VH-MDX Meteorological Conditions

Analysis aiding the search for missing aircraft VH-MDX

Version: 2nd Edition, October 2015

1st Edition, May 2014

Glenn Strkalj

Distribution: Public

Copyright and distribution of this document

Document purpose

This document was drafted to support VH-MDX search related operations.

The contents of this document are purely intended to clarify accident events to the best of the author's ability to offer a solid base in determining the location of VH-MDX.

This document must not be used for any purpose other than to provide guidance in locating VH-MDX.

The information and data presented in this document must not be used for any legal purpose, as the content may be inaccurate or subject to interpretation errors of the author.

Acknowledgement

Many people have provided significant assistance to the author in producing this and other VH-MDX research documents. Most individuals have requested anonymity and the author would like to thank these people for their important input.

Special thanks go to the National Archives of Australia and the Airways Museum and Civil Aviation Historical Society for their fantastic support.

This reference paper will be subject to change as new information and data is found or errors corrected; it is a 'living' document.

Amendments:

2nd Edition: October 2015

- More pilot and ground reports included
- Grammatical corrections
- Inclusion of altimeter errors

Abbreviations

AAL	Above Aerodrome Level
ABV	Above
ADF	Automatic Direction Finder
AMD	Amended
AMSL	Above Mean Sea Level
AQZ	Area QNH Zone
ARFOR	Area Forecast
ASIB	Air Safety Investigation Branch
ATA	Actual Time of Arrival
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATS	Air Traffic Services
BASI	Bureau of Air Safety
BKN	Broken
BLW	Below
BOM	Bureau of Meteorology
CAT	Clear Air Turbulence
CAVOK	Ceiling and Visibility OK
CLD	Cloud
COT	Coast
CU	Cumulus
DALR	Dry Adiabatic Lapse Rate
DZ	Drizzle
DTRT	Deteriorating
ELR	Environmental Lapse Rate
FCAST	Forecast

FIS	Flight Information Service
FIR	Flight Information Region
FL	Flight Level
FM	From
FZL	Freezing Level
GNSS	Global Navigation Satellite Systems
GRADU	Gradual Change
GS	Ground Speed
INS	Inertial Navigation System
INTER	Intermittent period
INTSF	Intensifying
ISA	International Standard Atmosphere
˚M	Degrees Magnetic
MOD	Moderate
MON	Above Mountains
MS	Minus
MSL	Mean Sea Level
MTW	Mountain Waves
NVFR	Night Visual Flight Rules
NDB	Non-Directional Beacon
NM	Nautical Mile
MS	Minus
N	North
ONCL	Occasional
PCA	Planning Chart Australia
POH	Pilot's Operating Handbook
RAAF	Royal Australian Air Force
RA	Rain
RMK	Remark

S	South
SALR	Saturated Adiabatic Lapse Rate
SEV	Severe
SC	Strato Cumulus
SCT	Scattered
SEV	Severe
SH	Showers
SIGMET	Significant Meteorology Report
SN	Snow
ST	Stratus
°T	Degrees True
TAF	Terminal Area Forecast
TAS	True Air Speed
TURB	Turbulence
UTC	Universal Time Coordinated
VIS	Visibility
VOR	VHF Omni Directional Range
WX	Weather

© Glenn Strkalj 2014-2015

Executive Summary

The aim of this document was to collate and analyse data and information in order to make conclusions as to the meteorological conditions likely apparent during the VH-MDX accident.

The following weather conditions and outcomes were found for the accident area:

- Strong south-west to westerly winds 30-50 knots at 8000'AMSL
- Significant turbulence on the lee (east & north side) of significant terrain
- The only cloud appeared to be located along mountaintops and the south-west to western slopes of mountains (localised cloud)
- A dark night with no moon during the accident
- ISA-5 conditions
- Freezing level between 6000'AMSL and 7000'AMSL
- Highest risk icing conditions when in cloud between 6000'AMSL and 10000AMSL
- Snow fell along the mountaintops and windward approaches
- Altimeter over-read approximately between 130' to 280' in close lees.

A cold front had passed through the accident area approximately 9 hours prior to the accident. Accordingly, there was no 'storm front' during the accident as is commonly suggested. In fact conditions were generally clear skies.

A thunderstorm associated with this front was located *well out* to sea.

VH-MDX was found to have entered some of the only cloud in the general area. This was localised orographic cloud formed by the uplift of air by the steep and high elevation ranges in the Barrington and Gloucester Tops area.

Associated with the localised cloud was snow. Snow was observed on the ground around high terrain including Gloucester Tops in the days following the accident.

Likely aloft winds were determined from a variety of sources including airborne reports and weather balloon flights from Williamtown hours before and after the accident. The likely 8000'AMSL wind during the accident was concluded to be 230˚T-270˚T at 30-50 knots with somewhat slower speeds from similar directions at lower altitudes.

The pilot of VH-MDX reported picking up icing on two occasions. It was found that the meteorological conditions over and in close proximity to the Barrington ranges that VH-MDX flew through were of the *highest risk* for aircraft icing.

Moderate to severe turbulence existed around and over the Barrington ranges. Downdrafts would have existed in the eastern to northern lees of the main ranges. It was concluded that the best method of predicting the location and strength of downdrafts was by computer fluid dynamics modeling.

This document has determined defensible meteorological conditions likely apparent during the VH-MDX accident that can be used in flight path analysis.

© Glenn Strkalj 2014-2015

1. Introduction

1.1.Purpose

Understanding the meteorological conditions that existed during the time of the VH-MDX accident is crucial in narrowing down probable positions of the final resting place of the aircraft.

Much debate has been had regarding the meteorological conditions that existed during the VH-MDX accident so a robust overview with solid conclusions is required.

Wind velocities of reasonable confidence and accuracy are required to confidently plot dead-reckoned tracks whilst the knowledge of likely locations for clouds and where downdrafts may have occurred can also assist in developing realistic theories as to the flight path of VH-MDX in the crucial last few minutes prior to the final received transmission.

1.2.Aim

The aim of this document is to collate and analyse meteorological information relating to the VH-MDX accident and to make conclusions as to the likely meteorological conditions that existed.

1.3.Sources of meteorological information and data

Metrological information and data for the night of the VH-MDX accident can be obtained from the following available sources:

- Bureau of Meteorology reports and forecasts
- Bureau of Meteorology weather balloon data
- Department of Transport documents
- Meteorological reports from pilots
- Position fix timings from pilots
- Observations of conditions by search aircraft and people on the ground.

2. Weather overview

2.1.Timings and position

The VH-MDX accident occurred on the night of 9th August 1981 in the general area of the Barrington Tops/Gloucester Tops north-west of Newcastle, NSW[1].

As the progress of VH-MDX was *normal* up until just after Taree, the main period of interest in application of meteorological information and data is from 0850:00 UTC (Taree position) to 0941:20 UTC (No radar contact at RAAF Williamtown) on the 9th August 1981.

The final radio transmission received by Air Traffic Services (ATS) from VH-MDX was a '*5000*' (foot) altitude call at 0939:26UTC[1]. Assuming aviation low-level area forecast boundaries in 1981 were the same as in 2014, the accident occurred in the mid-southern section of Area 20.

2.2. Cold front

A cold front moving east and aligned roughly north-north-west/ south-south-east passed through the Barrington Tops area approximately 9 hours prior to the accident[1]. West to south-westerly winds were *forecast*[1] behind this front and it will be shown that these winds were generally reported.

2.3. Temperature

Freezing levels of 4000' and 7000' and an ISA deviation of around ISA-4 were forecast for Area 20[1].

VH-AZC reported an outside air temperature of -2° at Taree when cruising at 8000'AMSL[1]. This suggests an ISA -1 deviation and a freezing level (0° isotherm) of close to 7000'AMSL.

Williamtown weather balloon information indicates -0.6°C at approximately 6200'AMSL around 1 hour and 20 minutes after the final received transmission from VH-MDX. This indicates approximately ISA -4 conditions and a freezing level close to 6000'AMSL.

The same Williamtown weather balloon flight also suggests ISA -5 conditions at Williamtown airport level and at around 9500'AMSL.

<u>It can be seen outside air temperature sources suggest the 0°C isotherm (the freezing level) was between approximately 6000'AMSL and 7000'AMSL.</u>

It is likely that the Williamtown weather balloon data was the most accurate source of temperature information for the area of the Barrington ranges. <u>As a result ISA-5 conditions were most likely apparent.</u>

2.4. Thunderstorm

An isolated thunderstorm was reported off the coast of Port Stephens *well out* to sea around the time of the accident[1]. This thunderstorm reveals the position of the *cold front* that was also expected to be well off shore by this stage.

One pilot reported that this thunderstorm caused needle fluctuations of both Automatic Direction Finder's (ADF's) on his aircraft[1]. The pilot of VH-MDX also experienced ADF indication instability[1] but did not suggest a possible cause.

2.5. Cloud and turbulence

Pilot observations suggest the night was *very dark* with many pilots reporting no moon being visible[1].

Clouds were forecast for the western tops of mountains with only scattered cloud along the coast[1]. Most if not all pilot reports revealed widespread *clear* conditions along the coast without cloud[1].

Pilot reports indicate localised cloud was situated in proximity of the Barrington Ranges and indeed the pilot of VH-MDX reports flight in cloud and experiencing icing in the Barrington ranges area[1]. Turbulence, up to *severe* intensity, was reported by pilots in the area of the Barrington Ranges[1].

© Glenn Strkalj 2014-2015

3. Wind

3.1. Introduction

Section 1.1 highlighted the importance of determining the prevailing wind velocities during the VH-MDX accident. Available sources of wind data will be overviewed in this section.

3.2. Aviation Low Level Area Forecasts (ARFOR)

Aviation Low Level Area Forecasts (ARFOR's) provide a *general overview* of meteorological conditions within a defined geographical area suitable for *en-route* planning *between* departure and destination airports.

Specific information can also be included for critical areas such as particular mountain peaks or gaps within the defined area that aircraft regularly transit.

To identify the applicable ARFOR requires reference to the Planning Chart Australia (PCA) upon which the intended aircraft track is overlaid. Any defined area the track falls within results in the ARFOR's required for consideration.

Figure 1 shows a *2014* PCA chart. It can be seen VH-MDX's flight path along the Coolangatta to Bankstown sector requires an Area 20 and Area 40 ARFOR. It is *assumed* the ARFOR area boundaries presented are the same as those in 1981.

As the Barrington ranges lie in the middle-south of Area 20, ARFOR 20 is of particular interest.

© Glenn Strkalj 2014-2015

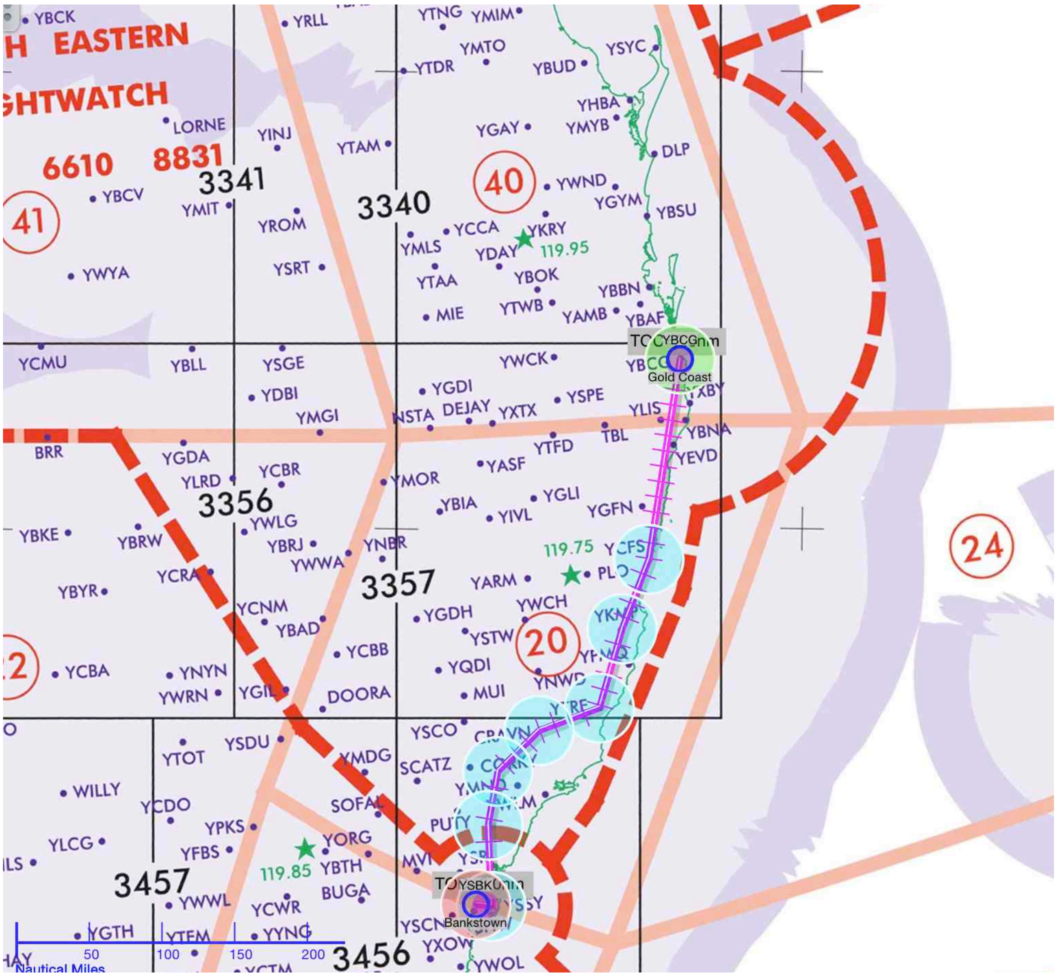


Figure 1: ARFOR areas (2014). The approximate planned track of VH-MDX is indicated by the dark pink line. ARFOR areas are delineated by light pink lines and identified by a red number with circle. Area 20 covers the Barrington Tops area that is located just east of YSCO (Scone). Area 20 is approximately bounded by Richmond (YSRI), Orange (YORG), Dubbo (YSDU), Moree (YMOR), Tenterfield (YTFD), Ballina (YBNA) and coastal to just north of Sydney (Airservices Australia/ OzRunways 2014).

Areas 20 and 40 ARFOR valid for the flight of VH-MDX are recorded in the NSW BASI (Bureau of Air Safety Investigation) VH-MDX Accident Investigation folio[1].

Both the area 20 and area 40 ARFOR were valid for 12 hours from 0500UTC – 1700UTC 9th August 1981[1]. The pilot of VH-MDX made his last received radio transmission at 0939:26UTC[1]. This time is approximately in the middle of the ARFOR validity period.

Annex A contains the 'raw' Area 20 and Area 40 ARFOR's for reference whilst figures 2 and 3 on the following pages present decoded versions.

Area Forecast valid from 0500UTC-1700UTC Area 20

Altitude (AMSL), Wind in (degrees *True*)/ (knots):

2000 feet	260˚/30
5000 feet	250˚/35
7000 feet	250˚/40
10000 feet	250˚/45 Temperature minus 9˚ Celsius (at 10000 feet)
14000 feet	250˚/55 Temperature minus 16˚ Celsius
18500 feet	250/˚70 Temperature minus 23˚ Celsius

Cloud:
Scattered (covering 3-4 eighths of the sky) Stratus at 2000 feet to 4000 feet above the western sections of mountaintops, occasionally Broken (covering 5-7 eights of the sky) with rain showers and drizzle.

Broken Cumulus between 4000 feet and 7000 feet above the western sections of mountaintops with occasional tops to 12000 feet.

Scattered Cumulus between 4000 feet and 6000 feet along the coast

Visibility:
40 kilometers deteriorating to 4000 meters in rain showers, drizzle and snow showers

Weather:
Scattered rain showers and drizzle over the western sections of mountaintops mainly in the south of Area 20.

Isolated snow showers over mountaintops mainly in the south-west of Area 20.

Freezing level:
4000 feet and 7000 feet

Icing:
Moderate icing in cloud above the freezing level

Turbulence:
Severe turbulence below 12000 feet over the eastern sections of mountaintops
Moderate turbulence in the remaining areas

Remark:
Mount Victoria conditions: visibility 10 kilometers, rain showers, scattered Stratus cloud 4000 feet, Broken Cumulus 4500 feet.
Murrurundi Gap conditions: visibility 10 kilometers, rain showers, broken Cumulus at 4000 feet.

Figure 2: Decoded Area 20 ARFOR.

<u>Area Forecast valid from 0500UTC-1700UTC Area 40</u>

<u>Altitude (AMSL), Wind in (degrees *True*)/ (knots):</u>
<u>North of a line Brisbane to Goondiwindi</u>

2000 feet	230˚/20
5000 feet	250˚/20
7000 feet	250˚/30
10000 feet	250˚/40 Temperature minus 4˚ Celsius (at 10000 feet)
14000 feet	240˚/50 Temperature minus 7˚ Celsius
18500 feet	240/˚60 Temperature minus 16˚ Celsius

<u>South of a line Brisbane to Goondiwindi</u>

2000 feet	250˚/30
5000 feet	240˚/30
7000 feet	240˚/40
10000 feet	240˚/50 Temperature minus 5˚ Celsius (at 10000 feet)
14000 feet	240˚/80 Temperature minus 10˚ Celsius
18500 feet	240/˚80 Temperature minus 20˚ Celsius

<u>Cloud</u>:
Broken (covering 5-7 eighths of the sky) *Stratus* at 1000 feet to 2500 feet in Drizzle.
Broken Strato-Cumulus 2500 feet to 6000 feet above mountaintops and west, south of Oakey.
Scattered Strato-Cumulus 3000 feet to 6000 feet elsewhere in Area 40.

<u>Visibility</u>:
60 kilometers deteriorating to 2000 meters in drizzle.

<u>Weather</u>:
Scattered drizzle over the mountaintops and west, south of Stanthorpe.

<u>Freezing level:</u>
7000 feet

<u>Icing</u>:
Moderate icing in cloud above the freezing level

<u>Turbulence</u>:
Occasional severe turbulence; refer to the SIGMET (significant Meteorology) report (a special *brief* report/forecast concerning potential meteorological hazards to aircraft).
Moderate turbulence elsewhere.
Mountain waves south of latitude 25˚S.

Figure 3: Decoded Area 40 ARFOR.

Winds of interest from the ARFOR are:
5000'AMSL = 250°T/35 knots
7000' AMSL = 250°T/40 knots
10000' AMSL= 250°T/45 knots

These winds were valid from 0500UTC – 1700UTC.

3.3. Aviation Terminal Area Forecasts (TAF)

TAF's are aviation forecasts generated for particular aerodromes and represent conditions within 5NM of the aerodrome[20].

TAFs for aerodromes located around the Barrington ranges region and beyond may give clues to wind characteristics at the altitudes VH-MDX was operating at.

TAFs forecast wind at 10 meters height[15]. This is representative of aerodrome (ground) level wind. Despite this, it is possible to apply known *general* trends of wind variation with height to obtain an *approximate* but indicative value aloft.

Winds normally *increase* in strength and *back* in direction with increase in altitude as a result of lessening friction effects of the terrain or the sea[2]. This results in aloft wind directions paralleling isobars more[2].

Changes of around 10° over the sea and 30° over land are typical between the surface wind and the wind clear of the boundary layer[15]. Figure 4 shows the backing of direction and increase in speed of wind with height.

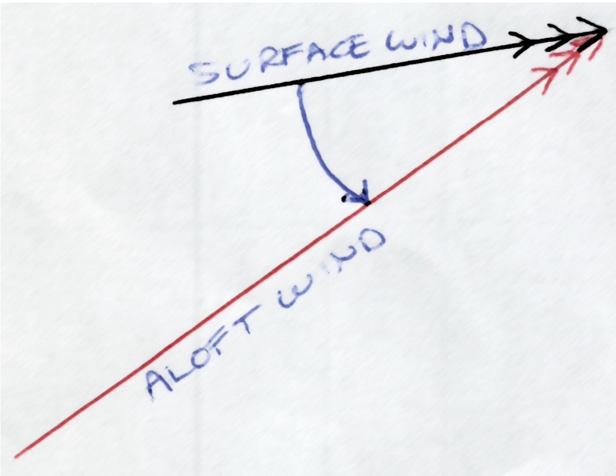


Figure 4: Wind change with height. Compared to the surface wind, winds aloft normally increase in strength and back (reduced bearing value) in direction. This is the result of lessening boundary layer friction effects with increased height. If a surface wind is known, an approximation can be made of the winds at altitude above the same location. Despite this, specific local effects can yield completely different results (Image Glenn Strkalj 2015).

Annex B contains the raw TAF's from the NSW BASI VH-MDX Accident Investigation folio[1] whilst figure 5 overleaf graphically depicts TAF *surface* winds at the various geographical locations.

