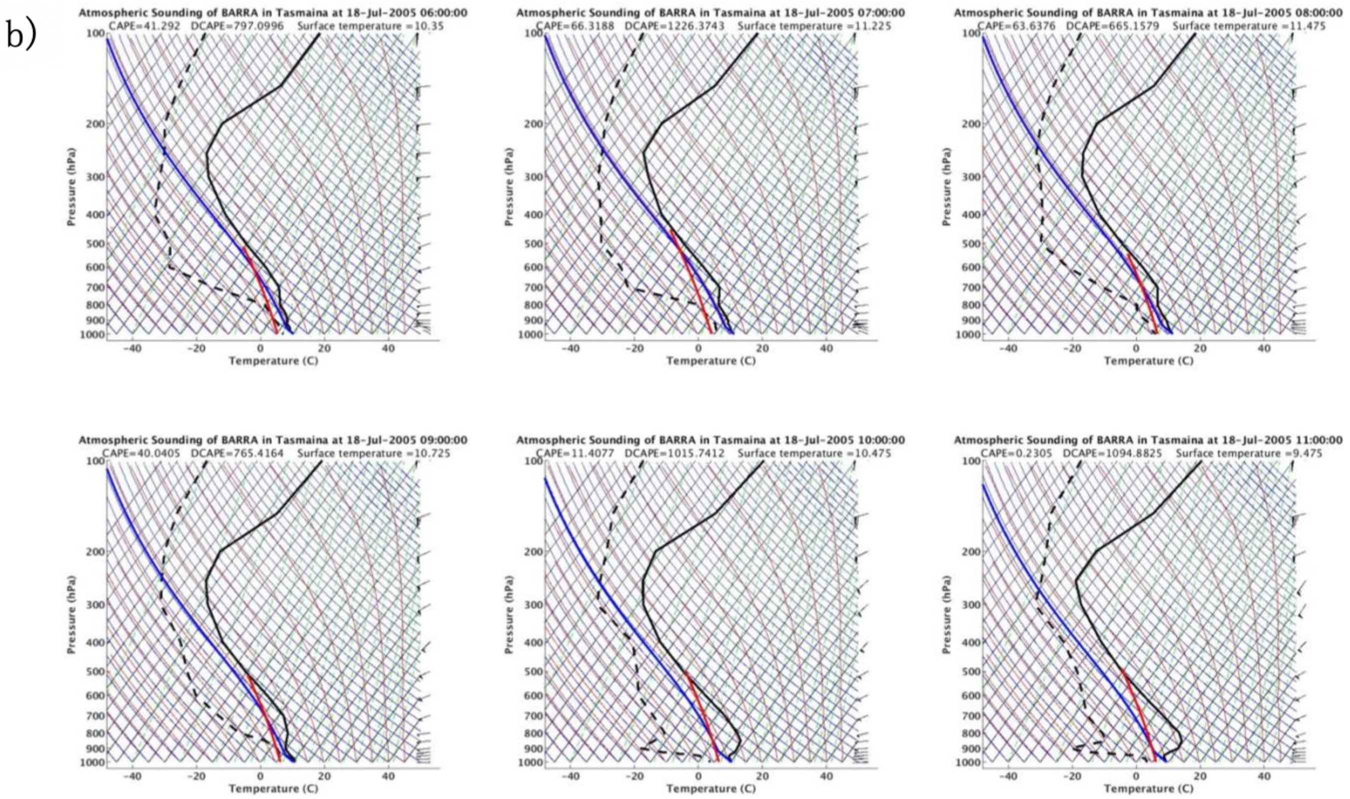


Figure 10 (a) The hourly maps of the Downdraft Convective available potential energy (DCAPE) over Mount Wellington *at from 06:00- 12:00* July 18, 2005 *UTC (*Mount Wellington *is in the centre of the map); (b) The hourly Atmospheric Sounding of* Mount Wellington*, with the index of CAPE, DCAPE, surface temperature at from 06:00- 12:00* July 18, 2005 *UTC; The red circle is the gust position.*

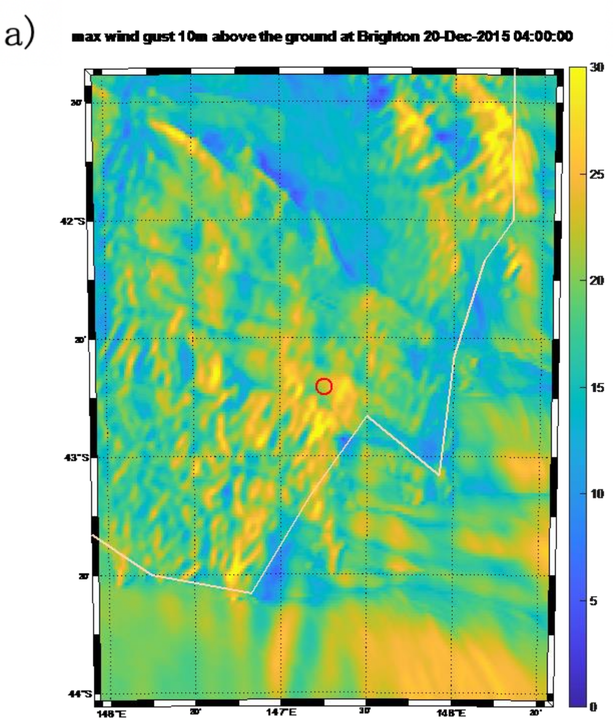
3.2.3 Weather conditions at 04:00:00 December 20, 2015 UTC in Brighton (ID 2)

This event is from the Severe Storms Archive. According to the Bureau of Meteorology, Some wind damage on an organised line of thunderstorms in the afternoon about southeast Tasmania. Damage reported near Brighton and on the Tasman Peninsula. And the Storm force gusts is record as the 93 km/h in Brighton.

