National Meteorological Library and Archive

Factsheet 13 — Upper air observations and the tephigram

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Fact sheet No. 13 – Upper air observations and the tephigram

Introduction

Knowledge of temperature, humidity and wind at levels well above the ground form an essential part of the meteorologist's basic data. Variations of wind, temperature and water content occurring well above the ground are as important for weather analysis and forecasting as variations in these parameters at the surface. Clearly, they cannot be measured by equipment on the ground, but information about the state of the upper air can be obtained in many ways, for example, aircraft reports, but the main one is by observations from balloon-borne equipment.

Balloon observations

These still provide the most valuable source of upper-air data, especially as routine sounding are made simultaneously by an established worldwide network of land-based stations, supplemented by a few observations from ships.

The standard method of obtaining values of temperature and humidity at upper levels is by use of a balloon carrying a small radio transmitter known as a ***radiosonde***.

Figure 1. Vaisala AS12 autosonde releasing a balloon-borne radiosonde.

Pressure is measured by an aneroid capsule, temperature by a tiny thermistor or capacitive sensor, and humidity by a small capacitive sensor. The temperature and humidity elements are exposed but the remainder of the instrument is enclosed within an insulated container. The radiosonde usually contains a GPS or other navigation aid receiver for wind information or the wind can be deduced by radar or radiotheodolite. As the balloon ascends it is carried along horizontally by the wind and by tracking the balloon the wind direction and speed can be deduced.

The heights attained by radiosonde balloons vary from about 65000 feet for small balloons to 115000 feet or more for large balloons. These figures seem large but compared with the whole depth of the atmosphere, which is over 700 km deep; radiosondes only penetrate a fraction of the earth's atmosphere. Reaching heights of up to 20 km, radiosonde ascents measure the temperature, humidity and wind levels in all of the troposphere and the lowest layer of the stratosphere.

The atmosphere

The Earth's atmosphere is divided into five spherical 'spheres' each characterised by the way its temperature varies with height. These five spheres are called the troposphere, stratosphere, mesosphere, thermosphere and exosphere. The top of each sphere is donated by a boundary or 'pause' and likewise the boundaries between these spheres are called the tropopause, stratopause, mesopause and thermopause respectively.

- **Troposphere**

  The lower layer of the atmosphere, extending to about 16 km near the equator, 11 km at a latitude of 50°, 8 km near the poles, and with an upper limit at the tropopause. About 80% of the atmosphere lies within the troposphere. In the troposphere, the average temperature decreases with height. It is also in the troposphere that nearly all the weather we experience on the Earth is to be found.

  The Tropopause: The atmospheric boundary between the troposphere and the stratosphere.

- **Stratosphere**

  That region of the atmosphere, lying above the troposphere and below the mesosphere, in which, in contrast to these regions, temperature does not decrease with increasing height. The stratosphere is a region which is characterized by relatively large amounts of ozone.

  The Stratopause: The atmospheric boundary between the stratosphere and the mesosphere.

- **Mesosphere**

  That part of the atmosphere, between the stratopause at about 50 km and the mesopause at about 85 km, in which the temperature generally falls with increasing height.

  The mesopause: The atmospheric boundary between the mesosphere and the thermosphere.

- **Thermosphere**

  That part of the atmosphere, extending from the top of the mesosphere at about 85 km to approximately 500 km, in which the temperature increases with increasing height.

  The Thermopause: The height of the thermopause varies from about 200 to 500 km, depending on solar activity. Above 500 km temperatures are difficult to define.

- **Exosphere**

  The exosphere is the highest layer of the atmosphere. The exosphere extends to 10,000 km above the Earth's surface. The exosphere is the transitional zone between the Earth's atmosphere and interplanetary space.

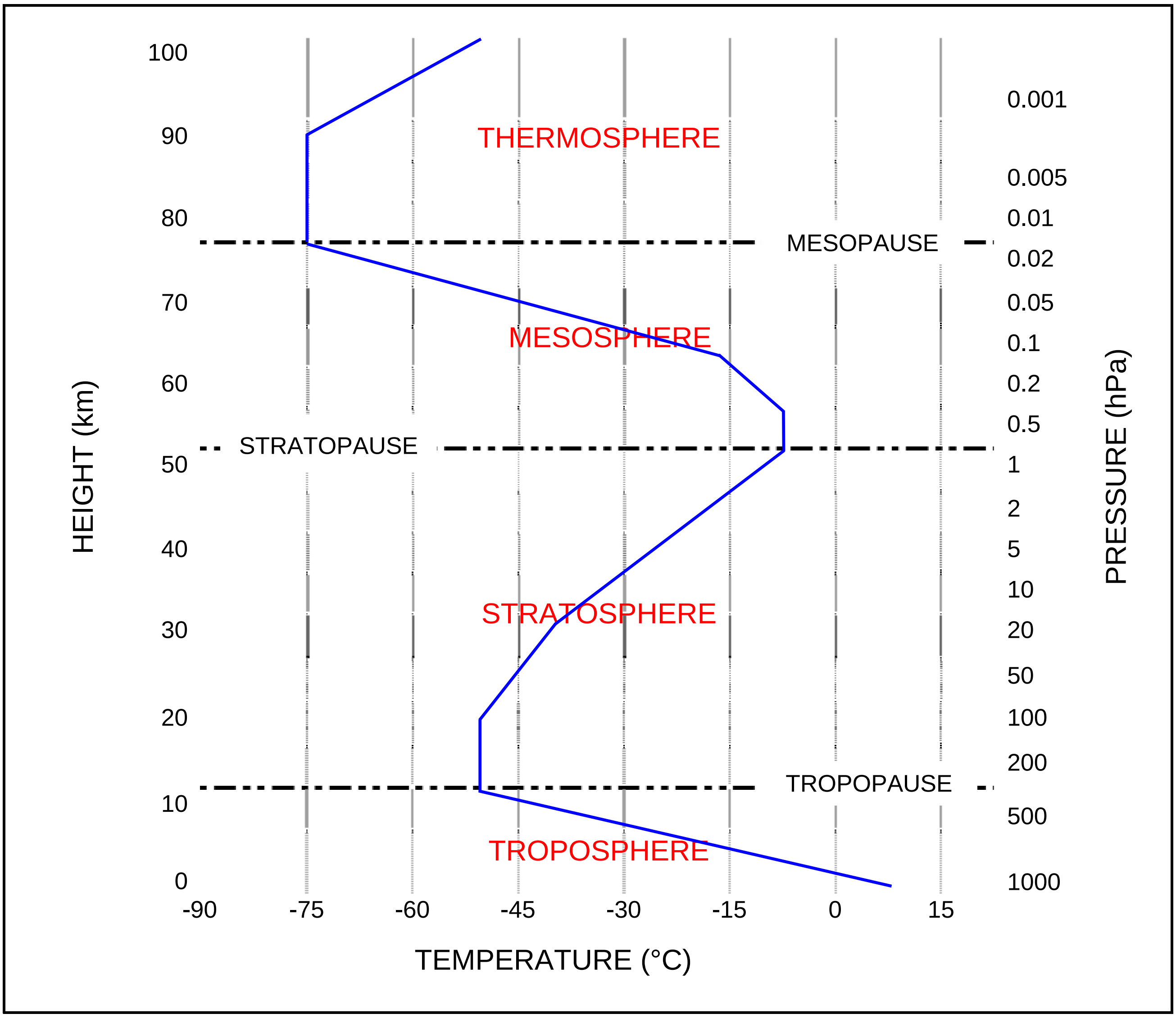


Figure 2. Vertical temperature profile for the ICAO standard atmosphere.