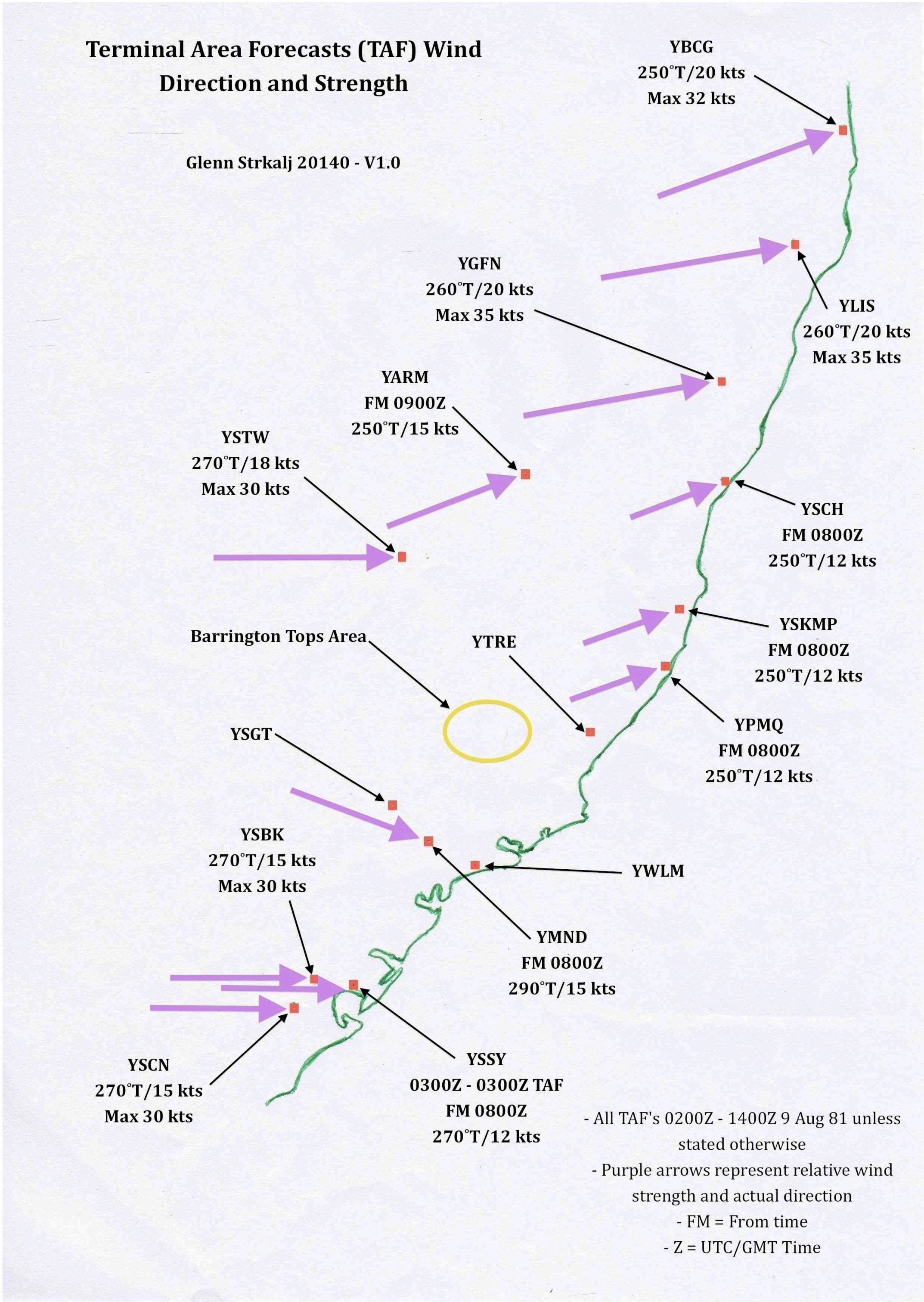


Figure 5: TAF winds (Surface level). Purple arrows depict relative wind strength and forecast direction at *surface* level. Readily obvious is that TAF forecast winds around the immediate Barrington Tops area are predominately westerly. TAF winds are surface level forecast winds. Wind would be expected to increase in strength and back in direction about 30° with increase in altitude. Accordingly, stronger south-westerly winds would be expected at altitude above the TAF aerodromes (Image: Glenn Strkalj 2014, TAF information: National Archives of Australia (Bureau of Meteorology) 1981[1]).

TAF's shown were valid from 0200UTC to 1400UTC except the Sydney TAF that was valid from 0300UTC to 0300UTC. A number of TAF's as annotated had *Gradual Change* periods terminating one half hour to an hour and a half before the accident (0800UTC – 0900UTC). This means the change in weather conditions would have been complete well before the time of the accident.

Accordingly, these Gradual Change (GRADU) periods have been referred to as a '*From*' (FM) times to reflect contemporary terminology for a 'hard' change point. The FM time is specified as the later GRADU time as the change in conditions was forecast to be complete by this time.

Maitland TAF is the closest geographical TAF to represent the upwind sector of the Barrington ranges area of interest. It would be expected winds at altitude above this TAF point would *back* (turn counter-clockwise) more to a *southerly* origin in the order of 30°[2] whilst the speed would likely increase[2].

From this, it can be seen Maitland (YMND) would very approximately have had winds from the following direction *at altitude*: 290°T-30°= 260°T. Accordingly, a wind around 260°T in the general upwind vicinity of the Barrington Tops was likely but it must be remembered Maitland is located in the Hunter Valley so, further local modification of winds from free stream was likely.

Kempsey (YKMP) and Port Macquarie (YPMQ) located downstream of the Barrington Tops area and on the coast were forecast to have a wind direction of 250°T at 12 knots at surface level. A rough adjustment for these winds to account for lessening friction effects at altitude suggests winds in the order of 250°T-30°=220°T aloft.

As stated in section 2.2 a cold front passed through the area approximately 9 hours previous. The passage of a cold front in the southern hemisphere *always* results in a final wind direction from the south to south-west as figure 6 shows[2].

This is reflected in the TAF forecast winds as flows at height above the TAF locations are generally south-westerly. ARFOR winds of section 3.2 also adhere to this rule.

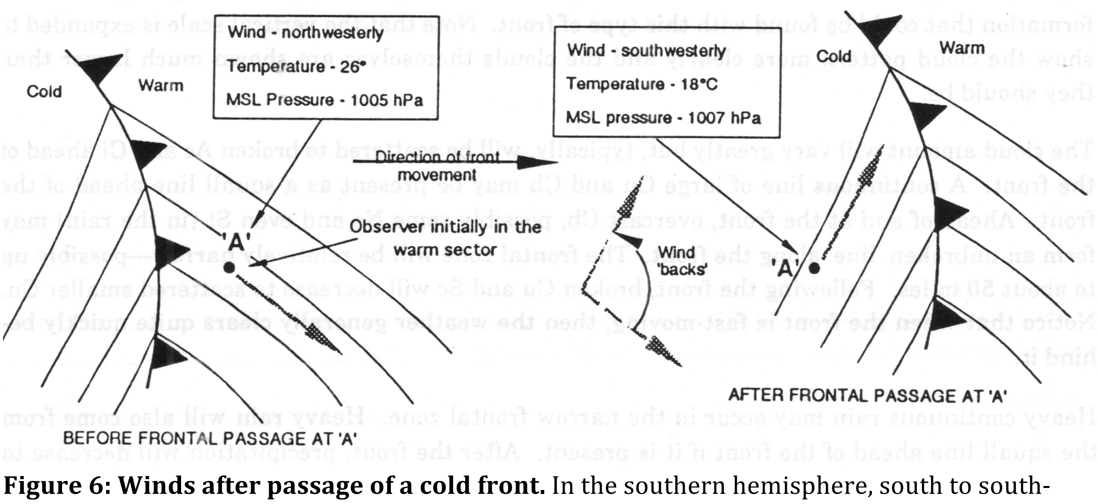


Figure 6: Winds after passage of a cold front. In the southern hemisphere, south to south-westerly winds are always apparent following passage of a cold front Image: (D-H Training Systems 1999).

Such coarse adjustments as carried out in this section would be approximately valid (notwithstanding effects of atmospheric stability and local effects) for altitudes above the boundary layer that is usually 2000'-3000' thick[2].

Local effects of rugged terrain and atmospheric stability could work to modify the above suggestions significantly. Despite this it is reasonable to *very broadly* conclude that from approximately 7000'-8000'AMSL and above winds would likely have originated from around 260˚T upstream of the Barrington Tops and flowed from approximately 220˚T downstream of the Barrington Tops.

Below 7000'- 8000'AMSL winds would be subject to local effects and would likely adopt a value between the surface wind and free stream wind aloft.

TAF's around the Barrington Tops region valid for the time of the accident *broadly* suggest (when approximately adjusted from ground-level) winds at 7000'-8000'AMSL and above originating from about 260˚T upwind of the Barrington Tops and 220˚T downwind whilst winds below 7000'- 8000'AMSL were likely to veer towards the west and decrease in strength from these values.

3.4.Bureau of Meteorology synoptic pressure charts

Mean Sea Level (MSL) pressure charts normally allude to the *gradient wind*: the wind above the boundary layer 'free' from friction effects[2].

MSL charts for 0500UTC (1500EST) on the day of and the day after the accident are presented in figures 7 and 8[13][4] and suggest a strong south-westerly wind.

The chart for the day of the accident (≈4.5 hours prior to the accident) depicts the position of the cold front *well off shore* abeam the Barrington Tops region.

As described in section 3.3, the passage of a cold front in the southern hemisphere *always* results in a south to south-westerly wind afterwards[2]. It can be seen a reasonably strong south-westerly flow was apparent many hours before the accident to at least 0500UTC on the following day.

The following traits of the MSL charts indicate such a wind:
- The close isobar spacing suggest a *strong* wind
- Wind flow at stronger speeds almost parallels isobars with a slight bias towards inflow into the low pressure system; this is south-westerly
- The direction of wind in the southern hemisphere is determined by placing the low-pressure system to the right hand side of a person, the wind direction then originates from behind (Buys Ballot's Law)[2]. This suggests a south-westerly wind.

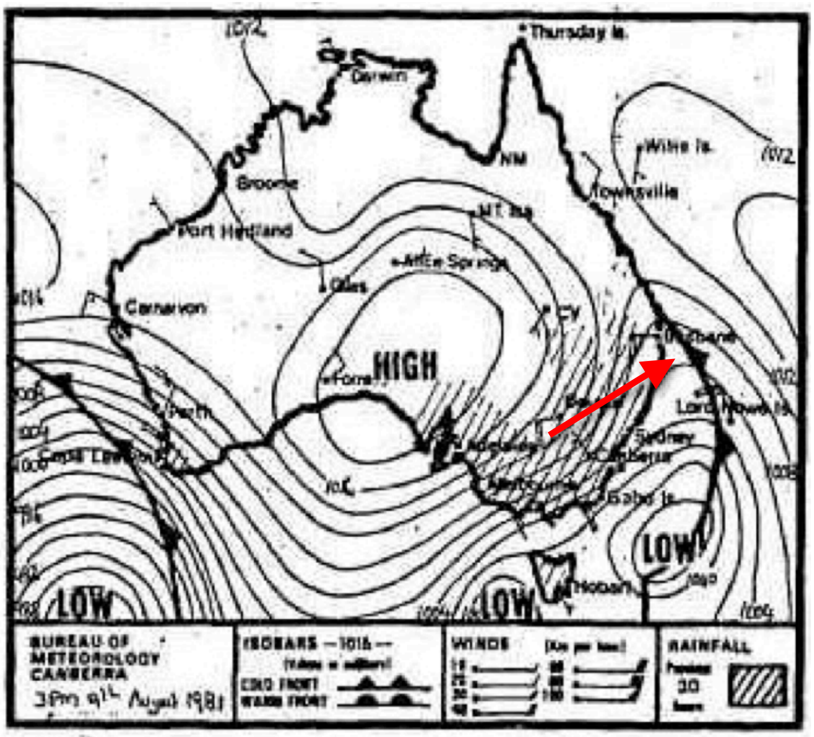


Figure 7: Synoptic MSL chart 1500EST (0500UTC) 9th August 1981: This was the synoptic situation approximately four and a half hours prior to the VH-MDX accident. The red arrow indicates very approximately the aloft wind direction in the Barrington Tops region (south-westerly). Reasonably close isobars suggest strong winds. The cold front had well and truly passed by 1500EST resulting in generally clear skies. Although widespread rain is depicted, rain seemed only to be associated with localised orographic uplift. (Image: Bureau of Meteorology, 1981, cited in *The Canberra Times*, 9th August 1981).

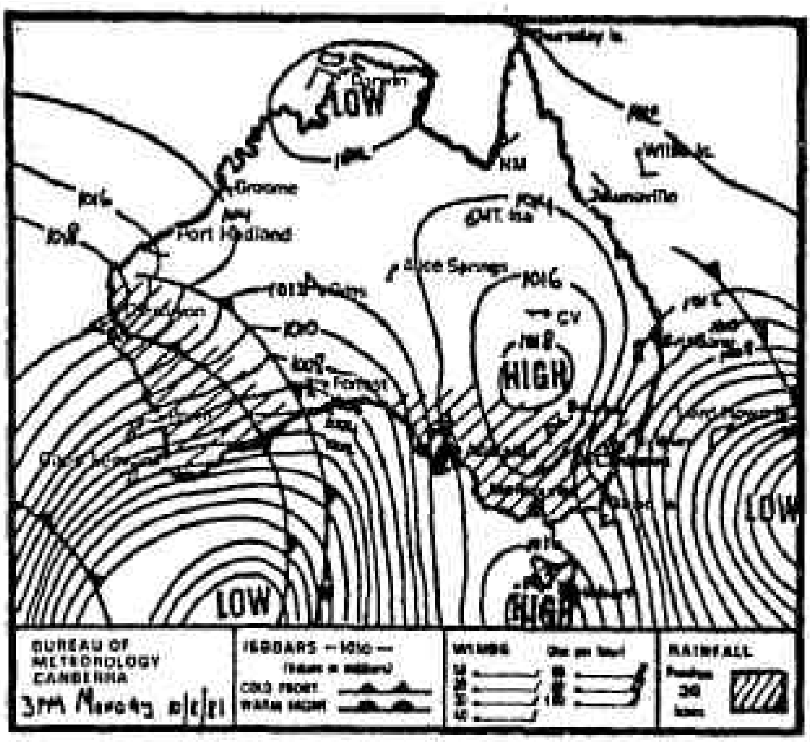


Figure 8: Synoptic MSL chart 1500EST (0500UTC) 10th August 1981): This synoptic for the day after the accident suggests similar conditions to the accident day (Image: Bureau of Meteorology, 1981, cited in *The Canberra Times*, 10th August 1981).

Synoptic MSL charts suggest a strong south-westerly wind was apparent in the Barrington Tops region for some hours before the VH-MDX accident to at least the afternoon of the following day.

3.5. Pilot reports/Communication transcripts

In-flight pilot reports can offer insight into actual winds through calculation of drift required to maintain a track and speed using time intervals between two fixes. In 1981 before the advent of prolific GNSS (Global Navigation Satellite Systems) use, such calculations were performed with clock, map, heading and a manual flight computer; a derivative of a mechanical slide rule calculator.

Position timings are obtained from Department of Transport (DoT) communications transcripts and pilot statements. Timings and drift held can be blended to reveal a likely wind.

Additionally, some larger aircraft of 1981 had equipment such as Doppler radar and Inertial Navigation Systems (INS) that could calculate wind reasonably accurately. As VH-MDX was operating below 10000'AMSL, the wind reports from these larger better-equipped aircraft generally flying above 10 000 feet are less relevant. Nevertheless such upper-level winds can be used to verify upper-level ARFOR winds which can then suggest the accuracy of lower-level winds.

The geographical positions of aircraft that will be referred to in this section for wind related information is shown in figure 9 below.

Figure 9: Airborne wind sources. Tracks of aircraft discussed in this section (Google Earth 2015, Base chart: Department of National Development and Energy 1981, plots: Glenn Strkalj 2015).

3.5.1. VH-AZC

VH-AZC was a Cessna 206 proceeding mainly coastal from Coolangatta to Bankstown along similar overfly points as VH-MDX including Coffs Harbour, Kempsey and Taree[1]. The discussed track segment of VH-AZC is shown in figure 9 as an orange line (note: a yellow line from another aircraft is overlaid as well).

As VH-AZC was operated under the Instrument Flight Rules (IFR) (unlike VH-MDX), the pilot of VH-AZC easily obtained a clearance to operate through RAAF Williamtown and Sydney Controlled airspace[1]. By Taree, VH-AZC was only seven minutes ahead of VH-MDX at the same altitude (8000')[1] thus, was conflicting traffic.

The leg from Taree NDB (Non Directional Beacon) to Williamtown NDB was a course of 200˚M and distance of 65NM[3]. A time interval of approximately 40 minutes between these positions is found from communication transcripts and the pilot's statement as shown below in figure 10 (Taree NDB ATA≈0845UTC Williamtown NDB ATA ≈0925UTC)[1].

This equates to a Ground Speed (GS) of 98 knots and aligns with the pilot's statement indicating 97 knots GS.

A True Air Speed (TAS) of 130 knots and Indicated Air Speed (IAS) of 120 knots at a cruise power setting of 23"/2300RPM are suggested by the pilot[1]. These figures are reasonable as the Cessna-206G Pilot's Operating Handbook (POH) suggests a TAS of around 135 knots for the prevailing or forecast conditions[5] whilst 120 KIAS adjusts to 136 KTAS given reported conditions (ISA-1˚) or 135KTAS in forecast conditions (ISA-5).

Assuming 130KTAS and heading of 215˚M as the pilot suggests, a wind of 263˚T at 43 knots is calculated. Should a TAS of 134 knots have been apparent then the calculated wind is 260˚T at 47 knots.

These winds differ mainly in *direction* from the pilot's suggestion of 240˚ at 40-45 knots. The pilot was probably still working in degrees *magnetic* and suggesting a *magnetic* wind direction that would then convert to 252˚T; ≈10˚ shy of 263˚T or 260˚T. These three figures effectively agree and would provide little practical difference in effect on aircraft navigation.

My estimate for Williamtown was 17. In fact I had to put my estimate back (twice I think) and eventually arrived there at 25. I remember 25 quite clearly. It had taken me 40 minutes to go 65 miles so my ground speed for that sector was 97 knots. This would indicate a headwind component of 33 knots (assuming the TAS of 130). I believe I was holding a heading of about 215 to make good the 200 TRE-WLM track. I guess that indicates a wind say from 240 of about 40 - 45 knots. For an aircraft flying TRE to CRV the wind would have been more of a headwind.

There was no turbulence at all at 8000' south of Kempsey on the KMP-TRE-WLM track.

The weather was so pleasant and the visibility so good that at about 22 I asked SY 121.6 if I would have a clearance coastal WLM-Norah Head-Palm Beach-MLY-HBB-BK. At first I was told it may be difficult given conflicting outbound traffic. Subsequently when I provided levels and time intervals to Mona Vale OCTA I was given a clearance to proceed Night VMC and at Hexham was transferred to WLM Control (133.1) for a descent to Norah Head, at first, to 5000'.

Figure 10: VH-AZC pilot reported winds: Taree-Williamtown. Wind direction can be determined by using time interval between two known points and heading used to maintain a track. A south-westerly (≈250˚T-260˚T) at 43-47 knots is found (Image: National Archives of Australia (Department of Transport) 1981[1]).

When north of Coffs Harbour, the pilot of VH-AZC commented to Flight Service that the winds experienced were more around 220˚ than the forecast 240˚T. Such a suggestion broadly agrees with the TAF adjusted winds of section 3.3.

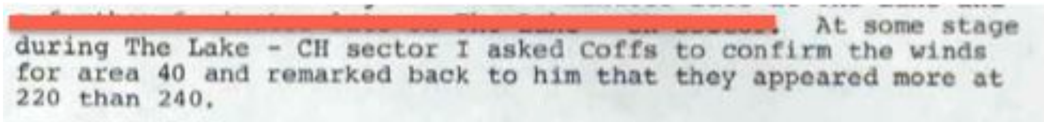

[redacted] At some stage
during The Lake - CH sector I asked Coffs to confirm the winds
for area 40 and remarked back to him that they appeared more at
220 than 240.

Figure 11: FS reported winds: The Lake-Coffs Harbour. The area discussed here is the far north NSW coast; well north of the accident area. Nevertheless, general trends can be gained. A more southerly (220˚) wind direction compared to Barrington Tops area winds agrees with TAF winds of the region adjusted for altitude from section 3.3 and to some extent the MSL charts (figure 7 & 8) (Image: National Archives of Australia (Department of Transport) 1981[1]).

<u>VH-AZC experienced a wind of around 260˚T at 45 knots between Taree and Williamtown from time 0845UTC to 0925UTC, the latter time being approximately 15 minutes before VH-MDX's last received radio call.</u>

3.5.2. VH-CNW

VH-CNW was a Piper model PA-28 aircraft conducting Night Visual Flight Rules (NVFR) training[1]. The planned flight was to fly Cessnock - Scone – Merriwa – Cessnock[1]. VH-CNW reported departing Cessnock at 0912UTC and tracking 334˚ on climb to 6500'[7].

Prior to Scone and abeam Lake Liddell, the pilot in command elected to divert to Singleton NDB due to '*a wall of cloud*' perceived to be along a line from Nelson Bay to Scone[1]. The discussed track segment of VH-CNW is shown in figure 9 as a black line.