First, we have to look at figure5 e&f, this event occurs between e and f. In other words, there should be a cold front crossing when our storm occurs. The cold front's transit brought conflicts between the heating and cooling groups. In the process, the powerful cold air from the west lifted the warm air from the east. The confrontation of heating and cooling groups may bring precipitation or thunderstorms. We see the satellite meteorological image is (figure 5 g & h). When the cold front transits, a large number of clouds are generated by the heating and cooling mass covering the entire Tasmania. With the storm of BoM, we can be sure that the day is in Tasma There are thunderstorms. At first, we can see that the sounding at 2:00 almost coincides with the two temperature lines. At this time, the atmospheric environment is very saturated. A lifting mechanism, such as an approaching front or low-pressure trough, to make the moist air rise rapidly. At 4:00, some surrounding areas and north-west Brighton have large DCAPE (figure 6a). In the dense region of the DCAPE, such as in Brighton, a corresponding strong wind speed (more than 25 meters per second) appeared (figure 5a).

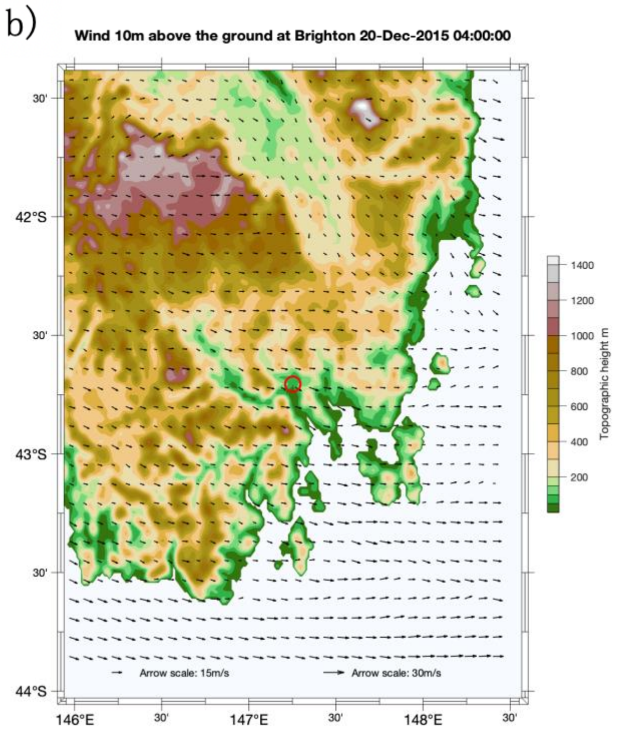
I noticed that there was no strong vertical air exchange movement or horizontal shear movement at this point. After verifying this event, there was a slight vertical movement of 1 m/s at 800 hpa. The northwest wind from 200hpa to 500hpa is the leading role in the entire weather. The air mass brought by the cold front is very low in absolute humidity because the cold front is dominated by the dry air mass dominated by the cold front. We can see that the air in 500hpa-900hpa in sounding has become very dry and is still drying. And because the relatively humid warm air is affected by the uplift of the cold trough and the uplift of the cold front, the upper atmosphere is removed. That is why we see that there is not so much significant change in relative humidity between the clouds and the upper part of sounding.

a)



max wind gust 10m above the ground at Brighton 20-Dec-2015 04:00:00

b)