Lapse rates

Anyone who has been up a mountain will have noticed that the higher you go, the cooler it becomes. This fall of temperature is known as the Lapse Rate and, in this case, is a characteristic of the atmosphere around. If, on the other hand, we consider a 'parcel' of air rising through the atmosphere, the situation is rather different. An analogy to the 'parcel' of air is a bubble of gas rising through a fizzy drink. It stays more or less unchanged all the way up.

When this parcel of air rises, it cools. The reason for this is that pressure falls with increasing height and, consequently, the air expands. As air expands, it does 'work' in order to occupy the larger volume.

This is a rather difficult concept to understand, so it might be easier to think of its opposite; that is, air becoming compressed. In this case, 'work' is being done on the air to force it into a smaller volume and this causes the temperature to rise.

When you pump up the tyres of a bicycle or a car, you are doing 'work' on the air as you operate the pump. This compresses the air so that it can be forced through the tyre valve against the pressure of the air already inside the tyre. The temperature of the air going through the pump rises and this can be felt by the tube connecting it to the valve becoming warm. This volume, or 'parcel', of air is undergoing adiabatic compression.

If you put too much air into the tyre and have to reduce the pressure, there is a rapid expansion of the air being released and it feels cold. This air is undergoing adiabatic expansion. The temperature changes are also called adiabatic. This word 'a-diabatic' means that no heat is being put in or taken out; the changes in temperature are entirely due to the 'work' being done. 'Diabatic' temperature changes are as the result of heat being put in or taken out; for example, boiling water in a kettle.

Vertical sounding of the atmosphere

During a radiosonde ascent, various measurements of temperature, humidity and pressure at fixed pressure levels and measurements taken at significant pressure levels are sent back to the receiving centre in the form of a code and this code is then plotted onto a tephigram.

Below is an example of a coded message from a radiosonde ascent. This example is from the Camborne (03808) ascent made at 2300z on 1st May 2006.

TTAA 51231 03808 99996 07819 17005 00057 ///// ///// 92698 03843 20018 85379 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 29586 77214 29090 42341 31313 48008 82315

TTBB 51238 03808 00996 07819 11995 08018 22990 08021 33980 07625 44969 06823 55948 05650 66915 03042 77875 00108 88867 00717 99859 01314 11855 01318 22851 00741 33845 02469 44840 03873 55831 04276 66817 03873 77816 03673 88786 01674 99734 02174 11667 07976 22618 11572 33607 12765 44601 11910 55548 15310 66517 17343 77462 22339 88455 22934 99441 24728 11398 30141 22377 33131 33327 39535 44308 42926 55267 50935 66244 55723 77226 58933 88219 60729 99207 62929 11200 61932 22194 59957 33187 59762 44185 59964 55174 54774 66171 54777 77160 57381 88143 53383 99120 54383 11113 52783 22100 54982 21212 00996 17005 11984 18514 22973 19018 33951 20517 44871 18521 55852 20019 66834 21022 77731 22530 88716 22033 99679 23029 11605 25034 22519 27036 33469 28042 44411 28053 55354 27056 66348 27061 77309 27570 88291 27071 99288 27069 11261 28065 22214 29090 33207 29586 44201 29573 55193 28547 66189 27048 77186 27053 88181 27559 99178 28054 11172 28039 22169 27032 33165 26034 44159 26040 55150 27547 66143 27033 77137 26031 88116 25535 99111 26538 11100 25523 31313 48008 82315 41414 28472 51515 11892 19022 22800 21025 33600 25034

As you can see, this message is broken into two sections (TTAA and TTBB). Part A of the code (TTAA) is the values at set pressure levels (1000mb, 925mb, 850mb, 700mb, 500mb, 400mb, 300mb, 250mb, 200mb, 150mb and 100mb. Also included is tropopause data and maximum wind data) and these levels are mandatory in any upper-air ascent. Part B (TTBB) is for values at ‘significant’ pressure levels.

Decode of the mandatory levels (TTAA) in the upper air code:

TTAA YYGGI IIiii	-	Message identification
99PoPoPo ToToTaoDoDo dododofofo	-	Surface data
00hhh TTTaDD dddff	-	1000 mb data
92hhh TTTaDD dddff	-	925 mb data
85hhh TTTaDD dddff	-	850 mb data
70hhh TTTaDD dddff	-	700 mb data
50hhh TTTaDD dddff	-	500 mb data
40hhh TTTaDD dddff	-	400 mb data
30hhh TTTaDD dddff	-	300 mb data
25hhh TTTaDD dddff	-	250 mb data
20hhh TTTaDD dddff	-	200 mb data
15hhh TTTaDD dddff	-	150 mb data
10hhh TTTaDD dddff	-	100 mb data
88PtPtPt TtTtTatDtDt dtdtdtftft	-	Tropopause data
77PmPmPm dmdmdmfmfm	-	Maximum wind data
31313	-	Regional data

Table 1. The Decode of the Upper-Air Code for Part A (TTAA)

All ascent can be broken down as follows:

- Message identification - **TTAA**

TTAA 51231 03808 99996 07819 17005 00057 ///// ///// 92698 03843 20018 85379 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 29586 77214 29090 42341 31313 48008 82315

Part A indicator (mandatory levels)

- Message identification – **YYGGI** (YY: month/date; GG: time of ascent; I: last standard isobaric level that wind data is given)

TTAA **51231** 03808 99996 07819 17005 00056 ///// ///// 92698 03843 20018 85379 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 29586 77214 29090 42341 31313 48008 82315

Last reported wind level (I)
(1 = 100mb)

Day of the month (YY)
(51 = 1st)
(Day of the month of observation plus 50, e.g. 55 = 5th day of the month)

Time of ascent (GG)
(23 = 2300z)

- Message identification – **IIiii** (unique station number)

TTAA 51231 **03808** 99996 07819 17005 00056 ///// ///// 92698 03843 20018 85379 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 29586 77214 29090 42341 31313 48008 82315

Unique WMO indicator for Camborne (IIiii)
(03808)

- Surface data – **99PoPoPo** (surface pressure)

TTAA 51231 03808 **99996** 07819 17005 00056 ///// ///// 92698 03843 20018 85379 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 29586 77214 29090 42341 31313 48008 82315

Surface information indicator (99)

Surface pressure (PoPoPo)
(996mb)

- Surface data – **ToToTaoDoDo** (surface dry-bulb and dewpoint temperature)

TTAA 51231 03808 99996 **07819** 17005 00056 ///// ///// 92698 03843 20018 85379 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 29586 77214 29090 42341 31313 48008 82315

Dew-point depression (DoDo)
(1.9 °C)