Wind at 7500'AMSL was reported as a '*direct westerly at 50 knots*'[1]. This wind report roughly agrees to an altitude-adjusted wind (290˚T-30˚=260˚T) from the Maitland TAF (being the closest archived TAF to VH-CNW's track). ARFOR wind for 7500'AMSL was approximately 250˚T at a little over 40 knots.

<u>VH-CNW reported a *direct* westerly wind at 50 knots in the Cessnock to Singleton area at 7500'AMSL. VH-CNW was airborne during and prior to the final received transmission time from VH-MDX at 0939:26UTC.</u>

3.5.3. VH-ESV

VH-ESV, a Cessna 402 was proceeding from Toowoomba to Williamtown via Sandon East at 9000'AMSL. The discussed track segment of VH-ESV is shown in figure 9 as a blue line. The pilot reported in a statement that he experienced a 35-40kt headwind due to '*very strong westerly winds*'[1].

Communications transcripts record the pilot of VH-ESV reporting a westerly wind at 70kts to Sydney FIS-5 (Flight Information Service 5)[1]. This statement implies that VH-ESV is experiencing 70 knot winds however the author believes that the pilot of VH-ESV is *repeating* what the pilots of turboprop aircraft operating around FL200 were reporting on the FIS-5 frequency.

© Glenn Strkalj 2014-2015

In an ASIB (Air Safety Investigation Branch) Inspector's statement of interview with the pilot of VH-ESV, there is reference to an '*east coast commuter aircraft northbound assessed these as 65 knots plus*'[1].

'Commuter aircraft' likely refers to turboprop aircraft operating around FL200 hence reflecting higher altitude winds rather than at 9000'AMSL that VH-ESV was cruising at. The ARFOR 20 wind at 18500' was 250˚T/70 knots which also supports this suggestion.

It is unknown what VH-ESV's actual tracking was prior to Sandon East but it was likely to be via Glen Elgin NDB or Glen Innes NDB then to Armidale NDB given a time interval of 23 minutes between an unknown position and Sandon East.

Armidale NDB was 54 NM from Sandon East and a GS of 140 knots equates if considering a time interval of 23 minutes. When adjusted for a 35-40 knot *headwind*, a TAS of around 175-180 knots results. This TAS is likely for a Cessna 402. Relevant courses are Toowoomba – Glenn Innes NDB 174˚M[3] Armidale - Sandon East 165˚M[6], Sandon East – Williamtown 165˚M[6].

Combining these courses with the approximate TAS and headwind component indicates a south-westerly wind at around 45 knots or a westerly at around 100 knots. The westerly can be discarded on the grounds of being too strong compared to all the winds from different sources discussed thus far.

VH-ESV was experiencing these winds at least during the period 0847UTC-0913UTC, some 26 minutes before the final received call from VH-MDX.

<u>Accordingly, it is suggested likely that VH-ESV experienced headwinds of 35kt-40kt as reported and that a south-westerly wind of approximately 45 knots was experienced.</u>

Additionally, VH-ESV refueled at Williamtown and departed to conduct VH-MDX search operations. At 1139UTC Sydney ATS requested '*..to provide a wind drift*'[14].

The pilot of VH-ESV responded at 1143UTC, approximately 2 hours after the final received transmission from VH-MDX with '*..wind drift is 11 to 12 degrees 30 knots*'[14].

At the time of the wind check, VH-ESV was operating at 6000'AMSL in vicinity of a position 012˚M/39NM from West Maitland[14]. This position is near the foothills of the eastern section of the main Barrington Ranges, approximately 2km south of Big Ben.

It is unknown what track or airspeed VH-ESV was maintaining during the wind check so, accurate conclusions cannot be drawn. It is accepted that a 30 knot wind was apparent at 6000'AMSL and when considering other sources of wind information, a south-westerly direction of origin was likely.

3.5.4. VH-TVG

VH-TVG (probably a PA-28) was tracking Cessnock – Singleton - West Maitland – Aeropelican - The Entrance at 4000'AMSL and required 50° layoff on the Aeropelican – The Entrance leg due '*strong westerly winds*'[1]. The discussed track segment of VH-TVG is shown in figure 9 as an aqua line.

Cruise TAS planned for the PA-28 is normally 105 knots[8]. Aeropelican to The Entrance required a course of around 192°M[6]. Assuming a direct westerly wind direction was apparent then a wind speed of approximately 80 knots was required to achieve 50° of drift at 105KTAS. 80 knots is viewed excessive in light of other pilot wind reports.

To 'achieve' a wind in the order of 50 knots from a westerly direction (as has been found so far) with 50° drift along the stated track would require a TAS of around 60knots.

There were not many training aircraft that exhibited such a slow cruise TAS however it is possible although unlikely that the aircraft was a different type or was attempting to climb. Alternatively, local effects may have accelerated the air flow.

More likely is that the report of 50°drift may have been in error.

<u>The reported wind that VH-TVG experienced cannot be refined to an accurate value although what can be concluded is that a strong westerly wind was apparent.</u>

3.5.5. VH-FCF

VH-FCF believed to be a Fokker 27 type aircraft was tracking from Sydney to Coffs Harbour via Williamtown and Taree[1]. The aircraft's track is shown in figure 9. VH-FCF flying at FL170 (≈17000'AMSL) reported overhead Williamtown at 0917UTC and estimated Taree at 0934UTC[1]. The Williamtown Taree leg was 65NM on a course of 019°M[6]. A statement from the captain of VH-FCF is given below in figure 12.

> The weather at the time was sky clear on the coast and this situation extended for at least 30 NMs inland. Although there was no moon I could see a visible horizon at FL/170 in all directions. I will admit that at lower altitudes this may not have been so but certainly if this aircraft had been on the Coastal Route he would have had no trouble maintaining contact with the ground. There were winds at altitude giving a SW component of 60 K on that night and I do not doubt that a pilot inland at low altitude would have experienced standing wave conditions.

Figure 12: Excerpt from Air Safety Incident Report from Captain K. Holden. Captain Holden was Pilot in Command of VH-FCF (National Archives of Australia (Department of Transport) 1981[1]).

A wind of 60 knots from the south-west was reported by the captain of VH-FCF at 'altitude'[1] that is assumed to be FL170. It cannot be determined if this wind was obtained through navigation of the aircraft or if the captain was simply repeating the forecast wind.

© Glenn Strkalj 2014-2015

The *pilot reported* wind broadly agrees with interpolation between ARFOR winds at 18500’ of 250°T/70 knots and 14000’ of 250°T/55 knots thus validating the ARFOR winds to some extent.

It is likely that VH-FCF *experienced* a south-westerly wind of 60 knots at FL170 between Williamtown and Taree from 0917UTC to 0934UTC. The latter time is approximately 5.5 minutes prior to VH-MDX’s final received radio transmission.

3.5.6. VH-CUD

VH-CUD was operating VFR the morning after the VH-MDX accident. The area of interest is shown in figure 9 as a pink circle. The pilot of VH-CUD reported a south-westerly wind at 20 knots in the area 5NM south of Craven waypoint[12]. This information was passed on to the RCC from Sydney FS at 2111UTC; 0711EST on the morning after the accident[12].

3.5.7. VH-CEC

VH-CEC was a television station helicopter engaged in search activities commencing the morning after the VH-MDX accident[12]. VH-CEC positioned to Gloucester airfield from 2HD radio station at Newcastle[12] during the morning after the accident as shown by the west most red line in figure 9.

At 2130UTC (0730EST), the pilot reported a ‘*strong* wind’ at 4000’AMSL[12].

3.6. Williamtown Air Traffic Control Officer (ATCO)

At 0936:30UTC, a Sydney ATCO requested the Williamtown ATCO for the weather conditions at Williamtown, this being approximately 3 minutes prior to the final received radio transmission from VH-MDX[1].

The response was: ‘*My weather, we’re CAVOK-fairly strong winds, westerly at 20k*’[1].

Applying a similar correction to this surface wind as in section 3.3 (-30°), it can be seen a south-westerly wind was likely at altitude.

A westerly wind of 20 knots at near ground level was observed at RAAF Williamtown approximately 3 minutes prior to the final received radio transmission from VH-MDX . This alludes to a stronger wind from the south-west at *altitude* above Williamtown.

3.7. ASIB views

The following ASIB statement sums up the Branch’s assessment of weather conditions:

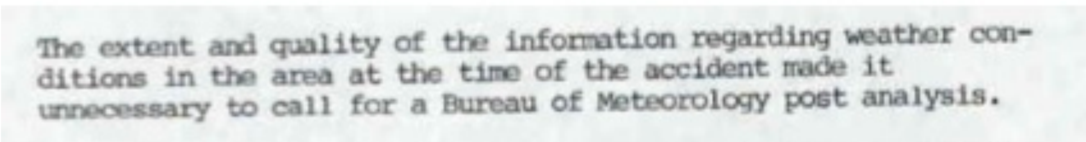

The extent and quality of the information regarding weather conditions in the area at the time of the accident made it unnecessary to call for a Bureau of Meteorology post analysis.

Figure 13: ASIB Statement regarding weather analysis. (Image: National Archives of Australia (Department of Transport) 1981[1]).

Within the ASIB/BASI VH-MDX Accident Investigation Report, the prevailing wind is given as 250˚ at 60 knots[1]. It appears likely that this wind was the result of blending ARFOR, pilot reported and possible *post accident* search reported winds.

During the night of the accident, it will be shown that continuous winds were unlikely to be above 50 knots. As the search progressed, varying reports from NSW Police regarding winds were recorded.

On the night of the accident, a Police officer on the ground approximately 2km south of Big Ben on the eastern foothills of the main ranges reported a *north-westerly* wind[14].

During the afternoon on the day after the accident, an ASIB Inspector at Mt Berrico reports '.*cloud coming in from Tamworth..*' alluding to a north-westerly wind[12].

Two days after the accident, Police advise the RCC of a weather report for the search area stating north-west to westerly winds at 40 knots[12]. About an hour later Police phoned the RCC and advised winds for the Gloucester area were north-westerly to westerly at 60 knots[12].

Section 3.5.3 highlights what appears to be confusion in the VH-MDX accident investigation folio regarding higher-level commuter aircraft reported winds in the order of 60-70 knots with those below 10000'AMSL.

As can be seen, potential input to the ASIB reported wind speed might have been derived from wind observations of inappropriate times and altitudes and, of questionable sources.

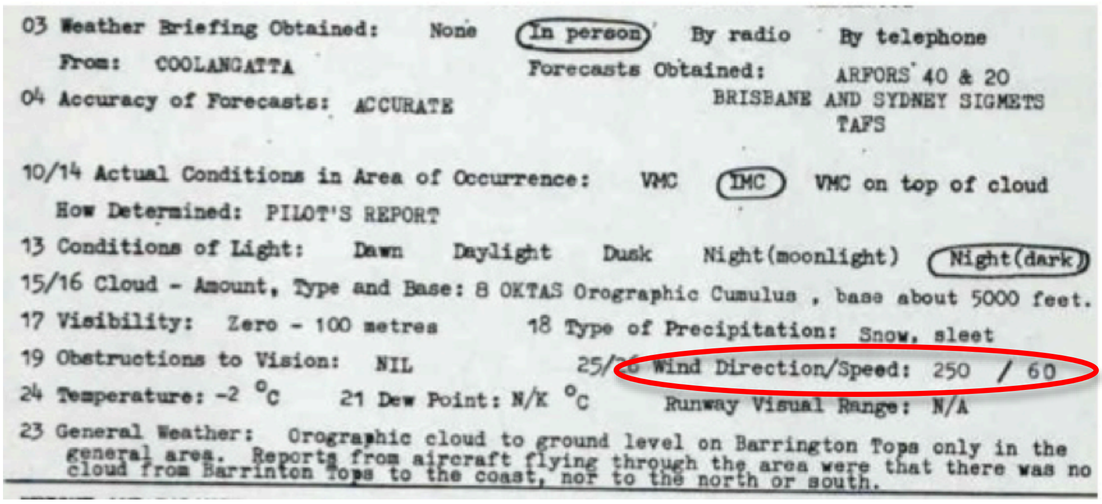

03 Weather Briefing Obtained: None In person By radio By telephone
From: COOLANGATTA Forecasts Obtained: ARFORS 40 & 20
04 Accuracy of Forecasts: ACCURATE BRISBANE AND SYDNEY SIGMETS
TAFS
10/14 Actual Conditions in Area of Occurrence: VMC IMC VMC on top of cloud
How Determined: PILOT'S REPORT
13 Conditions of Light: Dawn Daylight Dusk Night(moonlight) Night(dark)
15/16 Cloud - Amount, Type and Base: 8 OKTAS Orographic Cumulus , base about 5000 feet.
17 Visibility: Zero - 100 metres 18 Type of Precipitation: Snow, sleet
19 Obstructions to Vision: NIL 25/26 Wind Direction/Speed: 250 / 60
24 Temperature: -2 °C 21 Dew Point: N/K °C Runway Visual Range: N/A
23 General Weather: Orographic cloud to ground level on Barrington Tops only in the general area. Reports from aircraft flying through the area were that there was no cloud from Barrinton Tops to the coast, nor to the north or south.

Figure 14: ASIB Accident Investigation Report wind. Wind during the accident is given as 250˚, most likely *true* degrees, at 60 knots. This wind is most likely based on blended ARFOR winds, pilot reported winds and observed winds in the following days during the Search and Rescue operation (Image: National Archives of Australia (Department of Transport) 1981[1]).

<u>The ASIB conclude that the wind apparent during the VH-MDX accident was 250˚/60 knots. It is assumed the direction was in degrees true to be consistent with ARFOR's. It is viewed that such a wind speed reflects wind at levels well above 10000'AMSL.</u>

3.8.Ground witnesses

At 1231UTC on the night of the accident, police attending a fire of interest 2km south of Big Ben (eastern foothills) reported '*very strong wind gusts from the north-west*[14]. Given many other sources suggesting a south-westerly wind, the accuracy of the direction is viewed as questionable. Despite this, local effects from terrain may have modified the wind direction and indeed the wind may have been a north-westerly.

During search operations in the days following the accident, it was reported by a Gloucester Police Officer that '*many days were 60 knot to 80 knot winds'* also; *'with extreme turbulence in the Williams, Allyn, Chichester River valleys*[10]'.

It is unknown how the officer determined these wind speeds. Quite possibly the reports came from the Police helicopter crew. If the wind was determined by Police staff on the ground, the accuracy of the report is questionable.

<u>During the night of the accident a Police Officer reported very strong gusty winds from the north-west in the south eastern foothills area of the Barrington ranges. A Police Officer reported that winds during the search operation were on many days 60-80 knots.</u>

3.9.Wind modeling

A detailed fluid dynamics computer simulation of the airflow around Carey's Peak and the Upper Williams Valley area was carried out by Glenn Horrocks[9].

The simulation was carried out to support then-current theories relating to VH-MDX having impacted in or near the Upper Williams River area.

The simulation uses ARFOR winds and provides insight into *local* wind flows modified by terrain upstream and in within the area of analysis. The following conditions were predicted[9]:

- Flow separation existed over the top and lee flow area of Carey's Peak
- As a result of separation, there were no large downdrafts
- Downdrafts were limited to approximately +/-250fpm
- As altitude *decreased*, turbulence *increased dramatically*
- Winds in the middle of the Upper Williams River Valley at 5000'AMSL became *southerly* and blowing at *low* speed.

A profile of wind characteristics for the specific position analysed is given on the next page in figure 15.

The predicted winds are:

- Around 35 knots at 6000'AMSL
- Around 23 knots at 5000'AMSL.

These wind results are only valid for the particular geographic position specified.

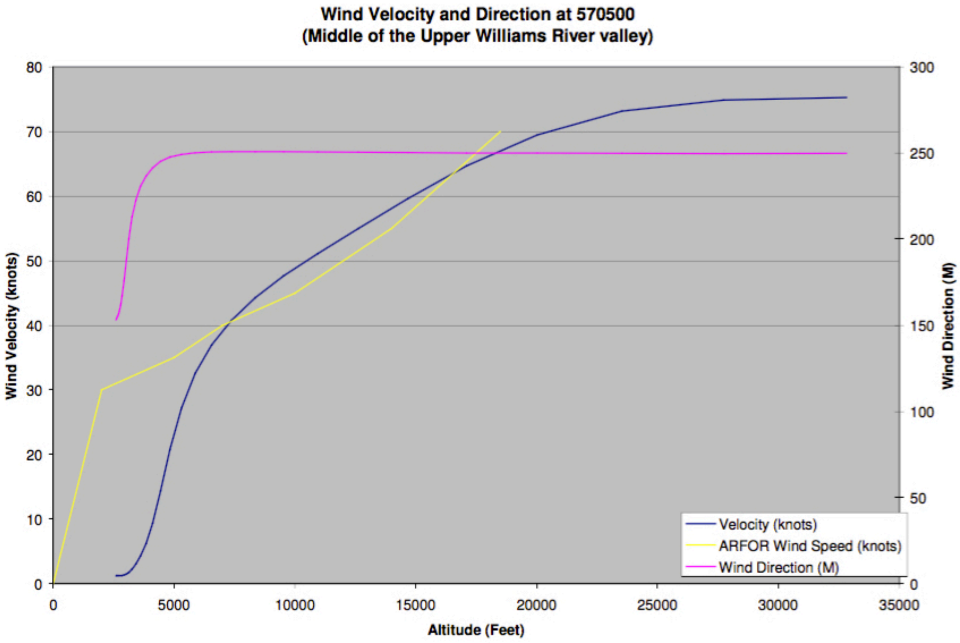


Figure 15: Wind profile at Upper Williams River. ≈35 knots at 6000'AMSL and ≈23 at 5000'AMSL are predicted in this particular geographical position (Image Glenn Horrocks 2013).

Winds of around 35 knots at 6000'AMSL and around 23 knots at 5000'AMSL are predicted by this model in the middle of the Upper Williams River Valley.

3.10. Weather balloon winds

Williamtown weather balloon reported winds have been obtained from the Bureau of Meteorology. Annex F contains the raw data. Some data is missing with the most important items being the sample heights that would have been obtained through radar tracking of the balloon.

Although missing some radar heights, wind data does exist along with pressure at the sample altitude. Applying the standard atmospheric pressure lapse rate below 10000' of 1hPa per 30' can yield heights that are accurate enough (within about 100'-200') for the purpose of determining the height of the sample. These lapse rate predicted heights are shown in red in the following tables.

There is Williamtown weather balloon data for:

- 2300Z 08 Aug 81 (0900EST on day of accident, approximately 10.5 hours *before* the last transmission from VH-MDX)
- 0500Z 09 Aug 81 (1500EST on day of accident, approximately 4.5 hours *before* the last transmission from VH-MDX)
- 1100Z 09 Aug 81 (2100EST on night of accident, approximately 1.5 hours *after* the last transmission from VH-MDX).

These will be presented in the following sub sections.

3.10.1. 2300Z, 08 Aug 81 Williamtown weather balloon flight

Wind Direction	Wind Speed (knots)	Pressure (hPa)	Geopotential Height in gpm (meters)	Height (Feet)
310	21.4	1005	8	26
300	36.9	950	-	1676
270	44.7	900	920	3018
270	42.8	850	1390	4560
-	-	800	1870	6135
270	33.0	750	-	7635
280	36.9	700	2930	9613
280	36.9	600	4090	13418
270	60.3	500	5420	17782

Figure 16: 2300Z, 8th August 1981 Williamtown weather balloon data. This data was obtained approximately 10.5 hours *before* the last transmission from VH-MDX (Data: Australian Government (Bureau of Meteorology) 1981).

3.10.2. 0500Z, 09 Aug 81 Williamtown weather balloon flight

Wind Direction	Wind Speed (knots)	Pressure (hPa)	Geopotential Height in gpm (meters)	Height (Feet)
290	23.3	1012	8	26
290	27.2	950	-	1886
270	33.0	900	-	3386
260	35.0	850	-	4886
240	40.8	750	-	7886
230	38.9	700	-	9386
250	42.8	600	-	12386
250	48.6	500	-	15386
250	70.0	400	-	18386

Figure 17: 0500Z, 9th August 1981 Williamtown weather balloon data. This data was obtained approximately 4.5 hours *before* the last transmission from VH-MDX (Data: Australian Government (Bureau of Meteorology) 1981).

3.10.3. 1100Z, 09 Aug 81 Williamtown weather balloon flight

Wind Direction	Wind Speed (knots)	Pressure (hPa)	Geopotential Height in gpm (meters)	Height (Feet)
290	15.6	1007	8	26
290	38.9	950	-	1736
260	44.7	900	930	3051
240	44.7	850	1390	4560
-	-	800	1880	6168
230	31.1	750	-	7668
230	36.9	700	2930	9613
240	38.9	600	4110	13484
240	58.3	500	5450	17880

Figure 18: 1100Z, 9th August 1981 Williamtown weather balloon data. This data was obtained approximately 1.5 hours *after* the last transmission from VH-MDX (Data: Australian Government (Bureau of Meteorology) 1981).