Wind 10m above the ground at Brighton 20-Dec-2015 04:00:00

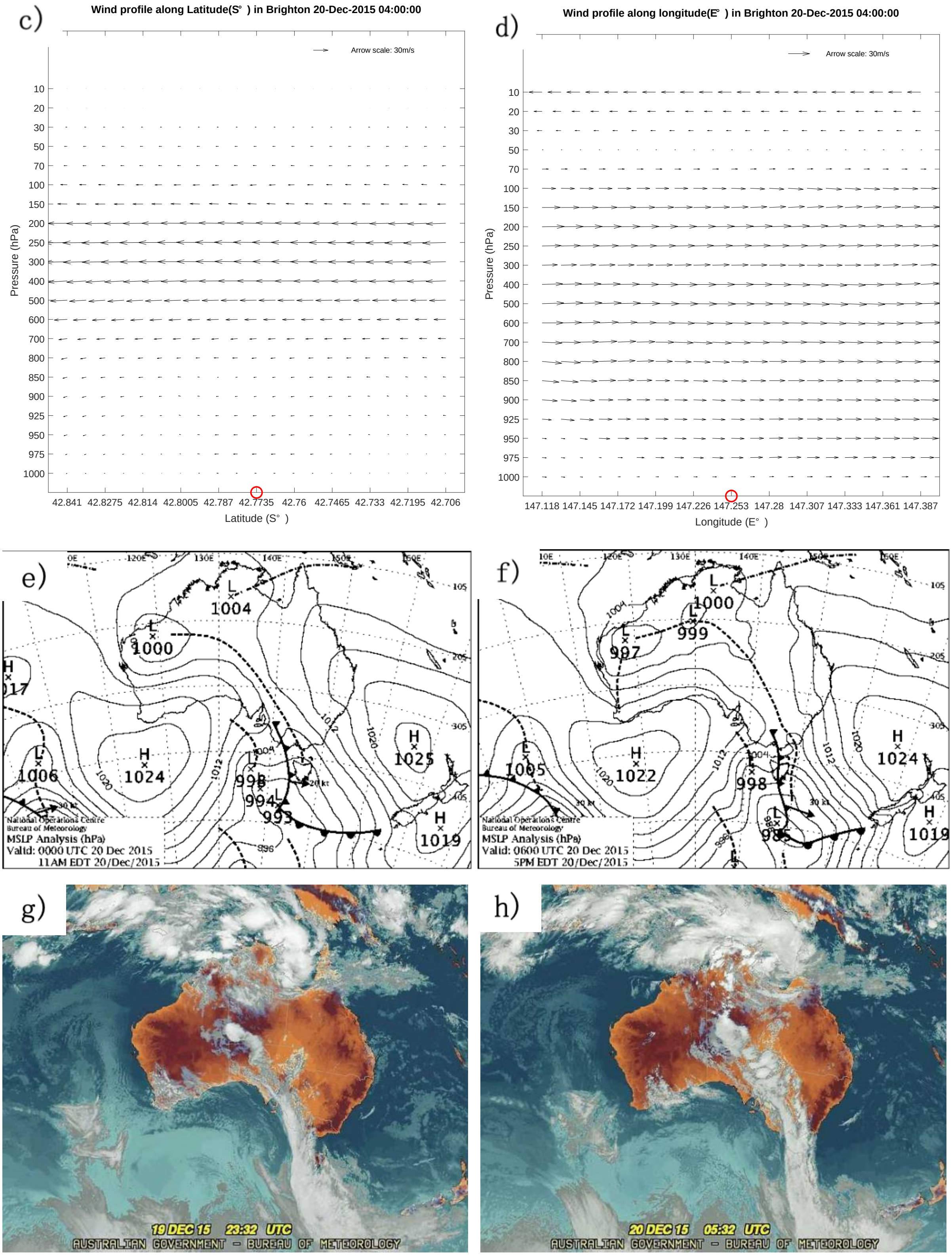
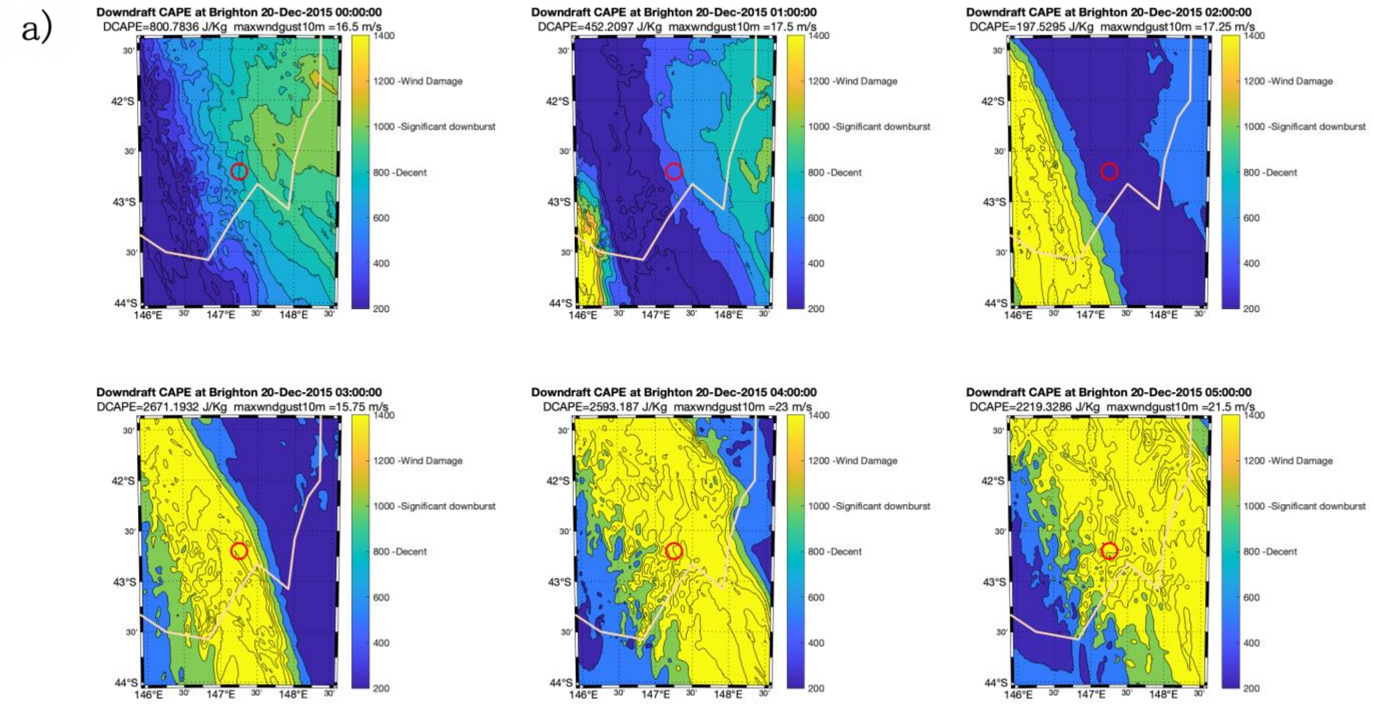