Surface air temperature (ToToTao)
(7.8 °C)
(Note – in the code, if this figure is an even number (0,2,4,6,8) the value if positive; if the figure is odd (1,3,5,7,9) then the value is negative)

- Surface data – **dododofofo** (surface wind direction and speed)

TTAA 51231 03808 99996 07819 **17005** 00056 ///// ///// 92698 03843 20018 85379 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 29586 77214 29090 42341 31313 48008 82315

Wind direction (dododo) and speed (fofo)
(170 degrees 05 knots)

- 1000 mb data – **00hhh** (height of the 1000 mb level)

TTAA 51231 03808 99996 07819 17005 **00056** ///// ///// 92698 03843 20018 85379 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 29586 77214 29090 42341 31313 48008 82315

1000mb height indicator (00)

Height of 1000mb level (hhh)
(056 = 56 metres)

- 1000 mb data – **TTTaDD** (dry-bulb and dewpoint temperature at the 1000mb level)

TTAA 51231 03808 99996 07819 17005 00056 ***/////*** ///// 92698 03843 20018 85379 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 29586 77214 29090 42341 31313 48008 82315

1000mb dry-bulb temperature and dew-point depression (TTTaDD)
(///// = no temperature data recorded for this level)

- 1000 mb data – **dddff** (1000 mb level wind direction and speed)

TTAA 51231 03808 99996 07819 17005 00056 ///// ***/////*** 92698 03843 20018 85379 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 29586 77214 29090 42341 31313 48008 82315

1000mb wind direction (ddd) and speed (ff)
(///// = no wind data recorded for this level)

- 925 mb data – **92hhh** (height of the 925 mb level)

TTAA 51231 03808 99996 07819 17005 00056 ///// ///// **92698** 03843 20018 85379 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 29586 77214 29090 42341 31313 48008 82315

925 mb height indicator (92)

Height of 925mb level (hhh)
(698 metres)

- 925 mb data – **TTTaDD** (dry-bulb and dewpoint temperature at the 925mb level)

TTAA 51231 03808 99996 07819 17005 00056 ///// ///// 92698 **03843** 20018 85379 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 29586 77214 29090 42341 31313 48008 82315

925 mb dew-point depression (DD)
(-0.5 °C)
(3.8 – 4.3 = -0.5)

925 mb dry-bulb temperature (TTTa)
(038 = 3.8 °C)
(Note – in the code, this figure is an even number so the value is positive)

- 925 mb data – **dddff** (925 mb level wind direction and speed)

TTAA 51231 03808 99996 07819 17005 00056 ///// ///// 92698 03843 **20018** 85379 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 29586 77214 29090 42341 31313 48008 82315

1000mb wind direction (ddd) and speed (ff)
(200 degrees, 18 knots)

- 850 mb data – **85hhh** (height of the 850 mb level)

TTAA 51231 03808 99996 07819 17005 00056 ///// ///// 92698 03843 20018 **85379** 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 29586 77214 29090 42341 31313 48008 82315

850 mb height indicator (85)

Height of 850 mb level (hhh)
(1379 metres)
(To convert the height value to metres at the 850 mb level, a leading 1 is necessary (see table below for more details))

- 850 mb data – **TTTaDD** (dry-bulb and dewpoint temperature at the 850mb level)

TTAA 51231 03808 99996 07819 17005 00056 ///// ///// 92698 03843 20018 85379 **00356** 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 29586 77214 29090 42341 31313 48008 82315

850 mb dry-bulb temperature (TTTa)
(003 = -0.3 °C)
(Note – in the code, this figure is an odd number so the value is negative)

850 mb dew-point depression (DD)
(56 = -6.3 °C (6.0 °C colder than the dry bulb))
(When the depression is 5.0 °C or less the value is in units and tenths. When the depression is more than 5.0 °C the units and tenths are reported but 50 is added to the total, therefore 56 is 6 whole degrees)

- 850 mb data – **dddff** (850 mb level wind direction and speed)

TTAA 51231 03808 99996 07819 17005 00056 ///// ///// 92698 03843 20018 85379 00356 **20020** 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 29586 77214 29090 42341 31313 48008 82315

850mb wind direction (ddd) and speed (ff)
(200 degrees, 20 knots)

- Wind speeds greater than 100 knots

Wind direction is reported to the nearest 5 degrees, e.g. 300 = 300 degrees, 095 = 95 degrees). However, sometimes the wind direction appears as either 301 or 306; this indicates either a wind direction of 300 or 305 and speed of 100 knots or more. For example, if we had a wind code of 35110, then the direction would be 350 degrees, and the wind speed would be 110 knots but if the wind code was 35610 then the wind direction would be 355 degrees and the wind speed would be 110 knots.

- Height conversion table

Pressure level (mb)		Conversion
Values above 850 mb	-	As read
850 mb level	-	Add a 1 to the front of the height value (1hhh)
700 mb level	-	Add a 2 to the front of the height value (2hhh)
For values between 500 and 300 mb	-	Add a 0 to the end of the height value (hhh0)
For values between 250 and 100 mb	-	Add a 1 to the front and a 0 to the end of the height value (1hhh0)

Table 2. Height Conversion Table.

- Tropopause data - **88PtPtPt** (Pressure level of the tropopause)

TTAA 51231 03808 99996 07819 17005 00056 ///// ///// 92698 03843 20018 85379 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 **88207** 62929 29586 77214 29090 42341 31313 48008 82315

Tropopause height indicator (88)

Pressure level of tropopause (PtPtPt)
(207 mb)

- Tropopause data - **TtTtTatDtDt** (dry-bulb and dewpoint temperature of the tropopause)

TTAA 51231 03808 99996 07819 17005 00056 ///// ///// 92698 03843 20018 85379 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 **62929** 29586 77214 29090 42341 31313 48008 82315

Tropopause dry-bulb temperature (TtTtTat)
(629 = -62.9 °C)
(Note – in the code, this figure is an odd number so the value is negative)

Tropopause dew-point depression (DtDt)
(29 = -65.8 °C (2.9 °C colder than the dry bulb))
(When the depression is 5.0°C or less the value is in units and tenths. When the depression is more than 5.0°C the units and tenths are reported but 50 is added to the total, therefore 56 is 6 whole degrees)

- Tropopause data - **dtdtdtftft** (tropopause wind direction and speed)

TTAA 51231 03808 99996 07819 17005 00056 ///// ///// 92698 03843 20018 85379 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 **29586** 77214 29090 42341 31313 48008 82315

Tropopause wind direction (ddd) and speed (ff)
(295 degrees, 86 knots)

- Maximum wind data - **77PmPmPm** (pressure level of the maximum wind)

TTAA 51231 03808 99996 07819 17005 00056 ///// ///// 92698 03843 20018 85379 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 29586 **77214** 29090 42341 31313 48008 82315

Maximum wind Indicator (77)

Maximum wind pressure level
(214 mb)

Maximum wind data - **dmdmdmfmfm** (maximum wind direction and force)