3.10.4. Comparison of relevant weather balloon winds

Altitude	2300Z (-10:40)	0500Z (-4:40)	1100Z (+1:20)
≈5000’	270°T/43kt	260°T /35kt	240°T /45kt
≈8000’	270°T /33kt	240°T /41kt	230°T /31kt
≈10000’	280°T /37kt	230°T /39kt	230°T /37kt

Figure 19: Comparison of weather balloon wind values at relevant altitudes and times.

Obvious from the comparison in figure 19 is that wind direction is *backing* with *time* although no real trend can be made of wind speed other than concluding speeds were *reasonably* stable.

<u>Williamtown weather balloon data suggests winds originating from 230°T-260°T at speeds between 31-45 knots at altitudes between approximately 5000’AMSL and 8000’AMSL. These were applicable above Williamtown around the time of the accident.</u>

3.11. Specific forecasts for VH-MDX search operation

Specific forecasts were requested from the Bureau of Meteorology to support the VH-MDX search operation. It is believed the winds were forecast for ground level.

3.11.1. 10 August 1981 EST

The first was issued at 1136UTC (2136EST) on the night of the accident valid for the next morning[14]. Wind in the Barrington Tops area was forecast to be 250°/25 knots[14]. It was likely the wind direction was in degrees *true* but the altitude for the forecast is unknown.

3.11.2. 11 August 1981 EST
Winds were forecast to be 10-15 knots with good weather for the day[27]. Wind direction and altitude unknown.

3.11.3. 12 August 1981 EST
Wind forecast for 0600EST were 5 to 10 knot winds[27]. Wind direction and altitude is unknown.

3.11.4. 13 August 1981 EST
Winds were forecast to be 20 to 30 knots varying from a westerly to south-westerly direction of origin.

3.12. Mountain winds

3.12.1. Complex flows
Wind flows near and over mountains are complex and depend on factors such as terrain shape, atmospheric stability, wind speed and wind angle[2][15]. Figure 20 below shows how the lower, more stable and denser air mass can flow *along* the sharp terrain whilst the higher air mass can flow *over* terrain given its lower density[15].

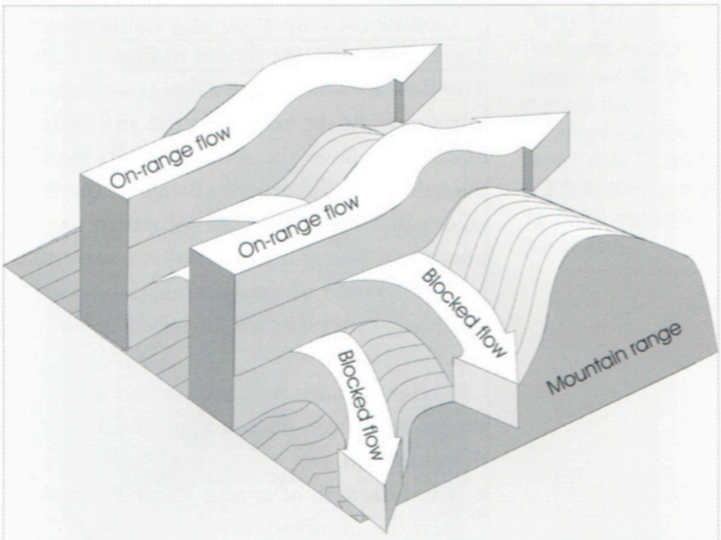


Figure 20: Mountain wind flows. Flows near and over mountains are complex (Australian Government (Bureau of Meteorology) 2003).

Reversed flow direction and even acceleration of wind is possible. Wind flows over hills and mountains can also result in the following phenomena or outcomes:

- Downdrafts
- Mountain waves
- Rotor zones
- Turbulence
- Lee trough (Significant altimeter errors).

Considering the flow complexity around mountains, forecast or reported winds may not be representative of winds around, over or close to mountains.

The best sources of wind information of the Barrington Tops area are from pilot reports and computer fluid dynamics modeling. The latter method has been carried out for a previous VH-MDX area of interest and will be conducted again for further areas.

3.12.2. Downdrafts

Flow over hills and mountains generally result in some form of downward flow on the lee as the flow attempts to restore to the pre-disturbance flow. The position and intensity of the downdraft is dependent on factors such as those described in section 3.12.1. This phenomenon will be discussed in section 6.

3.12.3. Mountain waves

Mountain waves are wind flows downwind of significant obstructing terrain that are wave/sinusoidal like in *vertical* flow. Such flow can be apparent at significant heights above the disturbing terrain[15]. Mountain wave wavelength can vary between 5km to 50km[16]. Figure 21 depicts mountain wave characteristics.

Knowledge of the existence of mountain waves is important to the VH-MDX accident as an understanding of the vertical flows can be gained that may assist determination of aircraft flight path.

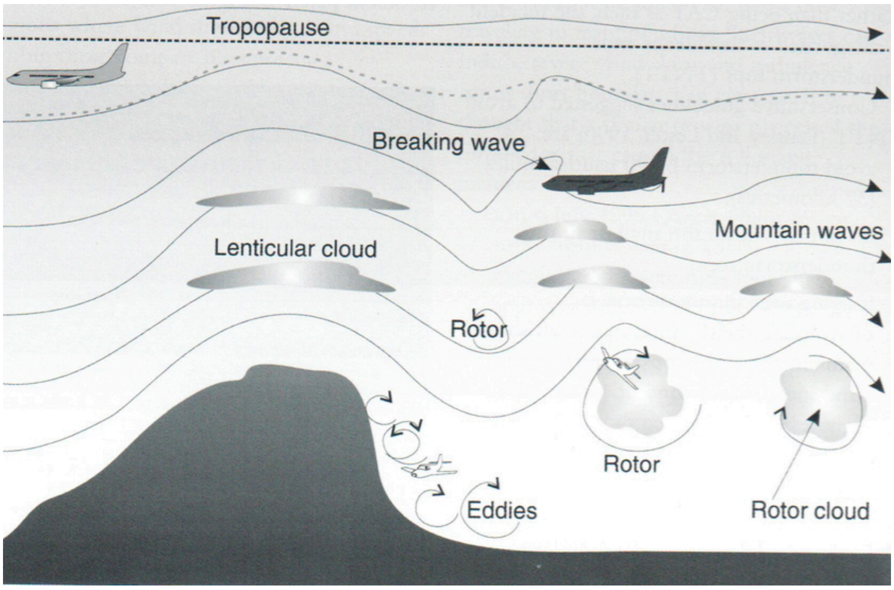


Figure 21: Mountain waves. (Image: Australian Government (Bureau of Meteorology) 2003).

Mountain waves do <u>not</u> have to be apparent for downdrafts to exist. Particular pre-conditions are required to generate mountain waves:

- Wind flow within 30° to perpendicular of the mountain range[24]
- Minimum wind speed near mountain top: 25[2][16][24]-30 knots[2][16]
- Increasing wind speed with increased height[16][24]
- Stable layer of air above the terrain sandwiched by an unstable layer below to ground level and an unstable or weakly stable layer above[16] (causes a venture-like effect)[28]
- Wind direction relatively constant with altitude[24].

Vertical airflows can exceed 15 knots (1500fpm) and have been measured at more than 40 knots (4000fpm) in the United States[16][28].

Figure 22 overviews these requirements compared to conditions that were apparent or forecast during the time of the VH-MDX accident.

Requirement	Forecast or apparent condition
Wind direction within 30° of perpendicular to the mountain range and near constant direction with height	230°T-270°T winds: - Close to perpendicular to Barrington Tops and Mount Royal range - Oblique to range associated with Gloucester Tops - Near constant direction with height
Wind speed near mountaintops minimum 25-30knots	30-50 knots at 8000'AMSL, around 25 knots near terrain
Increasing wind speed with height	- AROFR Area 20 and Upper Williams wind modeling suggest increasing wind speed with height. - WLM weather balloon *overall* suggests increasing speed with height, but a *slowing* of wind is evident between approximately 4000'AMSL and 13000'AMSL.
Stable layer above/near mountaintops	WLM weather balloon info suggests a *stable* layer around 4500AAL' to 6200'AAL at 1100UTC
Unstable layer below mountaintops to surface	- Cumulus cloud forecast along western tops of mountains - TAF's of some surrounding aerodromes had low level cumulus forecast - WLM weather balloon suggests an *unstable* layer *if in cloud* between 0-3000'AAL (extrapolating to ranges) at 1100UTC
Unstable to slightly stable layer above the stable layer	WLM weather balloon suggests a slightly stable <u>or</u> unstable atmosphere 6200'AAL to 9200'AAL (dependent on if in cloud or not: in cloud = unstable, in the clear = stable).

Figure 22: Mountain wave requirements vs. accident conditions. From this information, it is fair to suggest that mountain waves probably existed along the main ranges associated with the Barrington Tops during the VH-MDX accident.

Figure 23 presents environmental lapse rates (ELR) determined from the Williamtown weather balloon data at 1100UTC: approximately one and a half hours following the final received transmission from VH-MDX. ELR is used to determine atmospheric stability as used in figure 22.

Note that Williamtown is approximately 45NM south-east of the accident area and downwind of the Great Dividing Range accordingly, conclusions drawn offer insight rather than hard results.

© Glenn Strkalj 2014-2015

Height above Williamtown (AAL)	Approximate environmental lapse rate (ELR)	Stability (assuming SALR = 1.5°/1000' and DALR = 3.0°/1000')
0'-3000'	2.2°/1000'	*Conditionally unstable*: Stable if air considered has no cloud Unstable if air considered is in cloud
3000'-4500'	1.7°/1000'	*Very stable* if air considered has no cloud *Slightly unstable* if air considered is in cloud
4500'-6200'	0.9°/1000'	Absolutely *stable*
6200'-9600'	2.4°/1000'	*Conditionally unstable*: Stable if air considered has no cloud Unstable if air considered is in cloud

Figure 23: 1100UTC Williamtown 1100UTC weather balloon data and atmospheric stability.

From the information in figures 22 and 23, it can be seen that mountain waves probably existed in the Barrington Tops area during the VH-MDX accident.

Figures 24 and 25 show that mountain waves were *forecast* by ARFOR and SIGMET in the southern areas of AREA 40 (south of latitude 25°S (Bundaberg)) but not in Area 20 where the VH-MDX accident occurred[1].

SIGMET 1 090001 REVIEW 090400
SEV TURB. AND MARKED MTW FCST BLW 10000 FT MON AND
EASTWARD TO 60 NM SEAWARDS ABBN FIR S OF 26S. INTSF

Figure 24: Brisbane FIR SIGMET: Mountain waves (MTW) (Image: National Archives of Australia (Department of Transport) 1981[1]).

ARFOR 0500 TO 1700 AREA 40
WIND N ABBN/GDL
2000 230/20 5000 250/20 7000 250/30 10000 250/40
MS04 14000 240/50 MS07 18500 240/60 MS16
WIND S ABBN/GDL
2000 250/30 5000 240/30 7000 240/40 10000 240/50
MS05 14000 240/80 MS10 18500 240/80 MS20
CLD : BKN ST 1000/FT/2500 FT IN DZ
BKN SC 2500/6000 FT MON AND WEST S OF ABOK
SCT SC 3000/6000 FT ELSEWHERE
VIS: 60 KM DTRT 2000 M DZ.
WX: SCT DZ MON AND WEST S OF SPE
FZL: 7000 FT
TURB: OCNL SEV (REFER SIGMET). MOD ELSEWHERE. MTW S OF 25S.

Figure 25: Area 40 ARFOR: Mountain waves (MTW) (Image: National Archives of Australia (Department of Transport) 1981[1]).

If the air is dry, there may be no cloud associated with mountain waves but if sufficient moisture exists, clouds may form indicating mountain waves are present[16].

In particular, clouds of a lens-like appearance known as *lenticular clouds* forming in the areas of rising air and near the tops of a mountain range suggest mountain waves are present[16]. As figure 26 shows, lenticular clouds were present in the Barrington Tops area the *morning after* the accident[1].

it was reforming all the time. At the time of this discussion, we were looking at the cloud which he said was exactly as it had been on the previous afternoon. It looked like a vast lenticular cloud, with the top at perhaps 7500 to 8000 feet. It stopped abruptly at the Barrington Tops escarpment, and to the east northeast and southeast was cloudless.

Figure 26: Observed lenticular cloud. Lenticular cloud was observed the morning after the accident from Berrico Trig by an ASIB officer (Image: National Archives of Australia (Department of Transport) 1981[1]).

Such cloud suggests the existence of mountain waves and to some extent confirms the wind speed as being at least 25-30 knots near the mountaintops.

3.12.4. Rotor zones

Rotors are the result of air completely circulating[16] in the vertical plane in a relatively small radius at the lee of mountains. Large amplitude mountain waves combined with ideal shear conditions generate rotor zones[16]. Unstable air at lower altitudes below mountaintops encourages the rolling flow responsible for rotor zones at around the mountaintop level[28]. The rotor zone is shown below in figure 27.

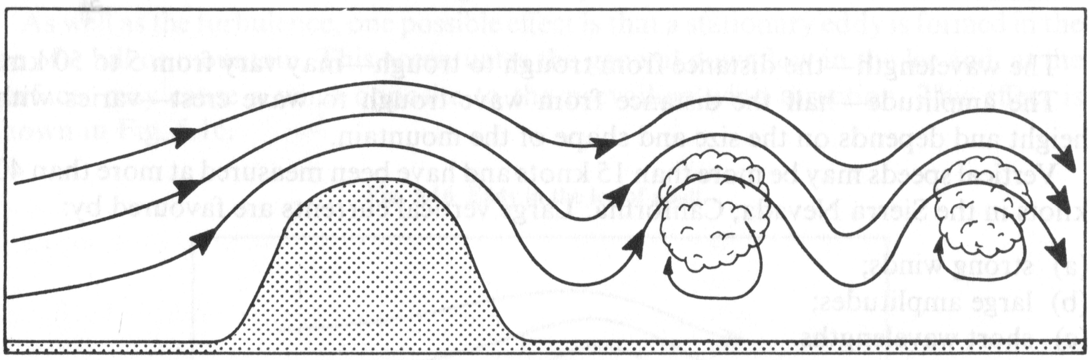


Figure 27: Rotor zone. Extreme turbulence and downdrafts are associated with rotor zones. Rotors clouds may or may not form (Australian Government (Bureau of Meteorology 1998[16])).

Rotor zones generate the most severe turbulence associated with mountain waves[16]. The strongest turbulence is associated with the rotor under the first wave *crest*[16]. At times, isolated ragged, rounded cloud known as rotor cloud, can be associated with rotors[16]. Rotors appear stationary relative to the ranges that generated them[2].

Pilots need to avoid rotor zones to avoid extreme turbulence and the possibility of contacting terrain.

3.12.5. Turbulence and lee troughs

These will be discussed in greater detail in sections 5 and 10 respectively.

3.13. Discussion: Wind

Figure 28 on the following page summarises the wind sources revealed in section 3.

There is little doubt that a south-westerly to westerly wind existed during the VH-MDX accident in the general area of the Barrington ranges at 8000'AMSL and below to the mountaintops. 230˚T- 270˚T is suggested as the likely wind direction range.

Wind speed wise, the 30-50 knot range at 8000'AMSL is suggested by the more reliable sources: i.e. weather balloon and aircraft time intervals between waypoints. Speed suggestions in excess of 50 knots are derived from more questionable sources.

Accordingly, a wind of 230˚T-270˚T at 30-50 knots is viewed as the most likely wind range apparent during the VH-MDX accident in the area of the Barrington ranges at around 8000'AMSL.

Wind speeds below this altitude would be reduced somewhat by boundary layer effects. Wind speeds of around 35 knots at 6000'AMSL and 23 knots at 5000'AMSL were predicted by computer fluid dynamics modeling at *one point* near the Barrington Tops. Such modeling offers insight to wind speeds at lower altitudes.

Wind *gusts* may also have existed that caused speeds in excess of 50 knots for relatively *short periods*.

Source	Time (UTC) Experienced /Forecast	Altitude (Feet)	Wind (°T/Knots)	Area Experienced/ Forecast
ARFOR 20	0500 – 1700	5000' 7000' 10000'	250°/35 250°/40 250°/45	Area 20
TAF	0800-1400	≈ >7000' ≈ >7000'	260° 220°	- Upwind of Tops - Downwind Tops
MSL Charts	0500 for 9th & 10th August	≈ >7000'	Strong south-westerly	General Area
VH-AZC	0845-0925	8000'	260°/45	TRE-WLM
VH-CNW	0932-0940	7500'	270°/50	CNK-SGT
VH-ESV	0847-0913	9000'	South-westerly ≈45 knots	GLI-ARM-SOE-WLM
VH-ESV	1143	6000'	30 knots with 11°-12° drift	Big Ben (Eastern foothills)
VH-TVG	?	4000'	Strong westerly	PEC-The Entrance
VH-FCF	0917-0934	FL170	South-westerly 60 knots	WLM-TRE
VH-CUD	≈2111	?	South-westerly 20 knots	5NM south of Craven waypoint
VH-CEC	2130	4000'	'strong wind'	East of Barrington ranges
WLM ATCO	0936:30	Ground Level	Westerly 20 knots	WLM
WLM ATCO ground level	0936:30	Aloft	≈ South-westerly	WLM modified for boundary layer
ASIB	N/A	N/A	250°/60	Barrington Tops Area
Police on the ground	Days following	N/A	60-80 knots	Barrington Tops Area
Police on the ground	1231	Ground level	Very strong gusts from north-west	Eastern foothills 2km south of Big Ben
Wind modeling	During accident	5000' 6000'	SW ≈23 knots SW ≈35 knots	Upper Williams River UTM 570 500
Weather Balloon	2300 08 Aug	4600' 7600' 9600'	270°T/43 270°T/33 280°T/37	WLM
Weather Balloon	0500 09 Aug	4900' 7900' 9400'	260°/35 240°/41 230°/39	WLM
Weather Balloon	1100 09 Aug	4600' 6200' 7700' 9600'	240°/45 xxxxx 230°/31 230°/37	WLM
Bureau of Meteorology	AM 10 Aug AM11 Aug AM 12 Aug AM 13 Aug	?	250°T/25 10-15 5-10 20-30	Barrington Tops Area

Figure 28: Summary of wind sources and values.

3.14. Conclusions: Wind

A wind of 230˚T-270˚T at 30-50 knots was likely experienced by VH-MDX in the Barrington Tops area at 8000'AMSL.

Winds just above the terrain were likely of a *similar* direction to those at 8000'AMSL but around 20-30 knots.

Gusts or modification to flow from terrain or atmospheric stability may have resulted in stronger or weaker winds over the mountaintops or at lower altitudes but such considerations are generally outside the scope of this paper.

4. Visibility

4.1. Forecast visibility

4.1.1. Area Forecast (ARFOR)

The Area 20 ARFOR forecast 40km visibility deteriorating to 4000 meters in rain showers, drizzle and snow showers[1].

So, as long as an aircraft was clear of precipitation or cloud, 40km visibility would be expected. Annex A contains the ARFOR's.

4.1.2. Terminal Area Forecasts (TAF)

Available TAF's of aerodromes located around the Barrington Tops in Area 20 forecast more than 10km visibility in the aerodrome terminal areas[1]. Annex B contains the TAF's.

4.2. Reported visibility

Many pilot reports exist of excellent visibility in the wider area of the Barrington ranges during the night of the accident. Reports of visibility also exist from people on the ground in the Barrington Ranges area.

4.2.1. VH-ESV

The pilot of VH-ESV overflew the accident area about 15 minutes before the final received radio call from VH-MDX. Whilst on descent from 9000'AMSL, the pilot reported seeing the glow of Sydney, the lights of Newcastle, Cessnock and Maitland and also seeing the lights of other towns in the Hunter Valley[1].

VH-ESV would have been located just south of Nowendoc, about 30NM north of the Barrington ranges when commencing descent.

VH-ESV also reported visual conditions at 6000'AMSL approximately 2.5NM south-east of Craven (2km south of Big Ben) at 1111UTC during a VH-MDX search task[14].

4.2.2. VH-FCF

The pilot of VH-FCF, a turboprop commuter aircraft operating from Sydney to Coffs Harbour via Williamtown reported sky clear conditions along the coast and at least 30NM inland[1]. The aircraft was cruising at FL170 and was overhead Williamtown about 23 minutes before the final received communications from VH-MDX[1].

4.2.3. VH-AZC
The pilot of an aircraft minutes ahead of VH-MDX at Taree and proceeding to overfly Williamtown at 8000'AMSL, VH-AZC, reported '*perfectly clear*' skies overhead Taree with '*…many stars..*' visible[1].

The pilot also observed smoke from 'bush fires' (believed to be controlled burns) on the mountains to the west and commented how there was no cloud along the coast and doubted there was any cloud east of the Barrington Tops[1].

4.2.4. VH-FCD
When north-east of Port Macquarie the pilot of VH-FCD reported VMC conditions south along the coast[14].

4.3. Moon
Many pilots reported a very dark night around the time of the accident. The pilot of VH-FCF flying near the Williamtown area about 23 minutes before the last received communications from VH-MDX reported that there was no moon[1].

Moonrise for Canberra was 12:05PM (1405UTC) on the night of the accident[13] and it is reasonable to assume that the moon rose at a similar time in the Barrington tops area. This is well after the time of the accident.