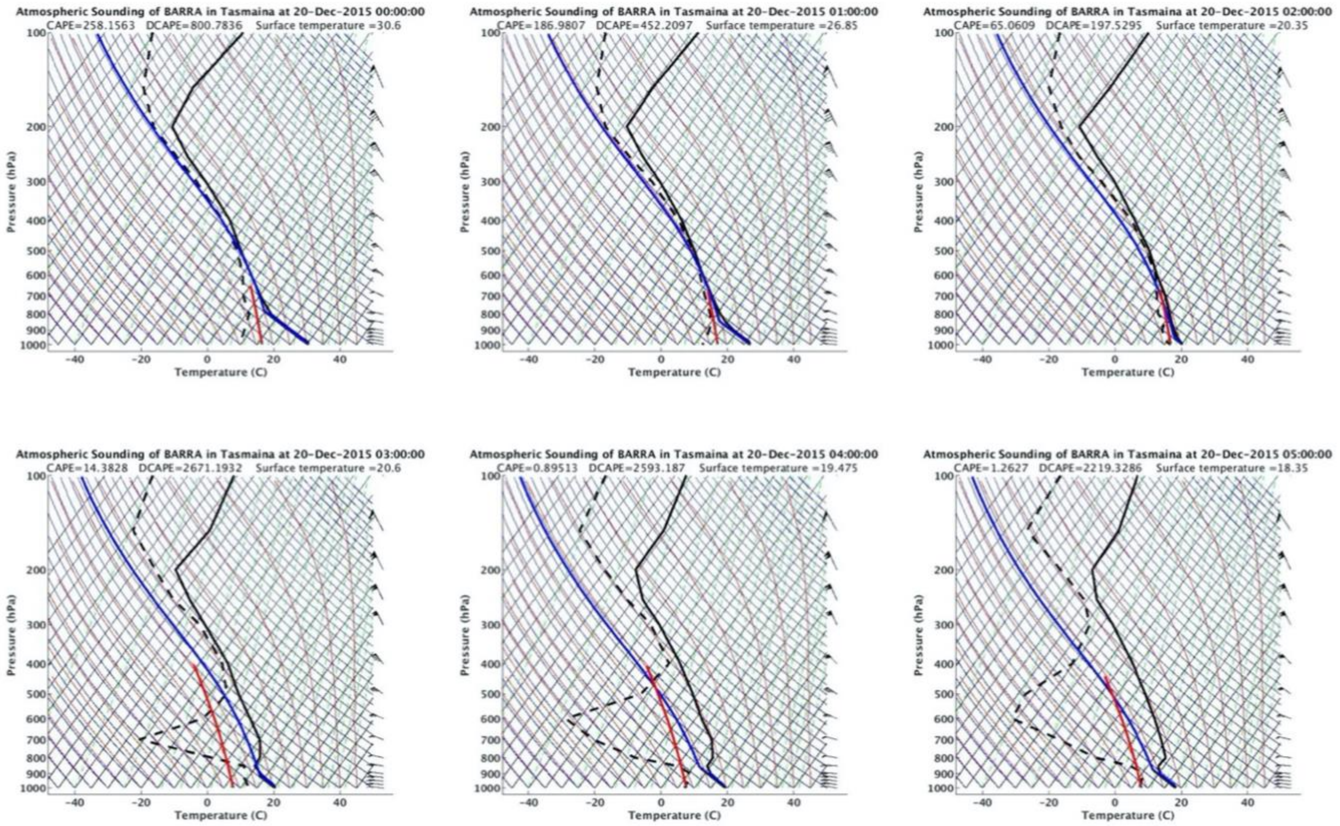
Figure 5 (a) The maps of wind over the Brighton at 04:00 December 20, 2015 UTC (Brighton is in the centre of the map); (b) Geographic height and the Wind direction and volume at 10 m above ground (Brighton is in the centre of the map); ; (c)Wind profile along Latitude (S°) in Brighton at 04:00 December 20, 2015 UTC; (d)Wind profile along Longitude (e°) Brighton at 04:00 December 20, 2015 UTC; (e) & (f) Typical MSLP analysis of 00:00 and 06:00 in December 20, 2015

UTC over the Australia; (g) & (h)The satellite meteorological images over the Australia at 23:32 December 19, 2015 UTC and 05:32 December 20, 2015 UTC; The red circle is the gusty position.

We can see in the figure 6a, that as this cold wind sweeps over Tasmania from the west and makes landfall. The difference between dewpoint temperature and temperature at 500hpa-700hpa in sounding allows us to calculate a huge DCAPE. The very large DCAPE means the duration of this thunderstorm will be more durable. We can see that the DCAPE map is a long belt, which is formed by the cold front. The dry lower layer and the relatively saturated and humid upper air provide a good environment for the formation of downburst thunderstorm. However, no downwind formation was observed. It may be because of a series of thunderstorms. The strong gusts recorded here were generated and spread in other nearby locations before.



b)



Atmospheric Sounding of BARRA in Tasmaina at 20-Dec-2015 00:00:00
CAPE=258.1563 DCAPE=800.7836 Surface temperature =30.6

Atmospheric Sounding of BARRA in Tasmaina at 20-Dec-2015 01:00:00
CAPE=186.9807 DCAPE=452.2097 Surface temperature =26.85

Atmospheric Sounding of BARRA in Tasmaina at 20-Dec-2015 02:00:00
CAPE=65.0609 DCAPE=197.5295 Surface temperature =20.35

Atmospheric Sounding of BARRA in Tasmaina at 20-Dec-2015 03:00:00
CAPE=14.3828 DCAPE=2671.1932 Surface temperature =20.6

Atmospheric Sounding of BARRA in Tasmaina at 20-Dec-2015 04:00:00
CAPE=0.89513 DCAPE=2593.187 Surface temperature =19.475

Atmospheric Sounding of BARRA in Tasmaina at 20-Dec-2015 05:00:00
CAPE=1.2627 DCAPE=2219.3286 Surface temperature =18.35