TTAA 51231 03808 99996 07819 17005 00056 ///// ///// 92698 03843 20018 85379 00356 20020 70934 04976 22032 50550 19143 27537 40713 29940 27552 30912 44335 27069 25032 54327 28571 20171 61931 29570 15353 54782 27047 10614 54982 25523 88207 62929 29586 77214 **29090** 42341 31313 48008 82315

Maximum wind direction (dmdmdm) and speed (fmfm)
(290 degrees 90 knots)

The same decode continues for the rest of the mandatory levels. Eventually you should be able to draw up a table thus:

Pressure (mb)	Height (m)	Dry-bulb temperature (°C)	Dewpoint temperature (°C)	Wind direction (degrees)	Wind speed (knots)
1000	56	-	-	-	-
925	698	3.8	-0.5	200	18
850	1379	-0.3	-6.3	200	20
700	2934	-4.9	-30.9	220	32
500	5500	-19.1	-23.4	275	37
400	7130	-29.9	-33.9	275	52
300	9120	-44.3	-47.8	270	69
250	10320	-54.3	-57.0	285	71
200	11710	-61.9	-65.0	295	70
150	13530	-54.7	-86.7	270	47
100	16140	-54.9	-86.9	255	23
Tropopause	207 mb	-62.9	-65.8	295	86
Maximum wind	214 mb	-	-	290	90

Table 3. Example of a TTAA (mandatory levels) decode.

The symbolic form of the upper-air code for Part B (TTBB) is as follows:

TTAA YYGGI IIiii	-	Message identification
00PoPoPo ToToTaoDoDo	-	Surface data
11PPP TTTaDD 99PPP TTTaDD	- -	Significant levels with respect to temperature and/or dewpoint changes
21212	-	Separation indicator between temperature and wind data
00PoPoPo dddff	-	Surface data
11PPP dddff 99dddff	- -	Significant levels with respect to wind

Table 4. The decode of the upper-air code for part B (TTBB).

All ascent can be broken down as follows:

- Message identification - **TTBB**

TTBB 51238 03808 00996 07819 11995 08018 22990 08021 33980 07625 44969 06823 55948 05650 66915 03042 77875 00108 88867 00717 99859 01314 11855 01318 22851 00741 33845 02469 44840 03873 55831 04276 66817 03873 77816 03673 88786 01674 99734 02174 11667 07976 22618 11572 33607 12765 44601 11910 55548 15310 66517 17343 77462 22339 88455 22934 99441 24728 11398 30141 22377 33131 33327 39535 44308 42926 55267 50935 66244 55723 77226 58933 88219 60729 99207 62929 11200 61932 22194 59957 33187 59762 44185 59964 55174 54774 66171 54777 77160 57381 88143 53383 99120 54383 11113 52783 22100 54982 21212 00996 17005 11984 18514 22973 19018 33951 20517 44871 18521 55852 20019 66834 21022 77731 22530 88716 22033 99679 23029 11605 25034 22519 27036 33469 28042 44411 28053 55354 27056 66348 27061 77309 27570 88291 27071 99288 27069 11261 28065 22214 29090 33207 29586 44201 29573 55193 28547 66189 27048 77186 27053 88181 27559 99178 28054 11172 28039 22169 27032 33165 26034 44159 26040 55150 27547 66143 27033 77137 26031 88116 25535 99111 26538 11100 25523 31313 48008 82315 41414 28472 51515 11892 19022 22800 21025 33600 25034

Part B indicator (significant levels)

- Message identification – **YYGGI** (YY: month/date; GG: time of ascent; I: Information about the instrumentation used to make the ascent (not important))

TTBB **51238** 03808 00996 07819 11995 08018 22990 08021 33980 07625 44969 06823 55948 05650 66915 03042 77875 00108 88867 00717 99859 01314 11855 01318 22851 00741 33845 02469 44840 03873 55831 04276 66817 03873 77816 03673 88786 01674 99734 02174 11667 07976 22618 11572 33607 12765 44601 11910 55548 15310 66517 17343 77462 22339 88455 22934 99441 24728 11398 30141 22377 33131 33327 39535 44308 42926 55267 50935 66244 55723 77226 58933 88219 60729 99207 62929 11200 61932 22194 59957 33187 59762 44185 59964 55174 54774 66171 54777 77160 57381 88143 53383 99120 54383 11113 52783 22100 54982 21212 00996 17005 11984 18514 22973 19018 33951 20517 44871 18521 55852 20019 66834 21022 77731 22530 88716 22033 99679 23029 11605 25034 22519 27036 33469 28042 44411 28053 55354 27056 66348 27061 77309 27570 88291 27071 99288 27069 11261 28065 22214 29090 33207 29586 44201 29573 55193 28547 66189 27048 77186 27053 88181 27559 99178 28054 11172 28039 22169 27032 33165 26034 44159 26040 55150 27547 66143 27033 77137 26031 88116 25535 99111 26538 11100 25523 31313 48008 82315 41414 28472 51515 11892 19022 22800 21025 33600 25034

Day of the Month (YY)
(51 = 1st)
(Day of the month of observation plus 50, e.g. 55 = 5th day of the month)

Time of Ascent (GG)
(23 = 2300z)

The next three groups are the same as the TTAA group, in that they give the WMO indicator of the station making the ascent (IIiii) and then data about the surface pressure (99PoPoPo), temperature and dewpoint (ToToTaoDoDo).

TTBB 51238 **03808 00996 07819** ...

- 1st significant pressure level data – **11PPP** (height of the 1st level)

TTBB 51238 03808 00996 07819 **11995** 08018 22990 08021 33980 07625 44969 06823 55948
05650 66915 03042 77875 00108 88867 00717 99859 01314 11855 01318 22851 00741 33845
02469 44840 03873 55831 04276 66817 03873 77816 03673 88786 01674 99734 02174 11667
07976 22618 11572 33607 12765 44601 11910 55548 15310 66517 17343 77462 22339 88455
22934 99441 24728 11398 30141 22377 33131 33327 39535 44308 42926 55267 50935 66244
55723 77226 58933 88219 60729 99207 62929 11200 61932 22194 59957 33187 59762 44185
59964 55174 54774 66171 54777 77160 57381 88143 53383 99120 54383 11113 52783 22100
54982 21212 00996 17005 11984 18514 22973 19018 33951 20517 44871 18521 55852 20019
66834 21022 77731 22530 88716 22033 99679 23029 11605 25034 22519 27036 33469 28042
44411 28053 55354 27056 66348 27061 77309 27570 88291 27071 99288 27069 11261 28065
22214 29090 33207 29586 44201 29573 55193 28547 66189 27048 77186 27053 88181 27559
99178 28054 11172 28039 22169 27032 33165 26034 44159 26040 55150 27547 66143 27033
77137 26031 88116 25535 99111 26538 11100 25523 31313 48008 82315 41414 28472 51515
11892 19022 22800 21025 33600 25034

1st significant level indicator (11)

1st significant pressure level height (PPP)
(995 mb)

- 1st significant pressure level data – **TTTaDD** (dry-bulb and dewpoint temperature at the 1st significant level)