4.4. Police Officer
At 1231UTC (2231EST) on the night of the accident, a police officer attending the scene of a suspect fire in the search for VH-MDX reported clear skies[14]. The officer was approximately 2km south of Big Ben (eastern foothills of the Barrington ranges)[14].

4.5. Discussion: Visibility
Away from precipitation, excellent visibility was forecast in the Barrington Tops area. Many airborne and ground based reports of clear skies with excellent visibility exist.

The ARFOR visibility of 40km was clearly apparent in the Barrington Tops area. The only exception would be if operating in the areas of isolated precipitation but it is likely that the aircraft would be in cloud in these areas in any case.

There appears to have been no moon in the sky during the accident.

4.6. Conclusions: Visibility
<u>Away from the isolated precipitation, visibility was excellent in Area 20 and specifically in the Barrington Tops area during the time of the accident.</u>

It is unlikely the moon was visible in the sky during the time of the accident.

5. Turbulence

5.1. Cause of turbulence

Turbulence in the area around the Barrington ranges was caused by strong winds being disturbed by the significant terrain of the Great Dividing Range of which the ranges associated with Mt Barrington are part.

Section 3.12 discussed characteristics of wind flow near or over mountains such as mountain waves, downdrafts and rotor zones. These all result in turbulence and as found in section 3 were all likely apparent during the VH-MDX accident.

5.2. Forecast turbulence

5.2.1. Area 20 ARFOR

The Area 20 ARFOR had the following forecast for turbulence[1]:

- Severe turbulence below 12000 feet over the eastern sections of mountaintops, and;
- Moderate turbulence in the remaining areas.

5.2.2. Area 40 ARFOR

The Area 40 ARFOR forecast the following turbulence[1]:

- Occasional severe turbulence (refer to SIGMET)
- Moderate elsewhere in Area 40
- Mountain waves south of latitude 25° south (south of Bundaburg).

5.2.3. Sydney Flight Information Region (FIR)

The Sydney FIR was *south* of a line from Moree, Armidale, Point Lookout, Coffs Harbour and north of a line roughly from Albury to north of Malacoota[18]. So, the Sydney FIR included the areas VH-MDX flew in from Coffs Harbour onwards.

A SIGMET (Significant Meteorology report) for Sydney FIR was passed to the pilot of VH-MDX when approaching Coffs Harbour[1]. The SIGMET indicated[1]:

- Occasional severe turbulence below 12000'AMSL
- Mountain wave activity.

This appears to be Sydney SIGMET 3 as shown in annex C. Sydney SIGMET 3 indicated[1]:

- Commencement time 0500UTC
- Review time 0900UTC
- Area of report is the Sydney FIR
- Occasional severe turbulence below 12000'AMSL over mountaintops , the coast, and out to sea 60NM from the coast.

The same conditions were specified in the previous Sydney SIGMET 1 valid at 0100UTC[1]. Sydney SIGMET 3 was a review of Sydney SIGMET 1 with the same conditions being carried forward.

© Glenn Strkalj 2014-2015

Sydney SIGMET 3 was cancelled by Sydney SIGMET 6 at 0900UTC[1]. This suggests that severe turbulence below 12000'AMSL over mountaintops, coastal areas and 60NM out to sea was no longer expected from 0900UTC.

VH-MDX made the last received radio call approximately 40 minutes *after* the cancellation of SIGMET 3.

5.2.4. Brisbane Flight Information Region (FIR)

Brisbane FIR was north of a line Moree, Armidale, Point Lookout, Coffs Harbour[18]. Accordingly, the area is well north of the accident area.

A SIGMET for Brisbane FIR was valid from 0001UTC and due for review at 0400UTC (SIGMET 1)[1]. The review was therefore due about 5 hours and 40 minutes before VH-MDX's final received radio transmission.

Brisbane FIR SIGMET 1 reports severe turbulence and marked mountain waves[1]:

- Below 10000'AMSL
- Over mountaintops and eastward to 60NM seawards
- Within Brisbane FIR *south* of latitude 26° South (approximately south of Gympie)
- Intensifying.

5.3. Pilot reports

Many pilot reports of turbulence in the Barrington Tops area exists for the time of the accident and during search operations during the days following the accident.

5.3.1. VH-MDX

Turbulence was initially reported by the pilot of VH-MDX at 0918UTC[1]. By dead reckoning, VH-MDX was likely just to the north to north-east of the Barrington ranges. This position is in the lee of the south-westerly to westerly wind blowing over the ranges so, turbulence would be expected.

The pilot repots '*considerable turbulence*' and '*quite a lot of downdraft*' at 0919:32UTC[1]. VH-MDX's track at this stage took the aircraft closer to the lee of the Barrington Ranges so, increased turbulence would be expected.

At 0928:57UTC, VH-MDX's pilot reports that turbulence wise it was no better at the current altitude[1] which appears to be just under 8500'AMSL. By this stage VH-MDX was overhead the western sections of the Barrington Ranges.

Various reports of or, insinuations of VH-MDX experiencing moderate to severe turbulence and downdrafts occur until final communications[1]. As VH-MDX was likely to be located over the main area of the Barrington ranges during the final ten minutes, such turbulence was to be expected.

5.3.2. VH-AZC

The pilot of VH-AZC minutes ahead of VH-MDX reported that there was no turbulence at all south of Kempsey along a track Kempsey-Taree-Williamtown[1].

5.3.3. VH-CNW

VH-CNW was tracking towards Scone from Cessnock and went as far as Lake Liddell[1] approximately 30NM south-west of the Barrington Tops. Turbulence was reported as slight, increasing to moderate[1].

Turbulence disappeared above 7500'AMSL where conditions were reported as *smooth*[1]. VH-CNW was between Singleton and Lake Liddell (upwind of the Barrington Tops) *during* the final received call from VH-MDX.

5.3.4. VH-ESV

VH-ESV flew over the accident area approximately 15 minutes prior to the final received radio call from VH-MDX. The pilot reported that there was some turbulence below 5000'AMSL '*but only moderate*'[1]. The aircraft's track was Sandon East - Craven - Williamtown.

5.3.5. VH-PHY

VH-PHY was assigned search tasks during the night of the accident and at 1421UTC (0021EST) reports that the turbulence in the search area was '*sufficient to cause a light aircraft significant problems*'[14].

VH-PHY was searching the eastern sections of the Barrington ranges near The Mountaineer and towards the town of Wards River at an altitude of 4000'AMSL[14].

5.3.6. VH-CEC

VH-CEC was a television station helicopter engaged in search activities from the morning after the VH-MDX accident[12]. VH-CEC positioned to Gloucester airfield from 2HD radio station on the outskirts of Newcastle on the morning after the accident so, was located to the east and downwind of the Barrington ranges[12].

During the positioning flight at 2130UTC (0730EST), the pilot reported that conditions were *very turbulent* at 4000'AMSL [12].

5.3.7. VH-TCH

Helicopter VH-TCH reported during search operations at 1305EST on the afternoon following the accident that the 5000'AMSL altitude was '*workable*' considering cloud base but not when considering the wind and turbulence[12].

5.3.8. Polair

A New South Wales Police Air Wing helicopter (Polair) was engaged in search activities and in being radar vectored to the final radar observed position of VH-MDX from Williamtown following the accident[19]. This activity probably occurred on the 17th August 1981.

This particular crew did not participate in search operations during the night of the accident[19].

During one task at 5000'AMSL just south of the '*highest point of the range*', the helicopter was reported to have been '*blown violently*' from south-westerly winds[19].

Post flight inspection found one of the main rotor blades was delaminated leading to grounding of the helicopter until new rotor blades were sent from Sydney and fitted[19].

5.4.Discussion: Turbulence

Severe turbulence was forecast over the eastern sections of mountaintops whilst aircrew reported varying intensities of turbulence around the time of the accident and in the days following.

Turbulence would have mainly been generated by strong winds being disturbed by the significant terrain of The Great Dividing Range as shown in figure 29.

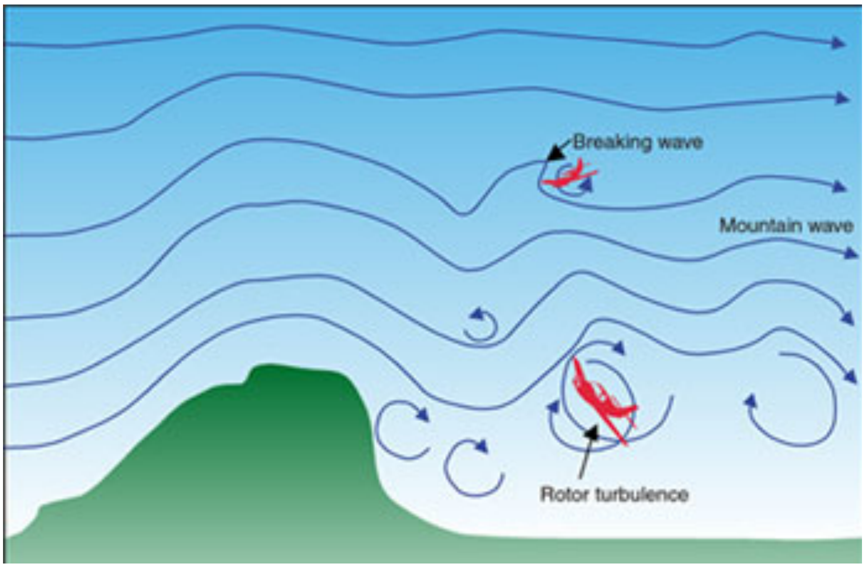


Figure 29: Terrain turbulence generation. Strong winds flowing over significant terrain break in the lees causing turbulence. Mountain waves if apparent add to the turbulence generation with downward flows and rotors zones (Image: Australian Transport Safety Bureau 1996).

The moderate to severe turbulence experienced by VH-MDX was a result of the aircraft being located over or close to the Barrington ranges that generated the turbulence.

5.5.Conclusions: Turbulence

<u>Turbulence was apparent in close proximity to or over The Great Dividing Range but not along the coast at least south of Taree</u>.

Numerous aircraft reported significant turbulence in the close vicinity of or over the Barrington ranges.

Turbulence could be expected in most areas over the Barrington ranges but particularly in the lees.

6. Downdrafts

6.1.Overview

Knowledge of the likely strength and locations of downdrafts could assist in determining VH-MDX impact locations and provide understanding of what situation the pilot of VH-MDX was in.

Confirming likely strength and locations of downdrafts may also explain why known average rates of descent of VH-MDX occurred offering refined understanding of likely flight parameters.

Downdrafts were reported by the pilot of VH-MDX several times[1] when in the vicinity of or over the Barrington ranges.

6.2.Requirements for downdrafts

Other than thunderstorm related downdrafts, a strong wind coupled with change in terrain elevation is required to produce a downdraft. Mountain waves also offer favorable conditions for the generation of downdrafts[2]. Rotor zones discussed in section 3.12.4 also generate or accentuate downdrafts. Lee eddies can also amplify downdrafts[16].

The requirements in the first sentence of this sub-section were both satisfied by environmental conditions during the VH-MDX accident. Section 3 showed that strong westerly to south-westerly winds were apparent during the accident whilst the Barrington ranges offered steep and significant changes in terrain elevation.

6.3.Location of downdrafts

Orographically generated downdrafts generally occur a short distance from mountaintops on the lee side[23]. Additionally, overview of two light aircraft accidents in the United States involving impact with terrain following flight in mountain wave conditions showed that both aircraft overflew the mountaintops with between 4000’ to 5000’ clearance[23].

These accidents show that an aircraft does not necessarily have to be close in height to the mountaintops in order to receive the full force of the downdraft.

6.4.Downdraft rate of descent

Rates of descent are contingent on the exact conditions and terrain present. In a United States document it was stated that in ‘moderate mountain waves’ rates of descent in excess of 1000fpm were apparent[25]. ‘Typical’ rates of descent in downdrafts are 1000fpm to 1500fpm[23] although rates well in excess of these have also been suggested.

It was shown in several downdraft related accidents in the United States that 1000’ per NM[24] (equating to 2000fpm at 120 knots ground speed) vertical profiles were flown by the accident aircraft in the lee of terrain to impact point.

Indeed rates of less than 1000fpm may also be apparent. The Australian Transport Safety Bureau (ATSB) states that mountain waves are classed as 'severe' when associated downdrafts exceed 600fpm and/or severe turbulence is forecast[26].

6.5.Predicting downdrafts

Downdrafts were likely to have occurred in the eastern to northern lees of the main range during the VH-MDX accident but may have also occurred on the upwind sides of the main range in large valleys.

Downdraft generation is contingent on the *specific combination* of the wind velocity and terrain shape. Suggesting that a downdraft will occur in the *immediate* lee of a steep ridgeline because of a strong wind is not viewed as an accurate assumption.

Wind speed may interact with a sharp ridgeline to form a downdraft well away from the immediate lee as a result of inertia. Reduced wind speed may actually produce a downdraft much *closer* to the terrain feature. Eddies in the lee of terrain may amplify downdrafts[16].

Winds approaching the area of interest regarding downdrafts are significantly modified by terrain upwind. Terrain within the Barrington ranges is complex and when coupled with other ranges upwind from the Barrington's, prediction of downdrafts becomes challenging.

6.6.Discussion: Downdrafts

Downdrafts generally exist in the lee of mountaintops and can exhibit values in the order of 1000fpm to 2000fpm although lower or higher values are also possible.

Conditions during the VH-MDX accident appear to be conducive to downdraft generation.

<u>Determining likely downdrafts with any confidence is best left to detailed fluid dynamics computer modeling rather than guessing an outcome based on simple overview of terrain</u>.

Further modeling will be carried out of future interest areas. The method and conclusions from such analyses will be published in separate, specific documents.

6.7.Conclusions: Downdrafts

Downdrafts were reported by the pilot of VH-MDX and were likely to have been located in many areas in the lee or even on the windward side of the main Barrington ranges.

Computer modeling will be used to determine likely downdraft locations and strength.

7. Cloud

7.1. Overview

Minimal cloud appears to have been apparent in Area 20 during and well before the VH-MDX accident. Cloud seems to have mainly been localised patches along mountaintops and approaches to the mountaintops as a result of orographic uplift.

7.2. Orographic cloud

Orographic uplift is the forced vertical lifting of a horizontal flowing air mass by terrain of significant vertical size. Once forced upward by terrain, the air mass cools *adiabatically* raising its relative humidity. Figure 30 overviews orographic uplift.

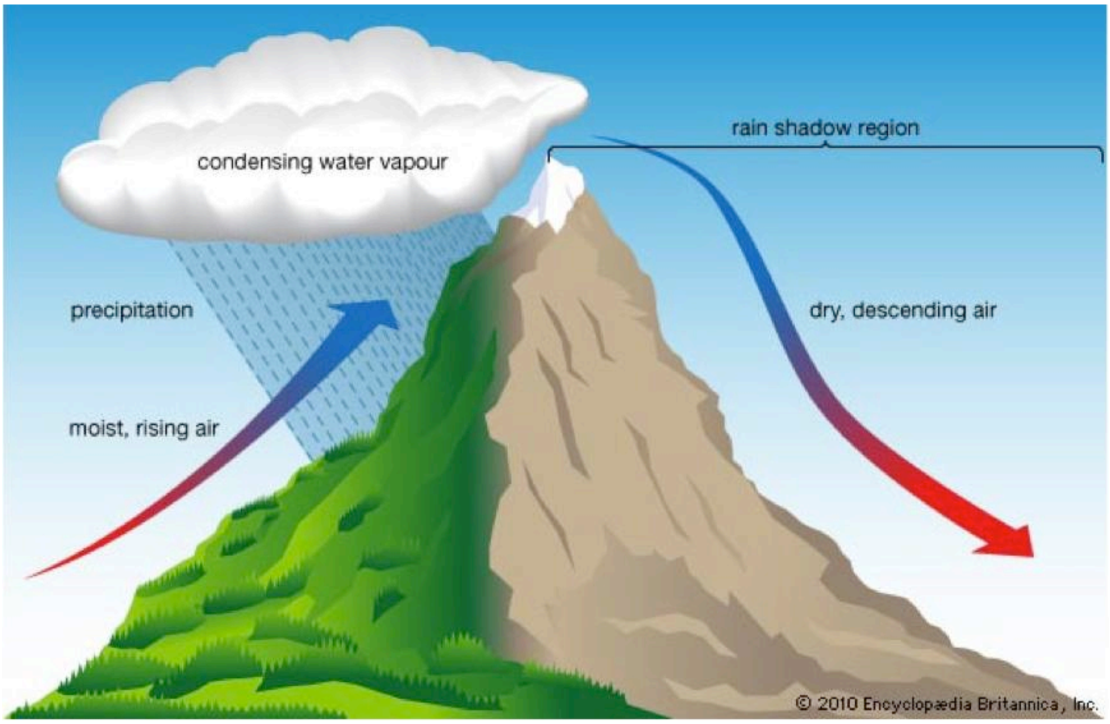


Figure 30: Orographic cloud formation. Orographic cloud stays 'stationary' on the windward side of and over mountaintops. The lee side is generally clear of cloud but small roll type clouds may be apparent. VH-MDX flew into orographic cloud over the Barrington ranges this being some of the only cloud in the general area (Image: Encyclopedia Britannica 2010).

An adiabatic process involves no transfer of heat from the moving air mass to the surrounding environment and occurs when an air mass moves into areas of higher or lower pressure[17].

The air mass cools through expansion when moving to an area of decreased pressure (in this case higher altitude) or heats when moving into an area of higher atmospheric pressure (descending).

If the air becomes saturated (>100% relative humidity), cloud will form and will appear stationary over the approach to and, over the mountaintops even though the air is *constantly flowing* over the terrain[17].

© Glenn Strkalj 2014-2015

In fact the cloud is *constantly forming* using 'new' air in the same position[17]. Precipitation in the form of rain or snow may also occur in the same areas.

On the lee of the terrain the airflow descends and heats adiabatically (increased atmospheric pressure). The air is also *drier* (lower relative humidity) than on the approach to the terrain as it has lost moisture content in the form of cloud generation and/or precipitation. Because of these two characteristics (heating and drying), cloud formation and precipitation is unlikely on the lee of the terrain[17].

Orographic formation of cumulus cloud indicates *slightly unstable* atmospheric conditions whilst stratus clouds reveal moist, stable air[17]. Both may exist as a result of orographic uplift and this was forecast for the time of the accident[1].

Section 3.12.3 briefly discussed atmospheric stability and showed that there were layers of unstable atmosphere likely in an area near the Barrington ranges. Forced ascent of the wind flow up the Barrington ranges was likely to generate instability leading to development of cumulus cloud as shown in figure 31.

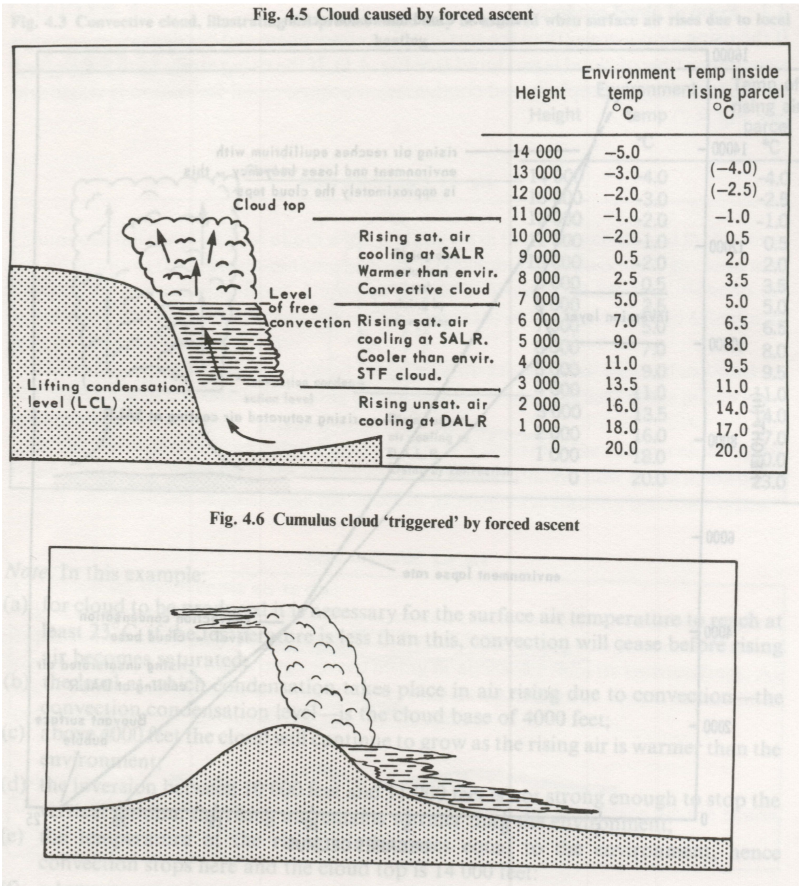


Figure 31: Cloud types and orographic lifting. Cumulus cloud is caused when uplift due to terrain triggers convection. Convection then lifts the air mass to a higher altitude than the terrain would have lifted alone (Image: Bureau of Meteorology 1998[16]).