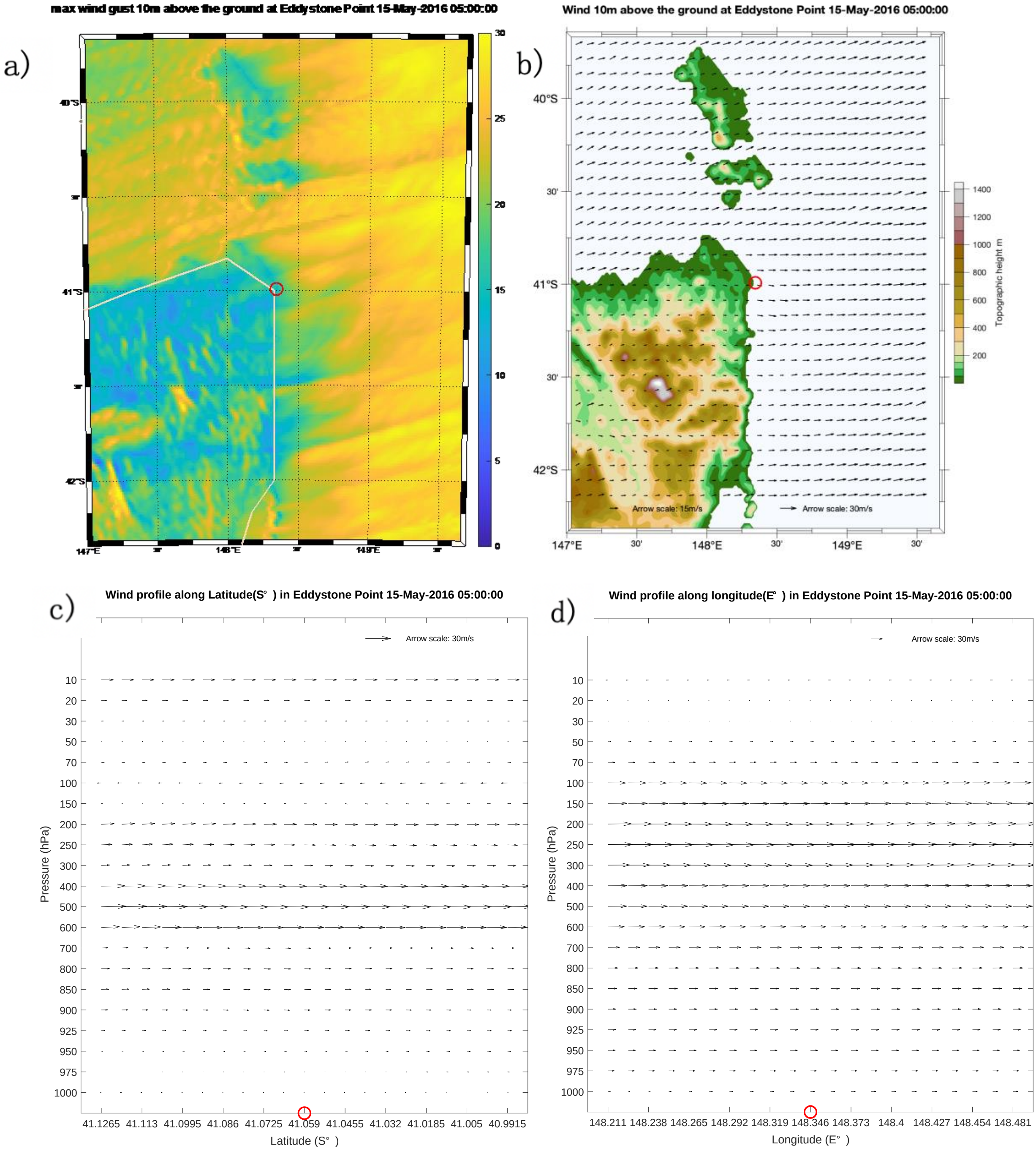
Figure 6 (a) The hourly maps of the Downdraft Convective available potential energy (DCAPE) over the Brighton at from 00:00- 06:00 December 20, 2015 UTC (Brighton is in the centre of the map); (b) The hourly Atmospheric Sounding of Brighton, with the index of CAPE, DCAPE, surface temperature at from 00:00- 06:00 December 20, 2015 UTC; The red circle is the gust position.

3.2.4 Weather conditions in 04:34:00 May 15, 2016 Eddystone Point (ID 6)

This event is from the Severe Storms Archive. According to the BoM, Line of storms that passed through Eddystone Point and the Storm force gusts in Larapuna (Eddystone Point) is about 106Km/h. This same line of the storm caused the power outages l around suburbs of Launceston and Ulverstone.

We can see in the BARRA data that the maximum wind speed data at this point is not very high (12 m/s). And no obvious vertical wind movements were observed. Like the above event, this is also a thunderstorm event dominated by the cold front. We can also see that our point is covered by clouds in figure 1h.

We can see that many large DCAPE areas in the DCAPE map are constantly forming and disappearing. Explain that the air environment and atmospheric circulation here are very complicated. It is consistent with the continuous and continuous formation of thunderstorm events. Regarding sounding, we can see that the entire sounding is affected by the dry air mass. And the wind speed between 200hpa-500hpa is also very large and the event.