TTBB 51238 03808 00996 07819 11995 **08018** 22990 08021 33980 07625 44969 06823 55948
05650 66915 03042 77875 00108 88867 00717 99859 01314 11855 01318 22851 00741 33845
02469 44840 03873 55831 04276 66817 03873 77816 03673 88786 01674 99734 02174 11667
07976 22618 11572 33607 12765 44601 11910 55548 15310 66517 17343 77462 22339 88455
22934 99441 24728 11398 30141 22377 33131 33327 39535 44308 42926 55267 50935 66244
55723 77226 58933 88219 60729 99207 62929 11200 61932 22194 59957 33187 59762 44185
59964 55174 54774 66171 54777 77160 57381 88143 53383 99120 54383 11113 52783 22100
54982 **21212** 00996 17005 11984 18514 22973 19018 33951 20517 44871 18521 55852 20019
66834 21022 77731 22530 88716 22033 99679 23029 11605 25034 22519 27036 33469 28042
44411 28053 55354 27056 66348 27061 77309 27570 88291 27071 99288 27069 11261 28065
22214 29090 33207 29586 44201 29573 55193 28547 66189 27048 77186 27053 88181 27559
99178 28054 11172 28039 22169 27032 33165 26034 44159 26040 55150 27547 66143 27033
77137 26031 88116 25535 99111 26538 11100 25523 31313 48008 82315 41414 28472 51515
11892 19022 22800 21025 33600 25034

1st significant level dry-bulb temperature (TTTa)
(080 = 8.0 °C)
(Note – in the code, this figure is an even number so the value is positive)

1st significant level dew-point depression (DD)
(6.2 °C)
(8.0 – 1.8 = 6.2)

This trend continues for all the other significant levels (22, 33, etc) until the indicator **21212** is reached (see above). This indicated the start of the wind data for the significant levels.

Note – the 1st significant level for temperature need not necessarily correspond to the first significant level for wind.

The first two groups after the 21212 indicator are the duplicate wind data for the surface pressure level.

- 1st significant pressure level data – **dddff** (wind direction and speed at the 1st significant level)

TTBB 51238 03808 00996 07819 11995 08018 22990 08021 33980 07625 44969 06823 55948 05650 66915 03042 77875 00108 88867 00717 99859 01314 11855 01318 22851 00741 33845 02469 44840 03873 55831 04276 66817 03873 77816 03673 88786 01674 99734 02174 11667 07976 22618 11572 33607 12765 44601 11910 55548 15310 66517 17343 77462 22339 88455 22934 99441 24728 11398 30141 22377 33131 33327 39535 44308 42926 55267 50935 66244 55723 77226 58933 88219 60729 99207 62929 11200 61932 22194 59957 33187 59762 44185 59964 55174 54774 66171 54777 77160 57381 88143 53383 99120 54383 11113 52783 22100 54982 **21212 00996 17005 11984 18514** 22973 19018 33951 20517 44871 18521 55852 20019 66834 21022 77781 22540 88716 22033 99679 23029 11605 25034 22519 27036 33469 28042 44411 28053 55354 27056 66348 27061 77309 27570 88291 27071 99288 27069 11261 28065 22214 29090 33207 29586 44201 29573 55193 28547 66189 27048 77186 27053 88181 27559 99178 28054 11172 28039 22169 27032 33165 26034 44159 26040 55150 27547 66143 27033 77137 26031 88116 25535 99111 26538 11100 25523 **31313** 48008 82315 41414 28472 51515 11892 19022 22800 21025 33600 25034

21212 Indicator (wind data follows)

Surface pressure data (00PoPoPo)
(996 mb)

Surface wind data (dddff)
(170 degrees 05 knots)

1st level indicator (11)

1st level pressure data (PoPoPo)
(984 mb)

1st level wind data (dddff)
(185 degrees 14 knots)

This trend continues for all the other significant levels (22, 33, etc) until the indicator **31313** is reached. Data after this point can be ignored as these figures simple indicate local features not plotted on the tephigram.

For ascents where the 1000 mb level is below sea level.

Occasionally, when there is a deep depression close by the observing site or where the station is close to sea level, the 1000 mb height might be significantly lower than mean sea level. However, the 1000 mb must still be reported as this is one of the mandatory levels and is used to calculate the thickness value for the air mass at that station.

If the 1000 mb level is below sea level, then the value for the 1000 mb height is plotted as 500 or greater. To get the height, simply subtract 500 from the height of the 1000 mb level and add a negative sign to the value. For example:

TTAA 51231 03808 99984 07819 17005 **00556** ///// ///// ...

1000mb height indicator (00)

Height of 1000mb level (hhh)
(556 = -56 metres)
(556 – 500 = 56 metres. Because this value is greater than 500 a negative sign is placed in front of this value. Therefore, the 1000 mb height of this ascent is -56 metres)

Once all the data has been collected the tephigram of the ascent can be plotted.

The tephigram

Introduction

The tephigram, or aerological diagram as it is sometimes referenced to, is a thermodynamic or energy diagram, devised by Sir Napier Shaw, a former Director-General of the Met Office. It is a graphical representation of the observations of pressure, temperature and humidity, made in a vertical sounding of the atmosphere.

The axis of the tephigram are temperature (T) and entropy (ø) hence the tephi(Tø) – gram.

The axis of the tephigram appears thus:

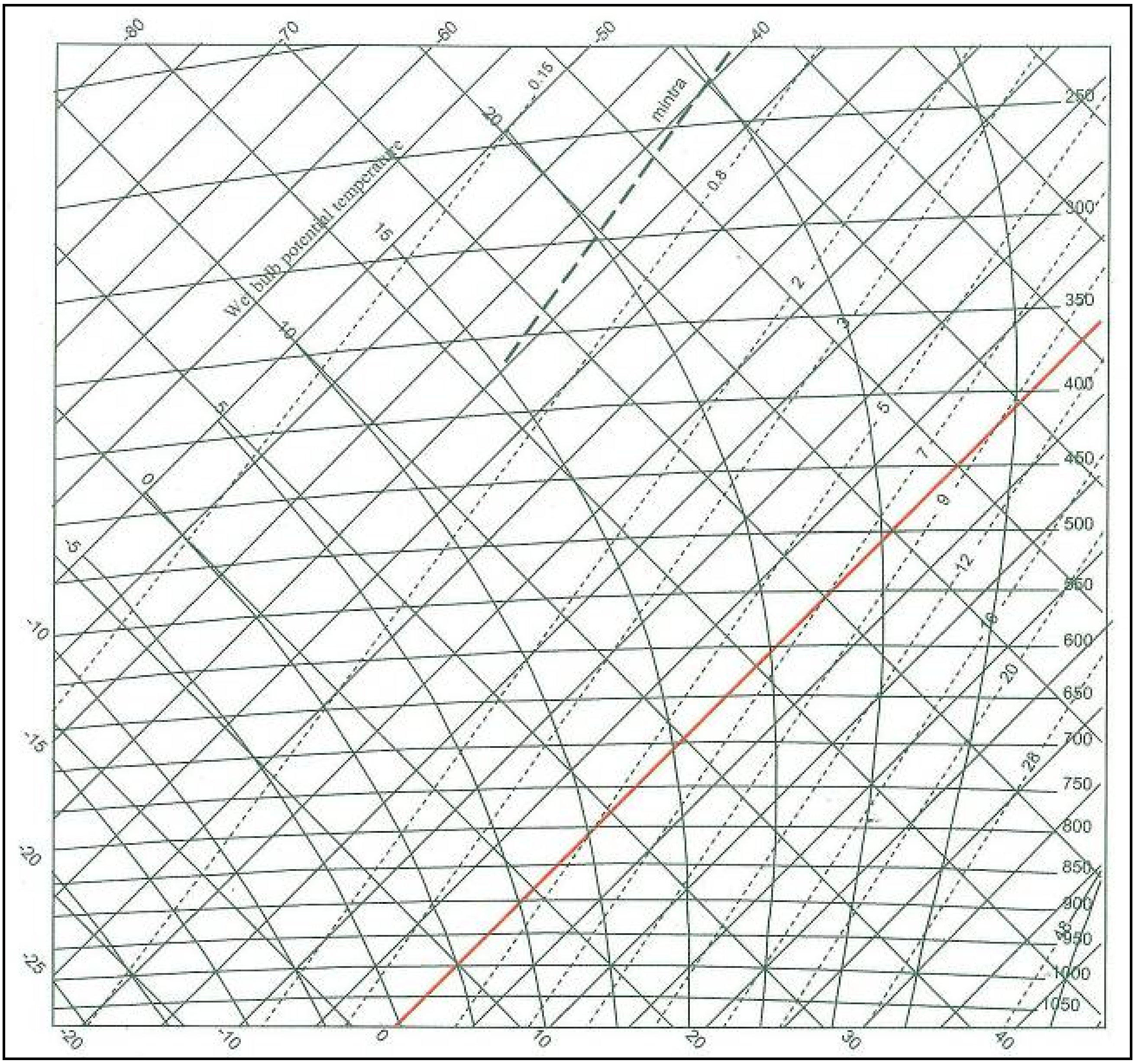
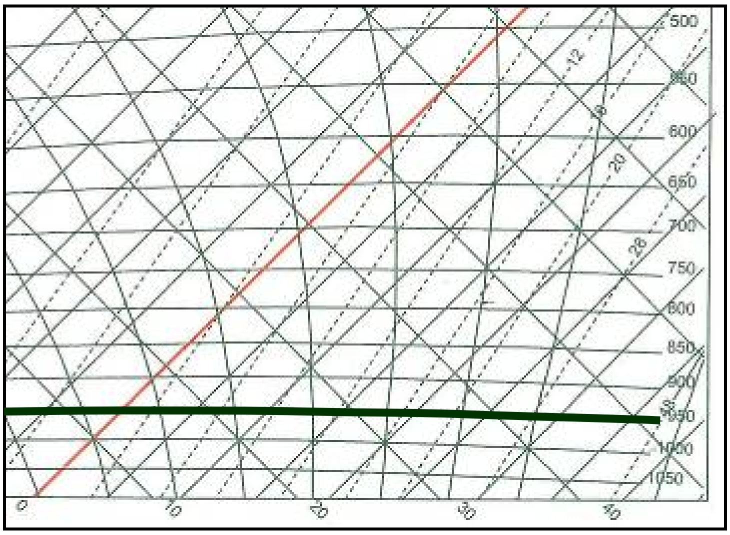


Figure 3. Axis of a tephigram.

The lines on the tephigram

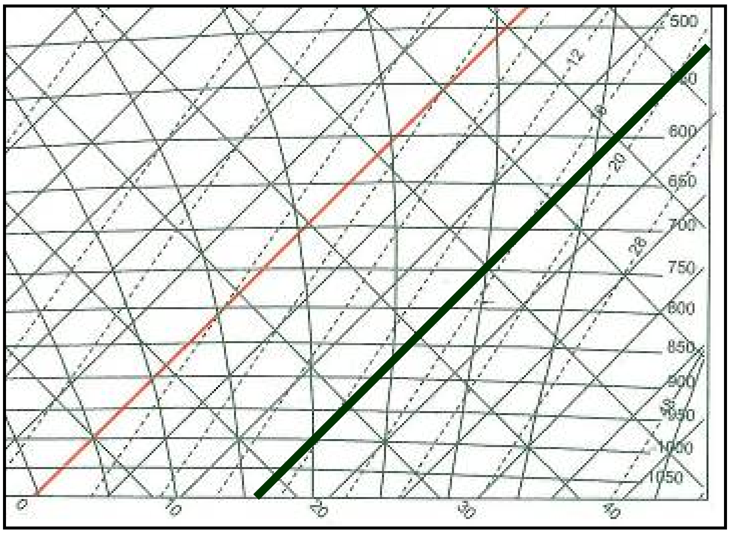
- Isobars – the ‘horizontal’ lines



Isobars are lines of equal pressure, almost horizontal and almost straight. Their vertical spacing increases as their value decreases. They are drawn at 10 mb intervals with the highest value (1050 mb) at the bottom and the lowest at the top, as in the real atmosphere. The value of the isobars can be found every 50 mb at the left edge of the diagram.

Figure 4. Isobars.

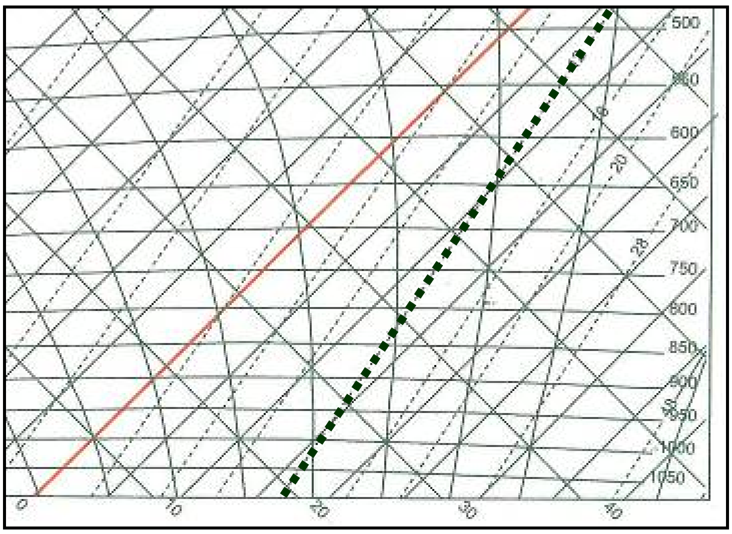
- Isotherms – the solid diagonal lines running bottom left to top right



Isotherms are lines of equal temperature. They are straight and parallel, running at 45° across the diagram from bottom left to top right. They are drawn at 10°C intervals. The temperature scale is marked along the 1000 mb isobar, near the bottom of the diagram, as well as along the right-hand and top edges. The line representing the 0°C isotherm is coloured red on the diagram.

Figure 5. Isotherms.