As observed by the author, orographic cloud is a common occurrence along the Barrington and Gloucester Tops with cloud, rain and/or snow apparent at the high elevations on the windward side and on mountaintops. In many cases there is no cloud surrounding the ranges for vast distances or at all despite snow and rain falling over the Barrington ranges.

A number of sources are available to confirm cloud apparent during the VH-MDX accident and these will be discussed in the following subsections.

7.3.Forecast cloud

7.3.1. Area Forecast (ARFOR)

AROFR's specify cloud at altitudes Above Mean Sea Level (AMSL)[20]. The following cloud was forecast for Area 20[1]:

- Scattered (covering 3-4 eighths of the sky) *stratus* at 2000' AMSL to 4000' AMSL above the western sections of mountaintops, occasionally broken (covering 5-7 eights of the sky) with rain showers and drizzle
- Broken cumulus between 4000' AMSL and 7000' AMSL above the western sections of mountaintops with occasional tops to 12000' AMSL
- Scattered cumulus between 4000' AMSL and 6000' AMSL along the coast.

ARFOR's cover vast areas and are a generalization of conditions for the entire area so, may not be completely representative of likely conditions at a specific point in the area.

If the atmosphere above RAAF Williamtown as found in section 3.12.3 were indicative of the atmosphere over the Barrington ranges during the accident, orographic uplift would likely have generated cumulus cloud.

7.3.2. Terminal Area Forecasts (TAF)

TAF's specify cloud as height Above Aerodrome Level (AAL)[20]. 'Oktas' is a method of specifying the amount of cloud in *eights* of the sky covered; e.g.; 2 oktas means 2/8 of the sky is covered by the stated cloud.

'CAVOK' is a term used to describe conditions that 'Ceiling and visibility are ok', specifically (1985 definition)[20]:

- No clouds below 5000'AAL or the highest minimum sector altitude (whichever is higher)
- No cumulonimbus
- Visibility at least 10km
- No precipitation, thunderstorms, shallow fog or low drifting snow or dust devils.

The following selected TAF's for aerodromes near the Barrington ranges indicated *CAVOK conditions* during the time of accident[1]:

- West Maitland
- Kempsey
- Port Macquarie

TAFs for the following aerodromes in the general area of the Barrington ranges forecast cloud[1]:

- Coffs Harbour: 3 oktas of Cumulus at 4000'AAL
- Armidale: 2 oktas of Stratus at 1200'AAL, 5 oktas of Cumulus at 2000'AAL, 5 oktas of Stratus at 1000'AAL
- Tamworth: 2 oktas of Stratus at 1500'AAL, 5 oktas of Cumulus at 2000'AAL, 5 oktas of Stratus at 1000'AAL.

7.3.3. Specific forecasts for VH-MDX search operation

As stated in section 3.11, specific forecasts were requested from the Bureau of Meteorology to support the VH-MDX search operation.

Forecast cloud for the morning after the accident was 2 oktas[14].

Forecasts for the 11th and 12th August 1981 indicated '*ceiling unlimited*' alluding to nil cloud in the search area[27].

Cloud was forecast for the search area on the 13th August 1981 although only as a general comment[27].

7.4. Pilot reports

7.4.1. VH-AZC

Clear conditions were reported along the coastal route by the pilot of VH-AZC. with the pilot also stating '*Many stars*' were sighted along with smoke from significant controlled burning activity from the day before[1].

The pilot of VH-AZC doubted there was any cloud east of the Barrington Tops but stated there may have been some cloud around Mount Sandon[1]. VH-AZC was approximately 10 minutes ahead of VH-MDX and also tracking southbound along the same route until Taree[1].

Figure 32 below presents an extract of the pilot's comments.

The conditions at Taree were perfectly clear - many stars were visible. There was some smoke from bush fires on the mountains to the west (this was all well below us). The bush fires had been there on the Saturday morning when I flew north. On the Saturday a.m. I had flown WMD-CRV-RDG-PLO and had remarked at the number of fires. On the Sunday p.m. there was a thunderstorm well out to sea from Point Stephens.

There was no cloud at all on the track south and in fact I doubt if there was any cloud anywhere east of the Barrington Tops. There may have been some cloud at MSO. (An aircraft flew MSO-PMQ about half an hour before we passed that route.) The temperature at Taree at 8000' was -2 degrees C. I remember remarking on the temperature to my passenger in the co-pilot's seat.

little better than mine. One news report mentioned icing. Although the temperature at 8000' was -2 degrees C, I doubt very much that there was any cloud east of the Barrington Tops and, if so, that it could have been sufficiently thick to cause icing - particularly at 6000'. My view is that there was no cloud at all in the area at the time of the accident - if in fact it was in the Gloucester Dungog area.

Figure 32: VH-AZC pilot report. Clear skies were reported (Images: National Archives of Australia (Department of Transport) 1981[1]).

7.4.2. VH-ESV

Around the Craven position at 0924UTC (determined by dead reckoning using time intervals), when queried by FIS-5 if there was any cloud '*in that area*' the pilot of VH-ESV reported that '*there's no cloud at all above 8000 feet*'[1].

In a post accident statement the pilot of VH-ESV reported that on his descent to Williamtown the glow of Sydney's lights and the towns of Newcastle, Maitland, Cessnock and other towns in the Hunter Valley could be seen[1]. The descent would have commenced north of Craven waypoint near the town of Nowendoc from 9000'AMSL.

A small amount of ground fog was observed forming at 012˚M/38NM Williamtown (about 3.5NM south-east of Craven waypoint) on the higher terrain but none to the south or east[1].

VH-ESV was tasked to assist in the search for VH-MDX after refueling at Williamtown[1]. At 1111UTC, VH-ESV was in a position approximately 2.5NM south-east of Craven waypoint (2km south of Big Ben) investigating a fire and reported Visual Meteorological Conditions (VMC) at 6000'AMSL[14].

7.4.3. VH-TVG

Post accident, the pilot in command of VH-TVG reported to ASIB that there was *no* cloud on track from Cessnock – Singleton – West Maitland – Aeropelican – The Entrance[1]. VH-TVG was flying along this route at the time of the VH-MDX accident[1].

7.4.4. VH-CNW

The pilot in command of VH-CNW operating to NVFR elected to divert from the planned track of Cessnock – Scone when abeam Lake Liddell and proceeded direct to Singleton NDB due to '*a wall of cloud*' lying on a line '*Nelson Bay to Scone*' reported to be Stratocumulus base 3500' and tops 7500' commencing west of Scone[1].

VH-CNW was at 6500'AMSL at the time[7] and just after 0938:00UTC reported a descent to 5500'AMSL due to cloud[1]. Accordingly VH-CNW was in the area south to south-west of the Barrington ranges during the final minutes of VH-MDX's flight.

As the extracts in the next to figures will show, ASIB discounted the suggestion of a '*continuous wall of cloud*' based on the geometry of the pilot's view that would have coalesced the cloud mass along the Barrington Tops with the thunderstorm off Port Stephens to result in the perceived continuous wall[1].

Nevertheless, cloud was no doubt in the area south to south-west of the Barrington ranges as described with the exception of the continuous wall suggestion.

> It should be noted that Killiingback was flying northwest into the Hunter Valley and his view would have been obliquely along the cloud mass on the Barrington Tops towards the east and the large thunderstorm off Point Stephens which may well have given the impression of being a continuation of the Barrington Tops cloud.

Figure 33: ASIB overview of the VH-CNW pilot statement (Image: National Archives of Australia (Department of Transport) 1981[1]).

(b) Meteorology:
Refer page 28 of the report: The only witness who spoke of the 'wall of cloud' from Nelson Bay to Scone was Killingback. His evidence was discounted because of the following considerations:

Pawnchee Hamid, pilot of commuter C.402 VH-ESV reported that on his descent from 9000 feet into Williamtown (commenced at 1913 EST. 5 minutes before MDX's ETA Craven) he could see the glow of Sydney, the lights of Newcastle and towns in the Hunter Valley. He said that there was no cloud on his track or to the coast but there was a thunderstorm out to sea. (Page 27 refers.)

Barbara Roberts, instructor of NASA, Cessnock reported that there was no cloud on track Cessnock/Singleton/West Maitland/Aeropelican/The Entrance. Her observation confirms that of Pawnchee Hamid. (Page 29 refers.)

../2

Figure 34: BASI comments regarding VH-CNW pilot's cloud report (Image: National Archives of Australia (Department of Transport) 1981[1]).

7.4.5. VH-FCF

VH-FCF was a Fokker 27 commuter aircraft that reported overhead Williamtown at 0917UTC (approximately 22 minutes prior to VH-MDX's final received transmission) at FL170 and was tracking to Coffs Harbour via Taree[1]. The Captain made a post accident statement indicating clear skies along the coast and at least 30NM inland[1]. An extract of the relevant component of the statement is shown in figure 35.

The weather at the time was sky clear on the coast and this situation extended for at least 30 NMs inland. Although there was no moon I could see a visible horizon at FL/170 in all directions. I will admit that at lower altitudes this may not have been so but certainly if this aircraft had been on the Coastal Route he would have had no trouble maintaining contact with the ground. There were winds at altitude giving a SW component of 60 K on that night and I do not doubt that a pilot inland at low altitude would have experienced standing wave conditions.

Figure 35: VH-FCF pilot report (Image: National Archives of Australia (Department of Transport) 1981[1]).

7.4.6. VH-FCD

VH-FCD was tasked to search for signs of VH-MDX on the night of the accident[14]. At a position north-east of Port Macquarie maneuvering to track to Williamtown, the pilot of VH-FCD reported Visual Meteorological Conditions (VMC) along the coast[14].

When operating at approximately 40NM north of Singleton NDB (Moonan Brook area) at 1029UTC, the crew report that the cloud tops were 7500'AMSL with a base at ground level[14]. This area is located on the western side of the Barrington Tops area in the Royal Range area.

7.4.7. QF26

QF26 was tasked to search for signs of VH-MDX on the night of the accident[14]. At 1016UTC when positioned 120NM from Sydney at 8000'AMSL the crew reported they were VMC but alongside a cloud bank[14].

The 120NM arc from Sydney includes the Polblue camping area and Moonan Brook. The exact location of QF26 is not known but given the likely search tasking (40NM north of Singleton NDB) it is likely the aircraft was west of the main ranges and observing the cloudbank to the east along the Royal Range.

7.4.8. VH-CUD

VH-CUD was operating VFR the morning after the VH-MDX accident[12]. The pilot of VH-CUD reported the weather as fine with no cloud in the area 5NM south of Craven waypoint[12]. This information was passed on to the RCC from Sydney FS at 2111UTC (0711EST) on the morning after the accident[12].

7.4.9. VH-CEC

VH-CEC was a television station helicopter engaged in search activities from the morning after the VH-MDX accident[12]. VH-CEC positioned to Gloucester airfield from 2HD radio station at Newcastle[12]. During the positioning flight at 2130UTC, the pilot reported that there was cloud to the west over the Barrington Tops down to ground level[12].

7.4.10. VH-SVF

VH-SVF was established in the search area at 2147UTC (0747EST) on the morning after the accident[12]. Cloud was reported to be 6500'ASML down to ground level. The exact location of VH-SVF during this report is unknown[12].

7.5.Ground based observations

7.5.1. NSW Forestry Officer

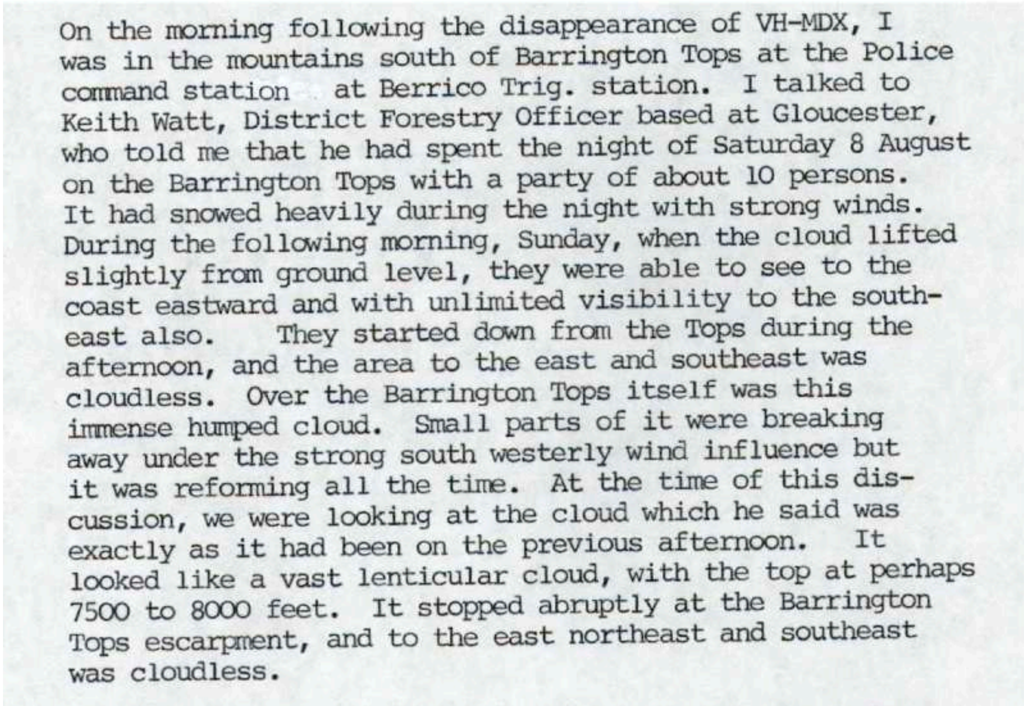
The following observations were made by a NSW Forestry Officer who had stayed overnight in the Barrington Tops on the night *prior* to the accident (specific location unknown) and of an ASIB Inspector observing conditions with this person the morning *following* the accident at Mt Berrico[1].

On the night before the accident heavy snow fell with strong winds[1]. Only localised cloud was evident both on the *night before* and the *morning after* the accident[1].

Cloud lifted a little from ground level during the *morning of the accident* to allow clear views of the coast to the east and to the south-east[1].

On the morning after the accident, '*immense humped cloud*' was observed over the Barrington Tops along with '*vast lenticular cloud*' with tops estimated around 7500'AMSL to 8000'AMSL[1]. Cloud stopped abruptly on the escarpment with no cloud whatsoever to the east, north-east or south-east of the escarpment[1].

As described in section 3.12.3, lenticular clouds indicate the presence of mountain waves and appear to maintain a stationary position despite the fact that air is flowing through the cloud continually (i.e. the cloud is continually re-generating)[17].



On the morning following the disappearance of VH-MDX, I was in the mountains south of Barrington Tops at the Police command station at Berrico Trig. station. I talked to Keith Watt, District Forestry Officer based at Gloucester, who told me that he had spent the night of Saturday 8 August on the Barrington Tops with a party of about 10 persons. It had snowed heavily during the night with strong winds. During the following morning, Sunday, when the cloud lifted slightly from ground level, they were able to see to the coast eastward and with unlimited visibility to the south-east also. They started down from the Tops during the afternoon, and the area to the east and southeast was cloudless. Over the Barrington Tops itself was this immense humped cloud. Small parts of it were breaking away under the strong south westerly wind influence but it was reforming all the time. At the time of this discussion, we were looking at the cloud which he said was exactly as it had been on the previous afternoon. It looked like a vast lenticular cloud, with the top at perhaps 7500 to 8000 feet. It stopped abruptly at the Barrington Tops escarpment, and to the east northeast and southeast was cloudless.

Figure 36: Ground witness reports of cloud and conditions (Image: National Archives of Australia (Department of Transport) 1981[1]).

7.5.2. Police officers

At 1231UTC (2231EST) on the night of the accident, police attending a fire of interest 2km south of Big Ben (eastern foothills) reported a clear night was apparent[14].

7.5.3. Williamtown ATCO

A Sydney ATCO or FSO requested the Williamtown ATCO for the weather conditions at Williamtown at 0936:30UTC. The response was: '*My weather, we're CAVOK-fairly strong winds, westerly at 20k*'.

It can be seen Williamtown had no *specific* reports of cloud during the time of the accident. Remembering from section 7.3.2 that CAVOK does not infer that there is *no* cloud but rather that there is no cloud below 5000'AAL (Above Aerodrome Level) or below the highest minimum safe /sector altitude whichever higher.

Either way in the Williamtown case this suggests no cloud below around 5000'AMSL to over 6000'AMSL.

7.6. Search and Rescue Situation Reports (SITREP)

SITREP number 2 during day one of the search effort (10th August 1981) indicated '*low cloud*' hampered aerial search efforts[21].

SITREP number 3 on 12th August 1981 reported that search activities in the high terrain for the previous day were hindered by '*scattered and broken cloud in late afternoon*'[21].

7.7.Discussion: Cloud

Both pilot reports and weather forecasts suggest AREA 20 was substantially clear of cloud except for localised cloud along mountaintops. The localised clouds were the result of *orographic uplifting*.

Around the time of the VH-MDX accident, coastal areas abeam the Barrington ranges were reported to have clear skies whilst the western areas of the Barrington ranges near Moonan Brook had significant cloud amassed to tops of around 7500’AMSL to 8000’AMSL.

On the day following the accident, an ASIB Officer observed immense humped cloud with tops to between 7500’AMSL and 8000’AMSL on the western sections of the Barrington Ranges. Vast lenticular cloud was also observed suggesting mountain wave activity.

Atmospheric stability in the greater Barrington Tops area suggest cumulus cloud was likely generated by orographic uplift. The large humped cloud supports this suggestion.

The isolated cloud clearly appears to have been located along the mountaintops and windward slopes of the main Barrington ranges.

7.8.Conclusions: Cloud

Cloud was isolated and limited to mountaintops and windward terrain.

Some cloud was also possibly located on the lee side of mountains.

The Barrington ranges likely had cumulus/ strato-cumulus and lenticular clouds apparent during the VH-MDX accident with tops around 7500’AMSL to 8000’AMSL.

8. Precipitation

8.1.Overview

Section 7 showed that cloud was highly localised and located on the windward side and along mountaintops during the time of the VH-MDX accident. Precipitation is associated with cloud. This results in precipitation also being generally limited to the windward side and mountaintops in the area of the Barrington ranges.

8.2.Forecast precipitation

Scattered rain showers and drizzle were forecast to be associated with cloud along mountaintops mainly in the southern areas of Area 20[1]. The Barrington ranges are located in the southern area of Area 20.

Isolated snow showers over mountaintops mainly in the south-west of Area 20 was also forecast[1].

TAFs for aerodromes surrounding the greater Barrington Tops area had no precipitation forecast with the exception of Tamworth Aerodrome that had 80% chance of rain showers forecast[1].

8.3. Pilot reports

In general, snow hampered search efforts the day after the accident.

8.3.1. VH-BNR

On the afternoon after the accident, the pilot of Cessna 310 VH-BNR stated that the Mt Royal area had snow covering the top approximate 100' of the mountaintop[12]. The search in this area was abandoned due to snow and low cloud[12].

The Mt Royal area forms the initial terrain barriers to the oncoming winds and is located south-west of the Barrington Tops.

8.3.2. VH-TCH

On the day after the accident, the pilot of helicopter VH-TCH reported that the snow line was located at 5000'AMSL however the exact area of the observation cannot be confirmed[14].

8.3.3. VH-CEC

Helicopter VH-CEC reports snow falling with possible snow on the ground at high elevations in the Mount Royal area during search operations on the morning after the accident[12].

8.3.4. VH-UTS

Two days after the accident, the pilot of VH-UTS was searching the Gloucester Tops area and reported snow over the Gloucester Tops[12]. The pilot also commented that attempting to spot a cream coloured aircraft amongst a snow background would be difficult[12].

8.3.5. Channel 9 helicopter

A Channel 9 helicopter crewmember reported snow on the ground in the search area after landing at Gloucester Airfield at 1210EST on the morning after the accident[12]. The exact location of the snow cannot be determined.

8.3.6. Search and Rescue Situation Report (SITREP)

SITREP No.4 issued at 1322 EST on 13 August 1981 states that there was '*Some snow and ice in trees at approx 5000ft*'[21]. This statement would have been based on reports from search aircrew and possibly ground parties.

8.4. Ground reports

8.4.1. Tomalla Station

A person at Tomalla Station located along the Mount Royal Range north of Polblue reported to the RCC at 1050EST on the morning after the accident that the area had occasional snowdrifts with ½"-1" of snow on the ground[12].

Tomalla Station is located in 3500'AMSL to 4000'AMSL elevation terrain adjacent to the Mount Royal Range. The Mount Royal Range forms the main barrier to westerly to south-westerly winds in the immediate area so, orographic cloud and snow would be expected in this area.

8.4.2. Forestry Officer
As section 7.5.1 described, a Forestry Officer spent the night on the Barrington Tops the night prior to the accident[1]. The officer reported that heavy snow fell with strong winds[1]. The exact overnighting location is unknown.

8.5. Discussion: Precipitation
Reports of snow seem to be limited to the upper elevations of the Barrington ranges, approximately between the 4000'AMSL to 5000'AMSL elevations. The areas included the southern and northern sections of the Mount Royal Range and both the Barrington and Gloucester Tops.