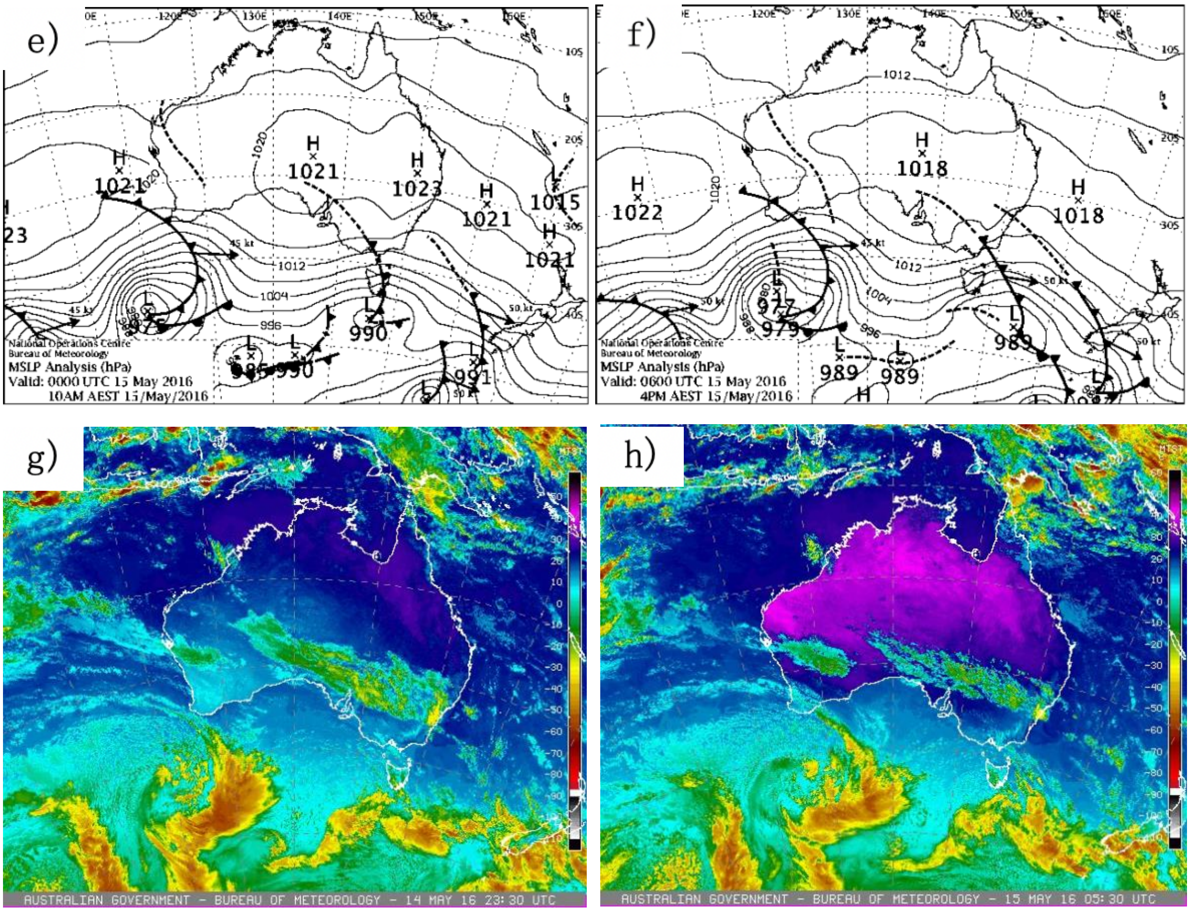


Figure 7 a) The maps of wind over the Eddystone Point *at 05:00* May 15, 2016 *UTC (*Eddystone Point *is in the centre of the map); (b) Geographic height and the Wind direction and volume at 10 m above ground over the* Eddystone Point *at 05:00* May 15, 2016 *UTC (*Eddystone Point *is in the centre of the map);* (c)Wind profile along Latitude (S°) in Eddystone Point at *05:00* May 15, 2016 *UTC*; (d)Wind profile along Longitude (e°) Eddystone Point at *05:00* May 15, 2016 *UTC*; *(e) & (f) Typical MSLP analysis of 00:00 and 06:00 in December 20, 2015 UTC over the Australia; (g) & (h)The satellite meteorological images over the Australia at 23:30 December 19, 2015 UTC and 05:30* 04:34:00 May 15, 2016 *UTC; The red circle is the gust position.*

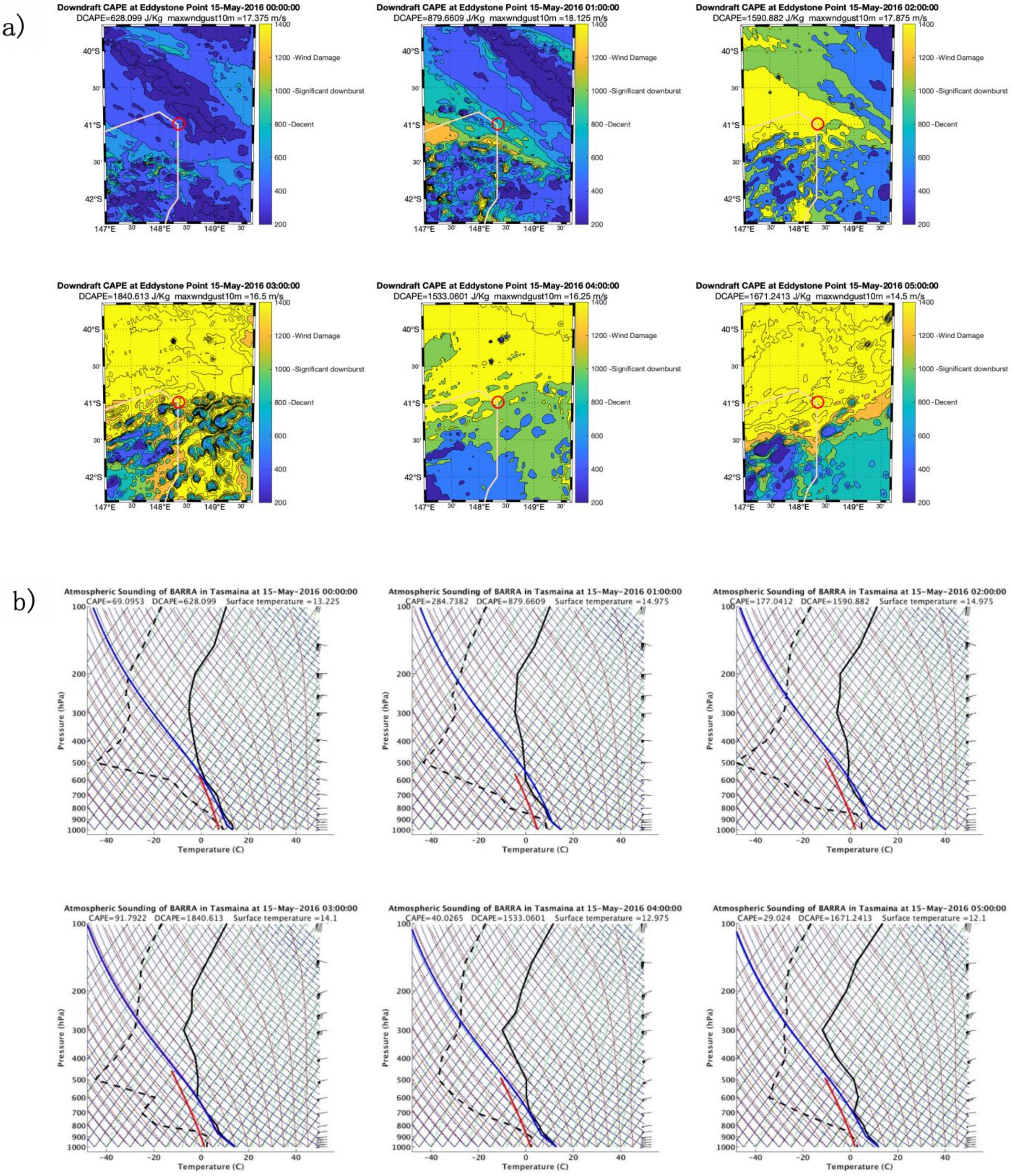


Figure 8 (a) The hourly maps of the Downdraft Convective available potential energy (DCAPE) over the Eddystone Point at from 00:00- 06:00 May 15, 2016 UTC (Eddystone Point is in the centre of the map); (b) The hourly Atmospheric Sounding of Eddystone Point, with the index of CAPE, DCAPE, surface temperature at from 00:00- 06:00 May 15, 2016 UTC; The red circle is the gust position.