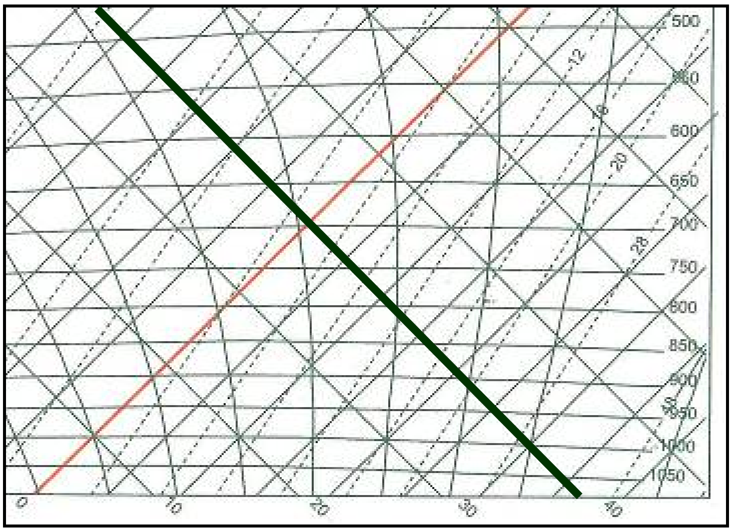
- Humidity Mixing Ratio Lines (HMR) – the pecked diagonal lines



Humidity mixing ratio lines are almost straight, pecked lines with a similar orientation to the isotherms, running diagonally across the diagram from bottom left to top right. A selection of lines is represented, their value gkg^{-1} can be found across the bottom of the diagram below the 1050 mb isobar. These figures represent the number of grams of water required to saturate 1 kg of air at that particular temperature/pressure.

Figure 6. Humidity mixing ratio lines.

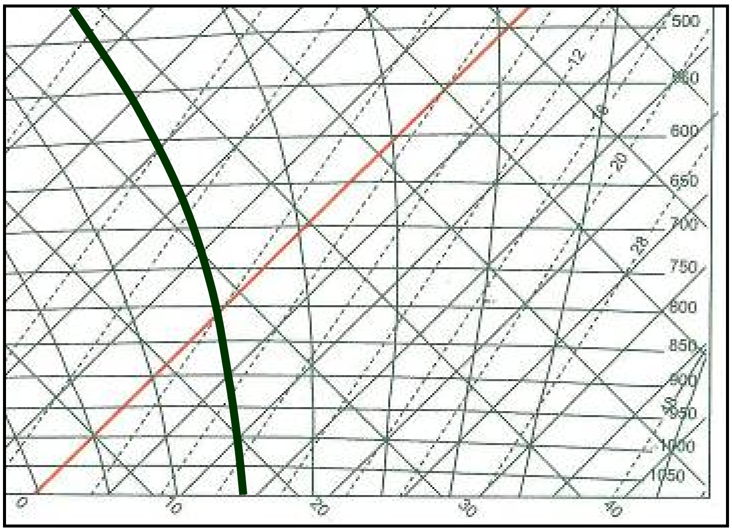
- Dry adiabats – the solid diagonal lines running bottom right to top left



The dry adiabats are solid lines representing the rate at which dry air (or more accurately unsaturated air), will cool when rising or warm when sinking. The dry adiabatic lapse rate or (DALR) is the rate at which cooling occurs if there are no other factors increasing or decreasing the temperature of a parcel as it rises. They are straight and parallel, running at 45° across the diagram from bottom right to top left.

Figure 7. Dry adiabats.

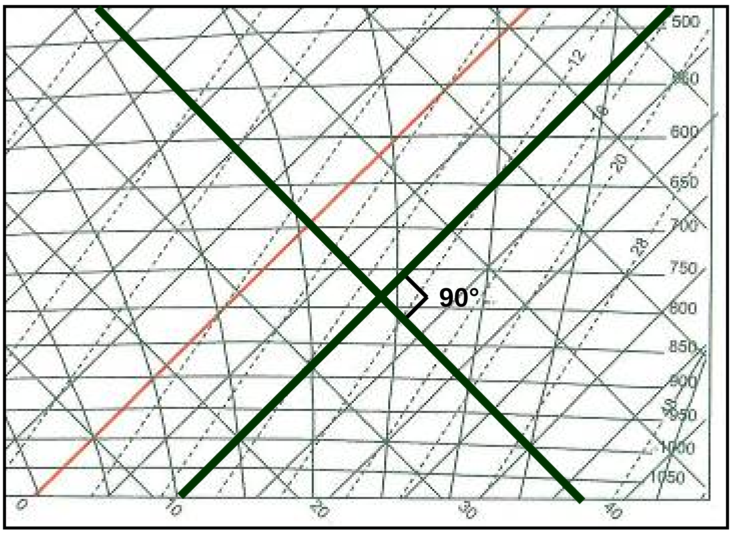
- Saturated adiabats – the curved lines



The saturated adiabats are lines representing the rate at which saturated air will cool when rising (the saturated adiabatic lapse rate, or SALR). As saturated air rises it cools and condensation occurs. This releases latent heat and warms the air so this rate of cooling is less that the DALR. The shape of the curve depends on the amount of water the air can hold; the higher the amount, the slower the rate of fall of temperature with height.

Figure 8. Saturated adiabats.

Consequently the lines curve from bottom right to top left and are not parallel. At very low temperatures the air holds little water and the SALR lines tend to become parallel with the DALR lines.



It is worth noting that since entropy and temperature are the axis of the diagram the dry adiabats and isotherms are at right angles to each other.

Figure 9. Relationship between the dry adiabats and the isotherm lines.

Environmental lapse rate

If you take a parcel of air and move it around vertically in the atmosphere without adding heat or taking heat away then the temperature of the parcel of air will follow the lines on the tephigram. In a perfect atmosphere, unsaturated air would rise up the dry adiabat and saturated air would rise up the saturated adiabat. As it moves up it cools, as it moves down it warms, all very predictable. Even a casual glance at any plotted tephigram will show that the temperature profile follows a rather more complicated path. This is known as the environmental lapse rate (ELR).