The snow is clearly associated with the orographic cloud generated by the steep and high elevation ranges.

8.6. Conclusions: Precipitation
Snow had clearly fallen along the high elevation areas of terrain in the area of the Barrington ranges between around 4000'AMSL and 5000'AMSL.

No evidence of rain has been found.

Snow clearly was associated with orographic cloud and was limited to the localised areas where such cloud formed.

9. Icing

9.1. Icing level
The icing level was forecast as being at 4000' and 7000'AMSL with *moderate* icing forecast for flight in cloud above the freezing level[1].

Moderate icing is defined by the following statement:

'*The rate of accumulation is such that even short encounters become potentially hazardous and the use of de-icing/anti-icing equipment or diversion is necessary*'[11].

9.2. Pilot reports
A number of aircraft reported icing accumulation during the search for VH-MDX during the night of the accident and for days following[12]. Search aircraft had to cancel search missions as a result of ice accumulation[12].

9.2.1. VH-MDX
The pilot of VH-MDX reported having accumulated ice on two occasions:

- '*We've picked up a fair amount of ice*'[1] at 0934:20UTC and
- '*…and we're picking up icing*' at 0937:32UTC[1].

This suggests flight in cloud or in precipitation beneath cloud around or before these times.

9.2.2. VH-SVF
VH-SVF was engaged in search activities on the morning after the VH-MDX accident[12]. The pilot reported picking up icing at 2147UTC (0747EST)[12].

9.2.3. VH-TGO
At 2220EST on the night after the VH-MDX accident, VH-TGO was unable to track from Singleton NDB to Mount Sandon NDB/VOR due to icing[12].

9.3.Icing requirements: Cloud
To accumulate aircraft icing requires flight through precipitation or cloud at the correct ambient temperature range.

As described in section 7.7, cloud was isolated and limited to mountaintops and windward terrain in the area of the Barrington ranges. Section 7 showed that cloud type was probably cumulus and lenticular and existed up to around 7500'AMSL to 8000'AMSL.

Search aircraft reported cloud cover over the Barrington ranges post accident[12] as described in section 7.

The pilot of VH-MDX reports entering cloud in the Barrington area[1] and also suggests flight in and out of cloud during the final 15 minutes of recorded communications.

Accordingly, cloud existed along the flight path of VH-MDX when flying over or in vicinity of the Barrington ranges.

9.4.Temperature
The highest risk of icing occurs when flying in cloud between the 0˚ and -15˚ isotherms[11]. Section 2.3 showed how the freezing level (0˚ isotherm) was between approximately 6000'AMSL and 7000'AMSL.

From this, temperatures of around -2˚C to -4˚C would be expected at 8000'AMSL and around -3˚C to -5˚C at 8500'AMSL.

Temperatures would unlikely then be lower than -10˚C at 10000'AMSL in the area of the Barrington Ranges.

The pilot of VH-MDX reports altitudes between 5000'AMSL and 8000'AMSL during flight over or in close proximity to the Barrington ranges. A maximum altitude of 8500'AMSL appears to have been achieved or almost achieved by VH-MDX .

9.5.Discussion: Icing
Large cumulus and cumulonimbus clouds produce the most severe icing as a result of containing abundant amounts of large sized water droplets[16]. The altitude just above the freezing level is the most dangerous as this is where the largest super-cooled water droplets exist[11].

Orographic lifting as was apparent over the Barrington ranges during the VH-MDX accident was likely to increase both the liquid concentration within a cloud and cloud depth leading to rapid ice accumulation in such areas[16].

VH-MDX flew through cloud in the area of the Barrington ranges and the cloud type was shown in sections 7 and 9.3 as likely to be cumulus.

Section 9.4 revealed that the temperature range VH-MDX flew in was between around 0˚C and +5˚C which is around the ideal temperature range for ice accumulation particularly the more dangerous *clear ice*[16].

Clear ice forms as a result of large super-cooled water droplets *freezing* relatively slowly as they translate back along an aircraft surface. This does not mean that ice *accumulates* slowly: quite the contrary. The result is ice accumulation that covers large areas and sticks strongly to the aircraft structure so, is difficult to shed[16].

Considering VH-MDX:

- Entered cloud at 8000'AMSL
- Likely did not exceed 8500'AMSL
- Likely was at not below 7500'AMSL from the initial Sydney radar fix to 0937:40UTC
- Experienced the ambient temperatures found in section 9.4:

<u>VH-MDX clearly flew into and stayed within, the highest risk weather conditions for icing.</u>

<u>There was high risk of icing between 6000'AMSL and 10000'AMSL in cloud during the time of the accident in the Barrington ranges area.</u>

9.6.Conclusions: Icing

High risk icing conditions existed in cloud around the Barrington ranges at altitudes below 10000'AMSL.

VH-MDX flew into weather conditions of the highest risk for icing accumulation from the point of initially entering cloud onwards.

10. Altimeter errors

10.1. Overview

Aircraft pressure altimeters are calibrated to work accurately *only* in ISA conditions. In practice, atmospheric temperature and pressure regularly varies from ISA conditions. Any deviations in ambient pressure or temperature away from ISA results in under or over reading pressure altimeters.

This means that the altitude *indicated* on the altimeter is either higher or lower than the aircraft's *true altitude* Above Mean Sea Level (AMSL) if conditions are not equal to ISA values.

© Glenn Strkalj 2014-2015

10.2. Pressure variations

Variation of ambient atmospheric *pressure* from ISA values results in *barometric error* in altimeters. The pilot has a means to almost eliminate this error.

10.2.1. Pressure compensation

Modern aircraft pressure altimeters have an input that the pilot uses to correct for changes in actual Mean Sea Level (MSL) pressure away from ISA (1013mb).

This input is in the form of a *barometric subscale* through which the pilot regularly updates the value of to reflect the *current* or *forecast* MSL pressure in the *area* or *terminal airspace* the pilot is operating within. The barometric subscale is shown below in figure 37.

Figure 37: Aircraft altimeter barometric subscale. The pilot turns the barometric subscale to the value of the local MSL pressure as specified by ATS agencies, pre-flight briefing, automatic weather stations, weather forecasts or weather reports. If the MSL pressure for the area is set (QNH) then the altimeter will have been corrected for variation of pressure from ISA conditions (Image: Glenn Strkalj 2015).

The barometric subscale setting sets the pressure level that the altimeter *starts measuring from*. Figure 38 on the next page shows how an aircraft can maintain the same true altitude but how the indicated altitude varies dependent upon the pressure level datum set in the barometric subscale. *The altimeter measures height* *from* *the pressure level set in the subscale*.

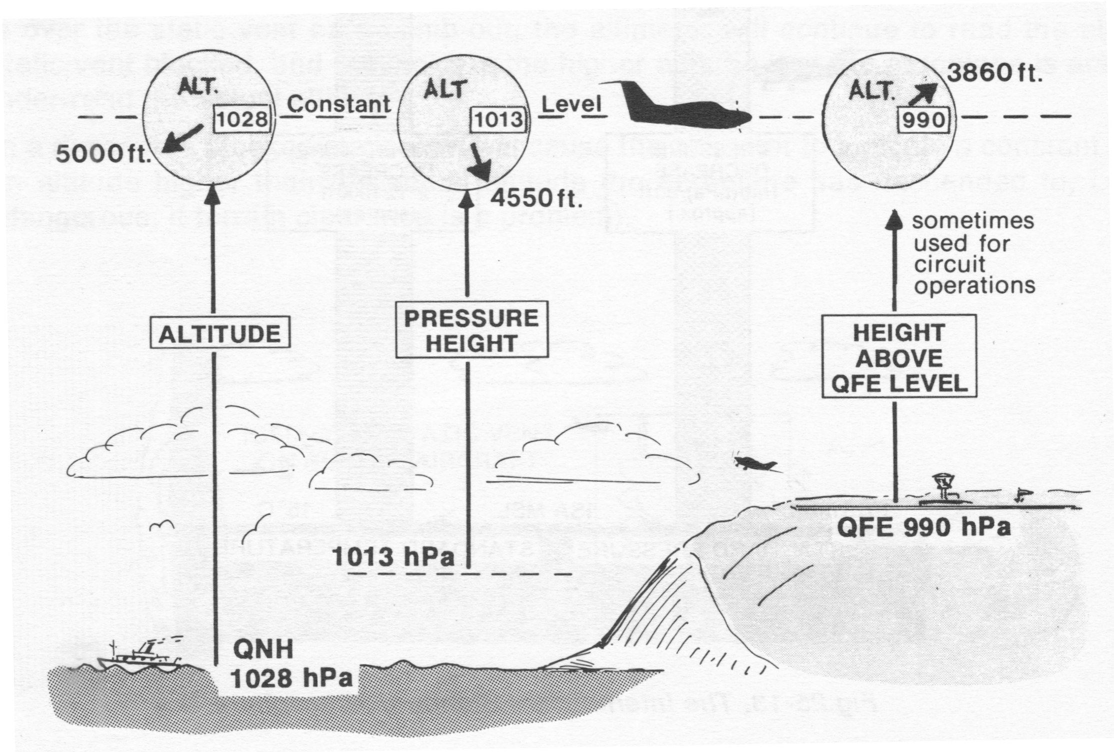


Figure 38: Altimeter subscale setting. The altimeter measures height from the pressure datum set in the subscale. If height above MSL is required, the subscale setting needs to reflect the MSL pressure presently existing. If height above the airfield is desired then the current atmospheric pressure on the airfield is set in the subscale (QFE). The normal subscale setting for aircraft below 10000"AMSL in Australia is QNH. The subscale setting when set to local or area QNH corrects for barometric error, the error due to pressure deviations from standard ISA conditions (Image: Aviation Theory Centre 1996).

Pilots obtain the actual sea level atmospheric pressure value for the area or terminal airspace they are operating within from ATS agencies, pre-flight briefing, automatic weather stations, weather forecasts and weather reports. This MSL pressure value is known as *QNH* and was given as a value (in Australia) in Millibars (mb) during 1981[20]. Note 1mb = 1 Hectopascal (hPa) and hPa is the unit currently used.

As VH-MDX was cruising between airports, the pilot would have entered the QNH value for the general area the aircraft was operating within. This is known as *area QNH.*

The last transcribed area QNH given to VH-MDX by ATS was 1006mb from Coffs Flight Service 1 (FS-1) when the aircraft was well up the NSW north coast near a waypoint called 'The Lake' (near the coastal town of Yamba) at 0740UTC[1].

At just prior to 0913UTC, Williamtown reported to FIS-5 a QNH of 1007mb whilst Sydney FIS-5 reported 1006mb, assumingly for the FIS-5 area of responsibility that included the general area of the Barrington ranges[1].

From this, it can be seen that VH-MDX had a QNH value within 1mb (30') of the close-by Williamtown airport approximately 30 minutes before the final received transmission.

Pressure change rate in the lower atmosphere approximately equates to 30' per 1mb. Detailed wind modeling as discussed in section 3.9 can predict local pressure variations in the Barrington ranges.

Area QNH in 1981 (September) was valid for 3 hours[20] and was a forecast value for a defined Area QNH Zone (AQZ)[20]. Forecast area QNH values were required to meet the following accuracies:

- +/-5mb of the actual QNH at any low level point (below 1000' AMSL) within or on the boundary of the appropriate area during the validity of the forecast[20]
- An area QNH must not differ from an *adjoining* area QNH by more than 5mb[20].

Accordingly, within an AQZ the area QNH may result in up to 5mb x 30'= 150' of altimeter *barometric error*. Similarly, an error of up to 150' may be apparent between adjoining AQZ's. So, with the correct area QNH set a maximum *barometric error* of 150' is possible.

In VH-MDX's case, given the area QNH set was 1mb lower than the QNH value from the close by Williamtown Airport issued at a time around 30 minutes prior to the final received transmission from VH-MDX, the QNH value that VH-MDX would likely have set on its altimeter(s) can be classed as 'accurate' for an area QNH value.

<u>30' of altimeter *under-read* would be expected due to barometric error alone.</u>

But, local pressure variations over and around the Barrington ranges also likely introduced error.

10.2.2. Local pressure variations

Wind flow over mountain ranges such as the Barrington ranges can result in local atmospheric pressure variations as a result of air mass interaction with terrain. Figure 39 below presents a generalised representation of such variations.

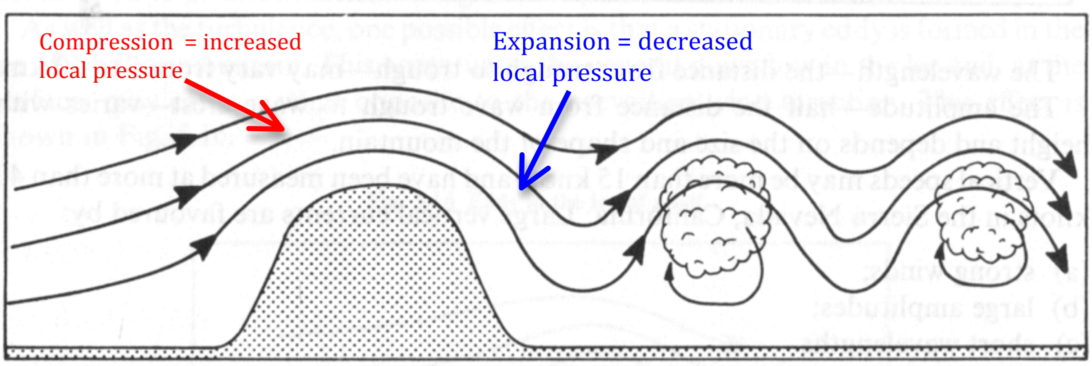


Figure 39: Pressure variations around mountains. In many cases the air mass is compressed on the windward side of the range resulting in increased local pressure. On the lee, the air mass diffuses, normally resulting in lower local atmospheric pressures. Notwithstanding these generalised outcomes, mountain wind flow is complex and the inclusion of eddies, sub flows along terrain features of a different direction to the main range and the like can lead to different outcomes.

Generally speaking, *increased* local atmospheric pressure would exist in the approaches to such terrain and a *decrease* in local atmospheric pressure in the *lees*. This is the result of air compressing as it meets the high terrain and expanding after passing the high points. As aircraft pressure altimeters sense local atmospheric pressure, it can be seen altitude indication errors can result.

The reduction in pressure in the lee of a mountain range is termed a '*lee trough*'[16]. Changes of 2-3mb due to 'local effects' resulting in up to 100' indicated altitude change are suggested possible by the Australian Bureau of Meteorology[16]. The stronger the wind flows over a mountain range the more pronounced the pressure drop would be on the lee of a mountain range[16].

Results from fluid dynamics computer simulation of airflows over the Upper Williams River Valley suggest that small local pressure reductions in the order of 1mb were likely in the lee sections during the VH-MDX accident[9]. This corroborates with the Bureau of Meteorology suggestion.

10.2.3. Example

If a pilot maneuvered an aircraft to maintain a constant *pressure altimeter altitude* across a mountain range with local pressure variations as described in the previous section, the aircraft's *true altitude* could actually increase approaching the range then decrease when located on the lee of the range.

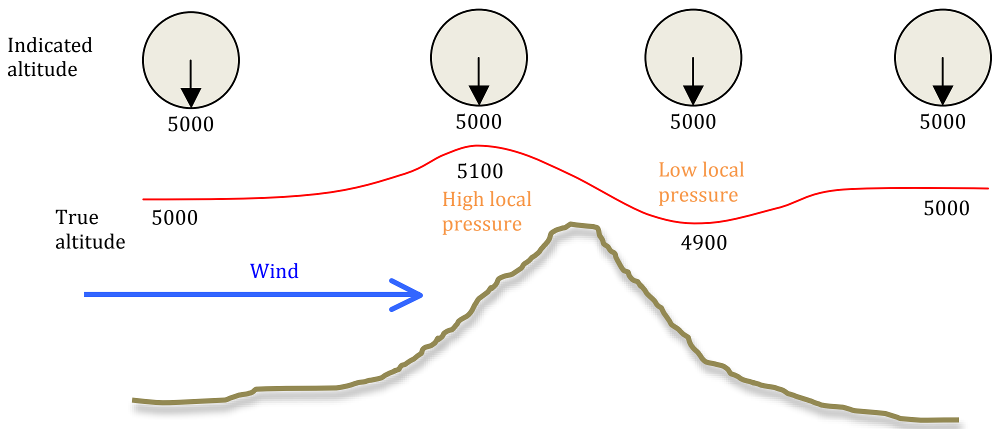


Figure 40: Overflying local pressure variations. In this case the pilot has held a constant 5000' *indicated* altitude with reference to the altimeter. Because of the local pressure variations, the aircraft's true altitude varied as the variations were overflown (Image: Glenn Strkalj).

In VH-MDX's case during the last few minutes of flight with communications, the aircraft was descending. Depending on where VH-MDX was located in relation to these local pressure variations, over or under-reading of the altimeter would have occurred due to local pressure variations.

10.3. Temperature variations

The pressure altimeter is also calibrated for ISA values of temperature and any deviation in actual temperature from ISA results in under and over-reading altimeters as well. This is known as *temperature error*.

In basic altimeters such as that used on VH-MDX, no significant means of temperature compensation exists other than the pilot applying standard correction figures to the readings during instrument approaches in very cold weather.

One general rule is to adjust the altimeter reading by 4% for every 10˚C deviation from ISA[16]. *Hotter* than ISA conditions result in *under-reading* altimeters and *colder* than ISA conditions result in *over-reading* altimeters.

Section 2.3 showed that conditions were likely to be ISA-5 during the VH-MDX accident.

Compensating for an ISA-5 deviation at the VH-MDX pilot's altitude call of 6500'AMSL results in:

- Indicated altitude = 6500'AMSL
- 2% compensation for temperature deviation = 130' deviation
- Temperature compensated altitude = 6370'AMSL.

<u>This means that temperature deviations apparent during the night of the accident contributed to the altimeter *over-reading* by around 130'.</u>

10.4. Other errors

10.4.1. Instrument errors

Further errors exist arising from the altimeter system design. These are difficult to quantify but generally result in minimal errors.

One instrument error that would have been applicable to VH-MDX is *time lag* error. This is due to lag in the capsule and mechanism response, resulting in *over-read* during descents with over-read value being related to rate of descent. VH-MDX was averaging a 1700fpm descent rate in approximately the last minute of recorded flight[1].

10.4.2. Alternate static air

One error that is of significance resulting in a substantial altitude deviation is error arising from the selection of alternate static air. Alternate static air is selected by the pilot when it is suspected or confirmed that the normal static ports externally mounted on the empennage of the aircraft are blocked or iced over. Such a blockage would result in a frozen or slow reacting altimeter reading.

When the pilot selects alternate air on the Cessna 210M, air is fed from the cockpit to the altimeter. Although the cockpit is unpressurised, there is still a slight pressure difference between the cabin and outside. As the cabin pressure is not exactly equal to the ambient pressure outside, an indication error results.

The Cessna 210M Pilot's Operating Handbook (POH) specifies the following corrections when using alternate static air[5]:

- Cruise 150' higher (over-read error)
- Approach 70' higher than normal (over-read error).

The altitude corrections relate to speed flown. Approach speeds commence from 90KIAS and move downwards.

10.5. Application to VH-MDX

In the case of VH-MDX, what are of interest are the deviations between true altitude and pressure altitude in the final few minutes of flight. Knowing the *true altitude* of VH-MDX at certain points can refine flight path determinations and radio propagation analysis.

Temperature deviations are effectively fixed (ISA-5) as determined in section 10.3 and in VH-MDX's case contributed to an *over-reading* altimeter. Pressure variations on the other hand could have contributed to an *over* or *under-reading* altimeter.

If it is found that VH-MDX was in an area of *reduced* local atmospheric pressure such as in the lee of significant ridgelines during a particular altitude transmission, such pressure deviations will bias the altimeter to *over-read*. This coupled with the *over-reading* bias of the *temperature deviation* would have a net result of the altimeter *over-reading*. This means VH-MDX true altitude would be *lower* than the pilot reported altitude.

If VH-MDX were found to be in an area of *increased* local atmospheric pressure during a particular radio transmission, the pressure deviations would bias the altimeter to *under-read* whilst the temperature deviation would bias the altimeter to *over-read*. The end result would be found through the vector addition of both of these errors and would tend to cancel each other out.

The 1mb per 30' rule can be applied to determine the level of altimeter over or under-reading bias. This information can then be used to effect in radio propagation analysis and flight path determination.

10.6. Summary of findings: Altimeter errors

For the sample case of indicated altitude 6500'AMSL with VH-MDX located in an area of reduced local pressure (mountain lee) the following net altimeter errors were likely:

Under-reading errors:

- Barometric error 30'

Over-reading errors:

- Temperature 130'
- Local pressure variations: lee trough, 1hpa = 30'

Net altimeter error: 130' over-read.

If the alternate static source was used then up to 280' of over-read error could be apparent although *around* 230' was more likely if VH-MDX was flying at around 110KIAS.

Time lag error would have resulted in increased over-read above these figures.

What this means is that when the pilot of VH-MDX transmitted a 6500' altitude, assuming the call was made at the instant of seeing 6500' on the altimeter, the true aircraft altitude would have been between *approximately* 6220'AMSL and 6370'AMSL when not accounting for time-lag error.