3.3 The potential and intensity of the thunderstorm downburst happen in Tasmania.

For the 2nd, 3rd, 5th, 6th, 7th ,11th, 16th, 18th and 19th events in the table 1.

- Tasmania's southern and eastern regions are densely populated. Because of the frequent westerly winds in Tasmania, the area is on the leeward side. 2nd, 18th and 19th. They are downburst thunderstorm, but the damage wind is not very strong is about 100km/h. Sometimes will cause some damage such as damage the house.
- In the 6th, 11th and 13th events happened in the windward side on the western and northern of Tasmania. They belong to the line of the storm. This also will cause the damage downburst thunderstorm, but the damage wind is not very strong is about.
- The large DCAPE events (3rd, 5th, 7th, 16th) occurring in the eastern foothills of the Wellington Mountains or the eastern foothills of the South Huon Valley are not the downburst. They are the not the downburst thunderstorm. They are the events; which air mass became dry after climbing the windward slope and fell along the Leeward slope due to gravity after losing the support of the hillside. The damage can also very strong in the Tasmania. The Tasmanian mountains are undulating, and the prevailing westerly winds are very easy to happen, but there are not many recorded cases in populated areas.
- What is more, the 25th events, is happened in the Tasman Sea, it is showed a downdraft wind formation and expansion. This is downburst thunderstorm happened in the sea. Usually this kind of events is much more danger than the downburst thunderstorm happened in the land because the stronger wind. But usually it is no do harm to the people or society. So, for the downburst thunderstorm happened in the Tasmania did not include those events.

Finally, seven large DCAPE incidents in urban areas were identified. There are 6 events. The 2nd, , 6th, 11th, 13th, 18th and 19th events in the table 1.

4 Discussion

The 6 events be determent in this project are all from the Severe Storms Archive. And To better explain the statistical nature of storm frequency, the percentage of a destructive thunderstorm event being exceeded in any one year (or probability) is now expressed as the Annual Exceedance Probability (AEP). The likelihood of the downburst thunderstorm is 20.0 % AEP which means downburst thunderstorm has a 20.0% probability or chance of occurring in any one year. We can see in the table 1 that the downburst events we found from the Severe Storms Archive occurred in areas with relatively high population levels and most of what we find from the BARRA data set takes place in relatively remote seas or places where very few people live.

In addition to using DCAPE data to determine the occurrence of downburst thunderstorms and based on the empirical equations proposed by McCann (1994)this research uses the BARRA dataset from 1990 to 2019 to calculate the comparative analysis of the thunderstorm gale that occurs in WINDEX and the Capital Airport area. Combined with the theory proposed by Geerts (2001),the strong wind gust formula GUSTEX in this area was obtained. Comprehensive judgment of the probability and severity of downburst thunderstorms in Tasmania. McCann's forecasted micro-burst torrent experience index WINDEX makes it possible to make a short-term forecast of the maximum gust value of thunderstorm. In addition, there are also cases where WINDEX and Thunderstorm's maximum gusts are quite different. WINDEX reflects the potential for downburst thunderstorm, and WINDEX's forecast of thunderstorm gale has its own limitations.

The WINDEX empirical equation is sensitive to both the environmental stratification state and the atmospheric declining rate. WINDEX is greater than the actual gust and differs greatly, probably because the WINDEX and GUSTEX coefficients are not fit Tasmanina very well. If WINDEX and GUSTEX coefficients are to be used to predict downburst for Tasmania, the coefficients need to be further accurate by referring to downburst events identified in this project. Calculated WINDEX is often small in the spring and autumn time periods. There is a positive correlation between the maximum wind speed of Tasmanian summer thunderstorm gale and WI, and WINDEX can better reflect the maximum gust wind speed of downburst thunderstorms.

The GUSTEX equation incorporates momentum download factors to obtain the characteristic coefficients GUSTEX3 and GUSTEX4 applicable to the wind speed, which more fully reflects the cause of the thunderstorm's largest gusts, and to some extent makes up for the limitations of WINDEX.

Using only DCAPE is limiting and does not fully reflect the occurrence of downburst thunderstorms. Many times, we found that the weather structure in many places has a Significant DCAPE, but we did not find the basis for downburst thunderstorms on Doppler wind charts, air model-pseudo-soundings calculated from BARRA and Typical MSLP analysis. So, for the occurrence of downburst thunderstorms, we need to combine DCAPE, WINDEX, and GUSTEX data.

The WINDEX re-analysis based on the hourly BARRA data could be done efficiently, therefore, cases were re-evaluated based on the hourly BARRA data temperature and dew point temperature input. Table 1 shows the rawinsonde-based WINDEX values along with the recomputed surface-based values. Based on this hourly analysis, the trend in the WINDEX forecasted wind gust does show potential value. Two of the five cases selected did show some potential in forecasting the observed microburst gust maximum.

Initially, I analysed the data because the requirements of DCAPE, WINDEX and GUSTEX were met at the same time. Therefore, a large number of downburst events are excluded. For example, the first Downburst thunderstorms in table 1 WINDEX$_1$ and GUSTEX$_1$ are very low, but we found that WINDEX$_1$ and GUSTEX$_1$ will have data higher than 25 meters per second one or two hours before Downburst thunderstorms. This is because the formation of gusts will take some time, so the prediction data like WINDEX and GUSTEX will appear in the unstable period after the air mass rises. So, we see that WINDEX and GUSTEX may appear before the DCAPE value becomes larger.

For the determine of strong gusts that cause by the thunderstorm downburst in Tasmania. Through the classification of the weather system and the diagnosis and analysis of atmospheric physical quantities, it is initially judged whether there is a possibility of thunderstorm strong winds. The WINDEX value is used to preliminarily determine the intensity of thunderstorm and strong wind. The critical values of DCAPE> 900 J / kg, WINDEX$_2$> m · s and GUSTEX$_{1,2}$> 27.8 m · s^{-1} were used as the criteria for identifying downburst thunderstorms alarms.

4.1 The characteristics of the downburst thunderstorms atmospheric condition

For downburst thunderstorm, the unsteady of the vertical air is very important. Because cold fronts, cold troughs, and suddenly elevated lower atmospheric temperatures can all cause downburst. However, to achieve the destructive downburst thunderstorm still requires strict your conditions. For example, our analysis of the incident that occurred in the Tasman Sea (ID 25). Because the surface temperature is abnormally increased (10 degrees Celsius/2 hours), the temperature in sounding becomes larger and the dewpoint temperature becomes smaller, which means the relative humidity of the air decreases and promotes the evaporation of precipitation during the descent below cloud base will increasing the formation of the cold pool. Thereby increasing the strength of downburst. The cold groove has a great effect on inducing atmospheric instability. In the case study (2nd, 18th and 19th), we find that they occurred in Tasmania is caused by the trough of the cold trough. The movement of the cold trough reflects the change in atmospheric conditions in the upper atmosphere, and most troughs bring clouds and a wind shift, particularly following the passage of the trough. This results from convergence or "squeezing", which forces lifting of moist air behind the trough line. Following this, the relatively dry lower air and unstable upper air are conducive to the formation of downburst. The uplift effect of the cold front on the heating mass can also cause atmospheric instability. Because the strong cold front will lift the warm and humid air into the upper atmosphere. The collision of cold and warm fronts will promote rainfall. There will be a downdraft. I found that the decline of downburst can not only be achieved by atmospheric circulation. In In the case study (ID 25), I found that the saturation of the upper atmosphere caused by the unstable rise of the underlying gas caused the sinking caused by the increase in density. The upper air supply can come from the advection of the upper air. And the advection direction and velocity of the upper air will affect the direction of the cold pool's diffusion.

4.2 The caveats

According to the time and location provided by the Severe Storms Archive, we sometimes cannot find the weather data that corresponds with downburst gusts. However, by comparing and referring to the Doppler wind chart of the corresponding time period, we can more clearly see whether the gust actually occurred. For incidents where gusts have occurred, we further determine the possibility of downburst. Considering that the time interval of the original data of the BARRA dataset is six hours, and the data in the intermediate time period is the predicted data obtained through simulation and analysis, our analysis and judgment of an event usually spans three hours before and after recording the event. In this way, we find that the meteorological data in favor of downburst events sometimes appears one or two hours early or late. In addition, most of the gusts that occur are Multicell thunderstorms or single-cell thunderstorms with a degree of a multicell character. So, the downburst gusts at some recording points come from the downdraft shear winds that occur in nearby areas. Therefore, the location of destructive winds is also identified to check whether there are qualified weather conditions. For example, high DCAPE value area.

BARRA's horizontal resolution is high, but the vertical accuracy of weather data for specific locations still requires improvement. For example, using the same formula to plot the profile of sounding, in the part of the 200hpa- 300hpa The final result loses a lot of detail (for example, the accuracy of the final data is replaced by a straight line), as a result of the accumulation of many data errors. Not conducive to the analysis of specific weather characteristics. For example, The BARRA dataset output has a big difference between 500hpa and the University of Wyoming data, but the DCAPE, WINDEX and GUSTEX we use in the calculation also meet the use of weather data to surface pressure at 500hpa. Although the detail of the 200-300hpa is lost, it has little impact on our analysis of the vertical movement of the air, it does not have much impact on the calculation of the data. All of our existing research methods can use the BARRA dataset to provide a reliable reference for the reconstruction of the air condition in the Tasmanian region. We can also use Doppler wind maps and Typical MSLP analysis images to help the analysis.

If WINDEX and GUSTEX coefficients are to be used to predict downburst for Tasmania, the coefficients need to be further accurate by referring to downburst events identified in this project. And use more data to test the prediction results of WINDEX and GUSTEX for downburst in this experiment.

5 Conclusions (1 figure/table & 300 words)

Because frequent strong west winds in Tasmania and the surrounding sea are unobstructed, gusts are very likely to occur. However, because the annual temperature change in Tasmania is not very large, it is not easy to form a very severe downburst thunderstorm. In addition, Tasmanian westerly winds combined with the undulating terrain are also prone to form very severe downhill winds.

We found six Severe downburst thunderstorms in the past 30 years over the Tasmania. The likelihood of the downburst thunderstorm is 20.0 % AEP which means downburst thunderstorm has a 20.0% probability or chance of occurring in any one year. In general, Tasmania has frequent thunderstorms, but destructive downburst thunderstorm is not very high and destructive compared to Tasmania's hurricane weather, but it is still worthy of people Care and attention. By studying the downburst thunderstorms cases at sea, windward slope, leeward slope, and four places at the foot of the mountain, we found that for downburst thunderstorm, the unsteady of the vertical air is very important. And cold fronts, cold troughs, and suddenly elevated lower atmospheric temperatures can all cause downburst.

Simply using DCAPE has a great limitation to fully reflect the occurrence of downburst thunderstorms. Many times, we found that the weather structure in many places has a great DCAPE, but we did not find the basis for downburst thunderstorms on Doppler wind charts, air sounding, and Typical MSLP analysis. I summarize from these six events. So, for the occurrence of downburst thunderstorms, we need to combine DCAPE, WINDEX, and GUSTEX data. The values of DCAPE> 900 J / kg, WINDEX$_2$ > 25 m · s and GUSTEX$_{3,4}$> 27.8m · s-1 can be used as the criteria for identifying downburst thunderstorms.

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