11. Summary of findings

The table below provides a summary of findings regarding likely meteorological conditions during the VH-MDX accident.

Phenomena	Location /intensity/values
Wind	At 8000'AMSL: 230°T-270°T at 30-50 knots Just above terrain: 230°T-270°T at 20-30 knots
Visibility	Excellent: 40km when clear of precipitation.
ISA deviation	ISA -5
Turbulence	Moderate to severe over and close to high terrain.
Downdrafts	Likely to be apparent on lee of high terrain Possible in valleys on the windward side.
Cloud	Limited to western and south-western facing areas of mountaintops and windward slopes. Other areas substantially clear of cloud.
Precipitation	Snow. Limited to localised areas associated with orographic cloud at high elevations (4000'AMSL to 5000'AMSL).
Icing	High risk in cloud between 6000'AMSL & 10000'AMSL.
Altimeter Errors	Normal static source: A little over 130' over-read Alternate static source: A little over 230' (likely) to 280' (max) over-read

Figure 41: Summary of findings.

12. Conclusions

Relevant meteorological information regarding the VH-MDX accident was collated and analysed.

Conclusions were made regarding the likely meteorological conditions apparent during the VH-MDX accident.

References

[1] National Archives Australia (NAA): Bureau of Air Safety Investigation (BASI); Series No C1789, Control Symbol SI/812/1036, Barcode 12067179, 1981 onwards, Aircraft Accident, VH-MDX C-210, 75km North of Singleton 9th August 1981 (NSW Regional Office folio).

[2] Dyson-Holland. V, Dyson-Holland. J.E, 1999, *Meteorology*, 6th Edition, D-H Training Systems, Tamworth.

[3] Ozrunways, 2015.

[4] Australian Government, Bureau of Meteorology, 1981, Weather forecast for 10th August 1981, cited in *The Canberra Times, 10th August 1981.*

[5] Cessna Aircraft Company, 1979, *Pilots Operating Handbook*, *1980 Model U206G*, Wichita, Kansas.

[6] Australian Government, c.1981, *Aeronautical Information Publication (AIP)*, *Enroute Chart Low (ERC-L)*, Department of Transport Australia.

[7] Australian Government, 1981, Audio recording of FIS-5 communications 9th August 1981, Department of Transport.

[8] Piper Aircraft Inc, PA-28 Pilots Operating Handbook.

[9] Horrocks. G, 2013, *Analysis of the Winds on 9 August 1981 in the Southern Barrington Tops Region,* July 2013.

[10] New South Wales Government, 1982, Inquest, *Deaths as a Result of Barrington Tops Air Disaster,* New South Wales Coroner's Court.

[11] Australian Government, Bureau of Meteorology 2015, *Hazardous Weather Phenomena, Airframe Icing*. 12 June 2015.

[12] Australian Government, Department of Transport, R, 1981.

[13] Australian Government, Bureau of Meteorology, 1981, Weather forecast for 9th August 1981, cited in *The Canberra Times, 9th August 1981.*

[14] Australian Government, Department of Transport, S, 1981.

[15] Australian Government, Bureau of Meteorology. 2003, *Manual of Meteorology*, First Edition.

[16] Australian Government, Bureau of Meteorology, 1998, *Manual of Meteorology, Part 2, Aviation Meteorology*, Second Edition, Australian Government Publishing Service, Canberra.

[17] Australian Government, Bureau of Meteorology, 1993, *Manual of Meteorology, Part 1, General Meteorology*, Second Edition, Australian Government Publishing Service, Canberra.

© Glenn Strkalj 2014-2015

[18] Australian Government, 1981, *Radio Navigation Chart, RNC-3, 9 July 1981,* Department of Transport.

[19] Strkalj. G, 2015, Discussions with Polair crewmember and Pilot involved in VH-MDX search activities, late 2015.

[20] Australian Government, 1985, *Visual Flight Guide*, Department of Transport Australia, Amendment 11, 10 April 1986. (note: many pages have earlier effectively including 1981).

[21] National Archives Australia: Department of Transport, Series no C273/29, Control Symbol 80/1739, Barcode 13704206, Search and Rescue Sydney Rescue Co-ordination Centre (RCC) Activations.

[22] Aviation Theory Centre Pty Ltd (Trevor Thom), 1996, *The Instrument Rating Manual*, Third Edition, June 1996, Williamstown.

[23] Lamb. M.W, 2013, Deadly downdrafts: Understanding the risks, In mountainous terrain beware of deadly winds, *Flying* Magazine, 7 December 2013, http://www.flyingmag.com/technique/weather/deadly-downdrafts-understanding-risks.

[23] Schroeder. B, 2011, Escaping a downdraft, *General Aviation News*, 30 May 2011.

[24] Philipson. S. H, 1996, *Mountain Wave for the ATC specialist*, 4 May 1996.

[25] Federal Aviation Authority, 2015, *Mountain Flying*, FAA Aviation Safety, April 2015.

[26] Australian Government, 2009, Mountain Wave Turbulence, https://www.atsb.gov.au/publications/2005/mountain_wave_turbulence.aspx, Australian Transport Safety Bureau, 29 October 2009.

[27] NSW Government, 1981.

[28] Aviation Theory Centre Pty Ltd (Trevor Thom), 1993, *Meteorology and Navigation*, Second Edition, December 1993, Williamstown.

© Glenn Strkalj 2014-2015

Annex A: Raw Area 20 and Area 40 Low-Level Area Forecasts

```
MET SITUATION FOR ASSY FIR AT 2300
COL[redacted]FRONT LYING TFD[redacted]THENCE SSE, MOVING E 20/25[redacted]/SW
STREAM BEHIND FRONT
                                                COOLANGATTA
                                                9 AUG 1981
                                                BRIEFING OFFICE      536

ARFOR 0500 TO 1700 AREA 20
WIND 2000 260/30 5000 250/35 7000 250/40 10000 250/45 MS09
14000 250/55 MS16 18500 250/70 MS23
CLD SCT ST 2000/4000 FT MON W OCNL BKN
     WITH RASH/DZ BKN CU 4000/7000 FT
     MON/W OCNL TOPS 12000 FT
     SCT CU 4000/6000 COT
VIS 40KM DTRT 4000M RASH/DZ/SNSH
WX   SCT RASH/DZ MON/W MAINLY IN S
     ISOL SNSH MON IN SW
FZL 4000/7000 FT
ICE MOD INC ABV FZL
TURB SEV BLW 12000 FT MON/E MOD REST
RMK MVI VIS 10KM RASH SCT ST 4000 BKN CU 4500
   *MURRURUNDI GAP VIS 10KM RASH BKN CU 4000
```

ARFOR 20. (Image: National Archives of Australia (Department of Transport) 1981[1]).

```
                                                COOL         535
                                                9 AUG
                                                BRIEFI
MET SITUATION FOR ABBN FIR AT 0800Z
TROUGH DYS/GAY/ABBN MOVING EAST FCST PSN 50NM E CHP/SYC AT 08Z
HIGH OVER SA WITH RIDGE EXTENDING OVER FIR

ARFOR 0500 TO 1700 AREA 40
WIND N ABBN/GDI
2000 230/20 5000 250/20 7000 250/30 10000 250/40
MS04 14000 240/50 MS07 18500 240/60 MS16
WIND S ABBN/GDI
2000 250/30 5000 240/30 7000 240/40 10000 240/50
MS05 14000 240/80 MS10 18500 240/80 MS20
CLD : BKN ST 1000/FT/2500 FT IN DZ
BKN SC 2500/6000 FT MON AND WEST S OF ABOK
SCT SC 3000/6000 FT ELSEWHERE
VIS: 60 KM DTRT 2000 M DZ.
WX: SCT DZ MON AND WEST S OF SPE
FZL: 7000 FT
TURB: OCNL SEV (REFER SIGMET). MOD ELSEWHERE. MTW S OF 25S.
```

ARFOR 40. (Image: National Archives of Australia (Department of Transport) 1981[1]).

© Glenn Strkalj 2014-2015

Annex B: Raw Terminal Area Forecasts (TAF's)

```
TAF ASCH 0214 25022/35 9999 3CU040
GRADU 0608 25012 18 18 1[illegible] 13 1008 1008 1009 1011
TAF MND 0214 29025/40 9999 3CU040
GRADU 0608 29015 CAVOK 1005 1005 1006 1008

TAF ARM 0214 25025/38 9999 2ST012 5CU020
INTER 0214 5ST010
GRADU 0709 25015 1010 1010 1011 1013
TAF KMP 0214 25022/35 9999 3CU040
GRADU 0608 25012 CAVOK 1007 1007 1008 1010
TAF PMO 0214 25022/35 9999 3CU040
GRADU 0608 25012 CAVOK 1007 1007 1008 1010

TAF ASTW 0214 27018/30 9999 80RASH 2ST015 5CU020
INTER 0814 5ST010 11 12 09 07 1011 1011 1012 1014

TAF ASBK 0214 27015/30 9999 3CU035 1004 1004 1006 1009
TAF ASCN 0214 27015/30 9999 3CU035 1004 1004 1006 1009

TAF
ASSY 0303 26020/35 9999 3CU040
GRADU 0608 27012 CAVOK 16 15 13 11 1004 1004 1005 1007
```

Area 20 TAFs. (Image: National Archives of Australia (Department of Transport) 1981[1]).

```
TAF ABCG 0214 25020/32 9999 2SC030 MOD TURB 21 20 18 15 1009
1009 1010 1012

TAF ABAF 0214 25020/32 9999 2SC030 MOD TURB 22 21 19 16 1010
1010 1011 1013

TAF
AMD ABBN 0014 29015/30 9999 2CU040
RAPID 0203 25015/30 MOD TURB
1402 25015 CAVOK 22 24 22 17 1010 1009 1009 1011
TAF ABBU 0214 30012 9999 3CU030
RAPID 0304 23015 CAVOK 23 21 19 16 1013 1012 1013 1015

TAF AMD CAS 0214 26020/35 9999 2SC030 MOD/SEV TURB 1010 1010 1011
1014
TAF AMD LIS 0214 26020/35 9999 2SC030 MOD/SEV TURB 1010 1010 1011
1014
TAF AMD GFN 0214 26020/35 9999 2SC030 MOD/SEV TURB 1010 1010 1011
1014
```

Area 40 TAFs. (Image: National Archives of Australia (Department of Transport) 1981[1]).

Annex C: Raw Sydney FIR SIGMETs

WSAU ASSY
SIGMET 3 090500 REVIEW 090900
OCNL SEV TURB FCST BLW 12000 FT MON/COT/60NM SEAWARDS ASSY FIR

Sydney SIGMET 3. (Image: National Archives of Australia (Department of Transport) 1981[1]).

20

SIGMET MESSAGE FORM

FF ASZZHJ ASZZHK

WSAU ASSY
SIGMET 1 090100 REVIEW 090500
OCNL SEV TURB FCST ASSY FIR
BLW 12000FT MON/COT/60NM
SEAWARDS

DATE 090036 ISSUING OFFICER

THREE-HOURLY REVIEW MADE AT BY

SIGMET MESSAGE FORM

FF ASZZHJ ASZZHK

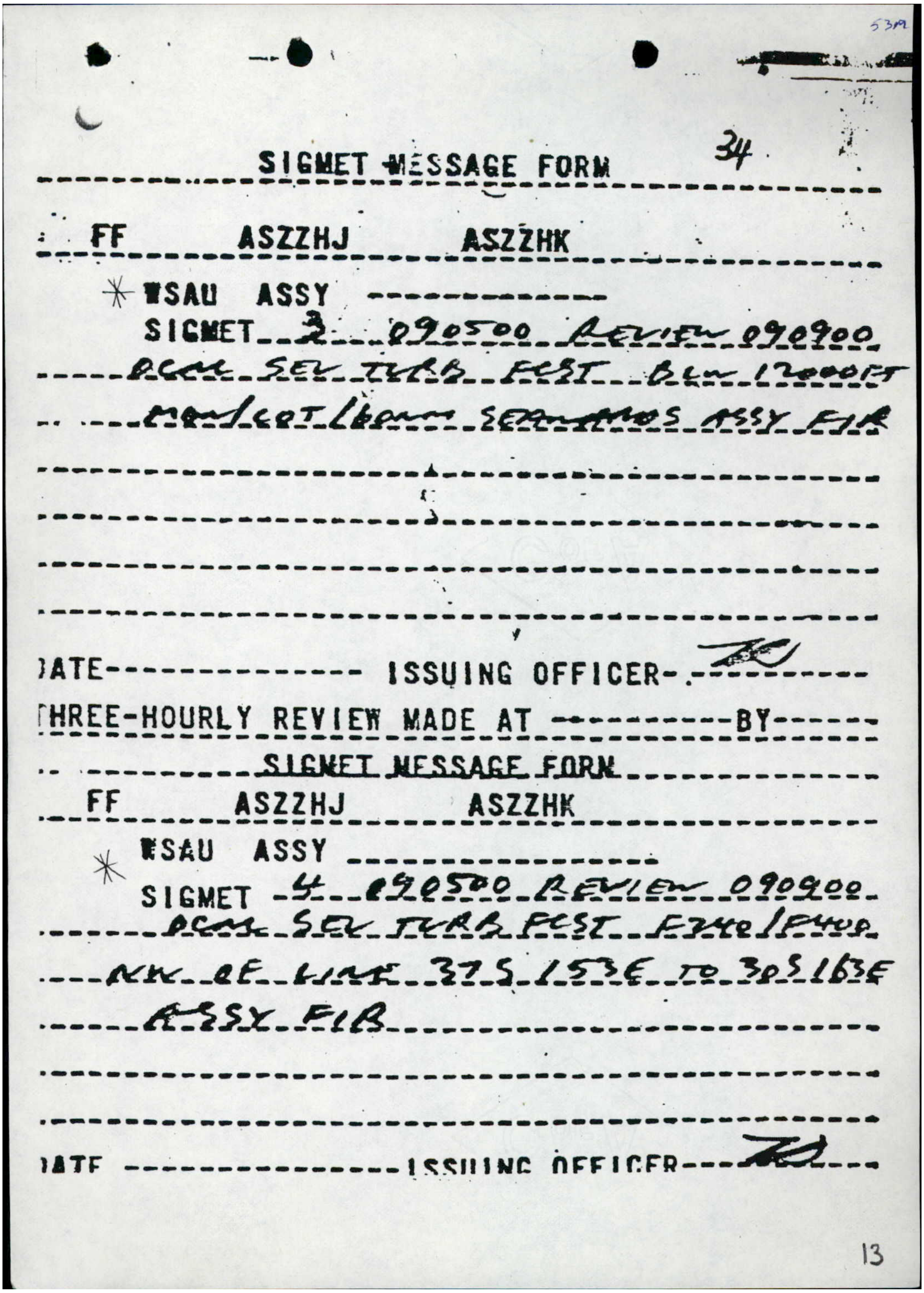
WSAU ASSY
SIGMET 2 090100 REVIEW 090500
OCNL SEV TURB FCST F240/F400
NW OF LINE 35S 150E TO 30S 163E

DATE 090041 ISSUING OFFICER

THREE-HOURLY REVIEW MADE AT BY

12

Sydney SIGMETs. (Image: National Archives of Australia (Department of Transport) 1981[1]).



34

SIGMET MESSAGE FORM

FF ASZZHJ ASZZHK

WSAU ASSY

SIGMET 3 090500 REVIEW 090900

OCNL SEV TURB FCST BLW 12000FT

[illegible] SEA[illegible]OS ASSY FIR

DATE ISSUING OFFICER

THREE-HOURLY REVIEW MADE AT BY

SIGMET MESSAGE FORM

FF ASZZHJ ASZZHK

WSAU ASSY

SIGMET 4 090500 REVIEW 090900

OCNL SEV TURB FCST F340/F400

NW OF LINE 37S 153E TO 30S 163E

ASSY FIR

DATE ISSUING OFFICER

13

Sydney SIGMETS. (Image: National Archives of Australia (Department of Transport) 1981[1]).

© Glenn Strkalj 2014-2015

55

SIGMET MESSAGE FORM

FF ASZZHJ ASZZHK

*WSAU ASSY

SIGMET NO 5 090900 Review 1300

OCNL SEV CAT FCST ABV F260

ASSY FIR

DATE 090900 ISSUING OFFICER

THREE-HOURLY REVIEW MADE AT BY

SIGMET MESSAGE FORM

FF ASZZHJ ASZZHK

WSAU ASSY

*SIGMET NO 6 090900

CANCEL Sigmet NO 3 FOR OCNL

SEV TURB BLW 12000 FT.

DATE 090900 ISSUING OFFICER

THREE-HOURLY REVIEW MADE AT BY

14

Sydney SIGMETS. (Image: National Archives of Australia (Department of Transport) 1981[1]).

Annex D: Raw Brisbane FIR SIGMET

SIGMET 1 090001 REVIEW 090400
SEV TURB. AND MARKED MTW FCST BLW 10000 FT MON AND
EASTWARD TO 60 NM SEAWARDS ABBN FIR S OF 26S. INTSF

Brisbane SIGMET 1. (Image: National Archives of Australia (Department of Transport) 1981[1]).

Annex E: Airport abbreviation code/decode

New Abbreviation	Old Abbreviation	Airport Name
YARM	ARM	Armidale
YBAF	ABAF	Brisbane/Archerfield
YBBN	ABBN	Brisbane
YBCG	ABCG	Coolangatta
YBUD	ABBU	Bundaberg
YCAS	CAS	Casino
YGFN	GFN	Grafton
YKMP	KMP	Kempsey
YLIS	LIS	Lismore
YMND	MND	West Maitland
YPMQ	PMQ	Port Macquarie
YSBK	ASBK	Sydney/Bankstown
YCFS	ASCH	Coffs Harbour
YSCN	ASCN	Camden
YSGT	SGT	Singleton
YSSY	ASSY	Sydney
YSTW	ASTW	Tamworth
YTRE	TRE	Taree
YWLM	ASWM	Newcastle/Williamtown

Annex F: Williamtown weather balloon data

2300UTC, 08 Aug 81

Temp (˚C)	Dew Point (˚C)	Relative Humidity	Wind Direction	Wind Speed	Pressure (hPa)	Geopotential Height in gpm (m)	Height Feet
13.3	2.6	48%	310	21.4	1005	8	26
-	-	-	300	36.9	950	-	-
4.0	-2.6	62%	270	44.7	900	920	3018
2.6	-11.9	33%	270	42.8	850	1390	4560
-0.4	-17.5	26%	-	-	800	1870	6135
-	-	-	270	33.0	750	-	-
-9.3	-22.4	33%	280	36.9	700	2930	9613
-20	-30.4	39%	280	36.9	600	4090	-
-27.4	-	-	270	60.3	500	5420	-
-33.6	-	-	270	81.6	400	7010	-
-41.9	-	-	-	-	330	8340	-
-42.8	-	-	270	79.7	300	8990	-
-	-	-	280	93.3	250	-	-
-40.6	-	-	280	97.2	200	11750	-
-50.1	-	-	270	81.6	150	13670	-
-57.7	-	-	280	75.8	100	16270	-

(Data: Bureau of Meteorology 1981).

0500UTC, 09 Aug 81

Temp (˚C)	Dew Point (˚C)	Relative Humidity	Wind Direction	Wind Speed	Pressure (hPa)	Geopotential Height in gpm (m)	Height Feet
-	-	-	290	23.3	1012	8	26
-	-	-	290	27.2	950	-	-
-	-	-	270	33.0	900	-	-
-	-	-	260	35.0	850	-	-
-	-	-	240	40.8	750	-	-
-	-	-	230	38.9	700	-	-
-	-	-	250	42.8	600	-	-
-	-	-	250	48.6	500	-	-
-	-	-	250	70	400	-	-
-	-	-	250	75.8	300	-	-
-	-	-	260	77.8	250	-	-
-	-	-	270	85.5	200	-	-
-	-	-	270	81.6	150	-	-
-	-	-	270	64.1	100	-	-

(Data: Bureau of Meteorology 1981).

1100UTC, 09 Aug 81

Temp (˚C)	Dew Point (˚C)	Relative Humidity	Wind Direction	Wind Speed	Pressure (hPa)	Geopotential Height in gpm (m)	Height Feet
10.2	2.0	57%	290	15.6	1007	8	26
-	-	-	290	38.9	950	-	-
3.6	-2.6	64%	260	44.7	900	930	3051
1.0	-6.3	58%	240	44.7	850	1390	4560
-0.6	-14.1	35%	-	-	800	1880	6168
-	-	-	230	31.1	750	-	-
-8.8	-20.1	39%	230	36.9	700	2930	9613
-18	-32.7	26%	240	38.9	600	4110	-
-27.2	-	-	240	58.3	500	5450	-
-36.7	-	-	240	89.4	400	7020	-
-44.1	-	-	-	-	328	8380	-
-43.9	-	-	250	73.9	300	8970	-
-	-	-	250	77.8	250	-	-
-45.1	-	-	260	77.8	200	11700	-
-50.2	-	-	260	75.8	150	13610	-
-56	-	-	260	60.3	100	16220	-

(Data: Bureau of Meteorology 1981).