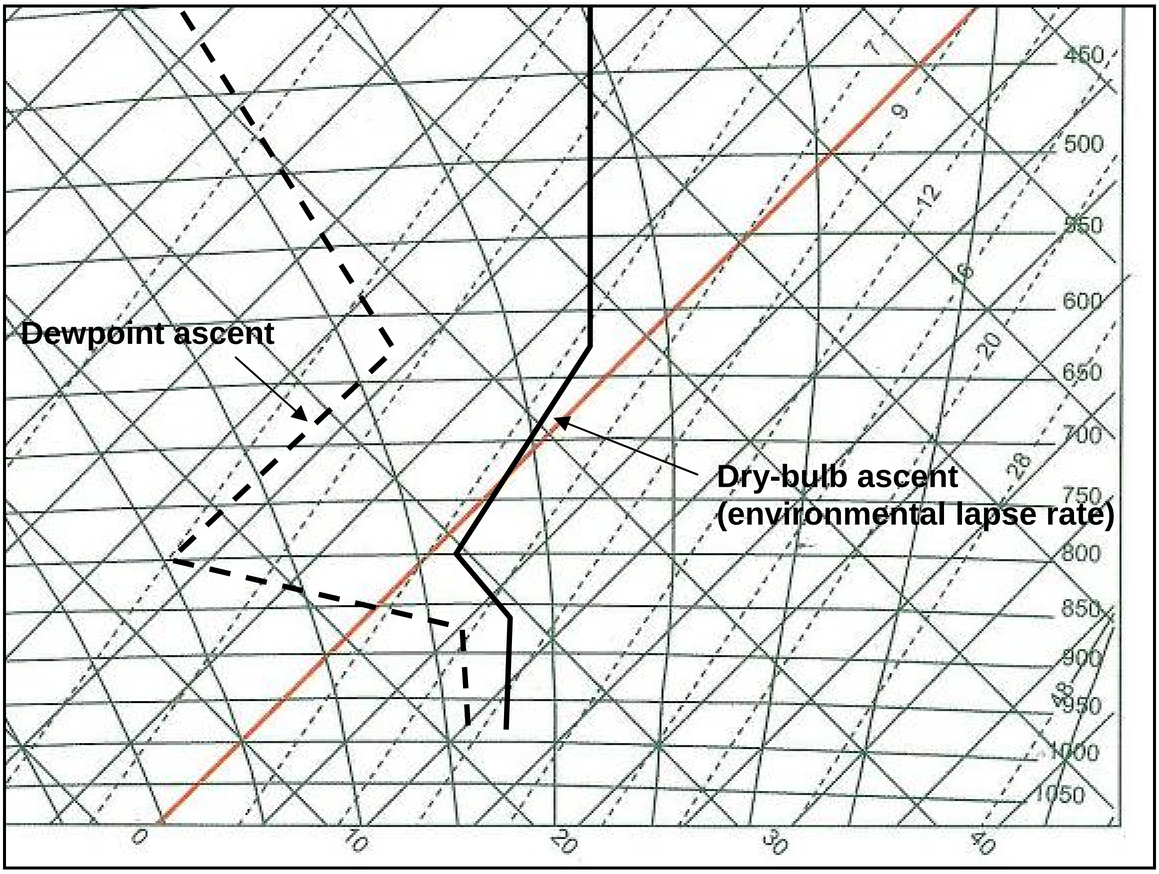


Figure 10. Environmental lapse rate.

By looking at the environmental lapse rate it is possible to find certain discrepancies in the ascent. These can be super-adiabats, isothermal layers and inversions.

Super-adiabats, isothermals and inversions

- A **super-adiabat** is a line where the temperature decreases very quickly with height, more quickly that is normally possible. Super-adiabats normally occur near the surface of the earth and usually during the summer months.

- An **isothermal** represents a layer of the atmosphere where the temperature is constant with changes in height.

- An **inversion** is where the temperature increases with height. The reason for this might be caused by an approaching airmass or cooling at the surface on a clear night.

Super-adiabatic lapse rate

A super–adiabatic lapse rate normally occurs near the surface of the earth as a result of strong solar heating.

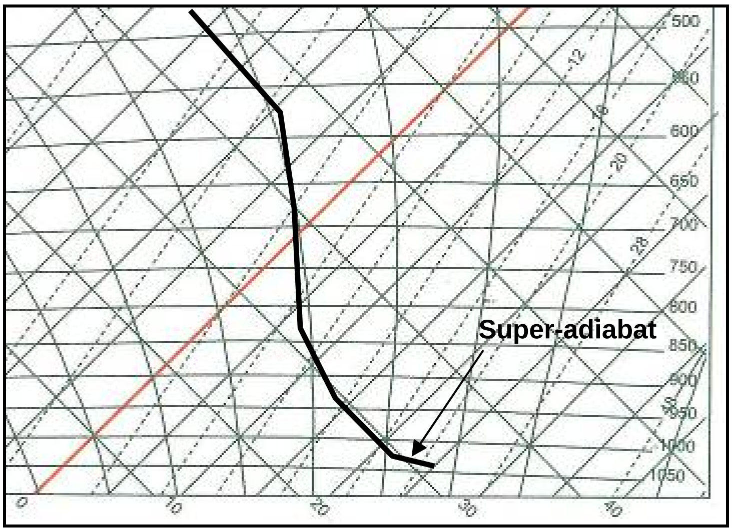


Figure 11. Super-adiabatic lapse rate.

Isothermal

This is a region where the temperature does not change with height. An isothermal of more than 200 mb in depth should be regarded as suspicious.

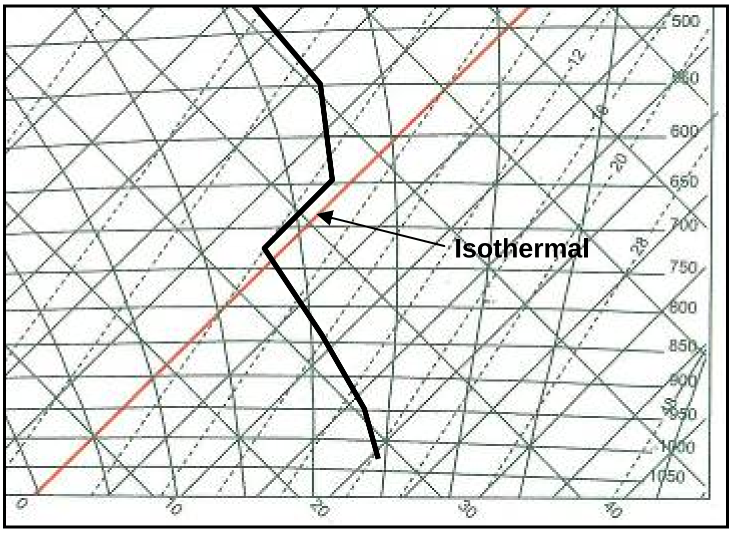


Figure 12. Isothermal layer.

Inversion

An inversion is where the temperature actually increases with height. These can occur at the surface of the earth or higher up in the atmosphere.

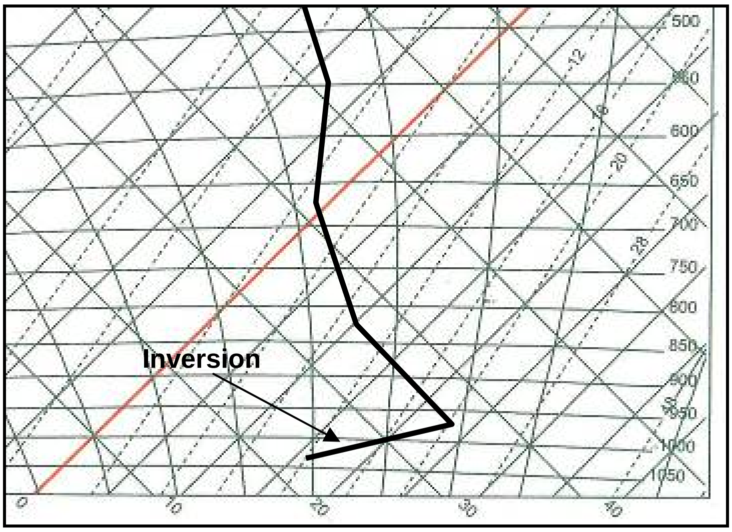


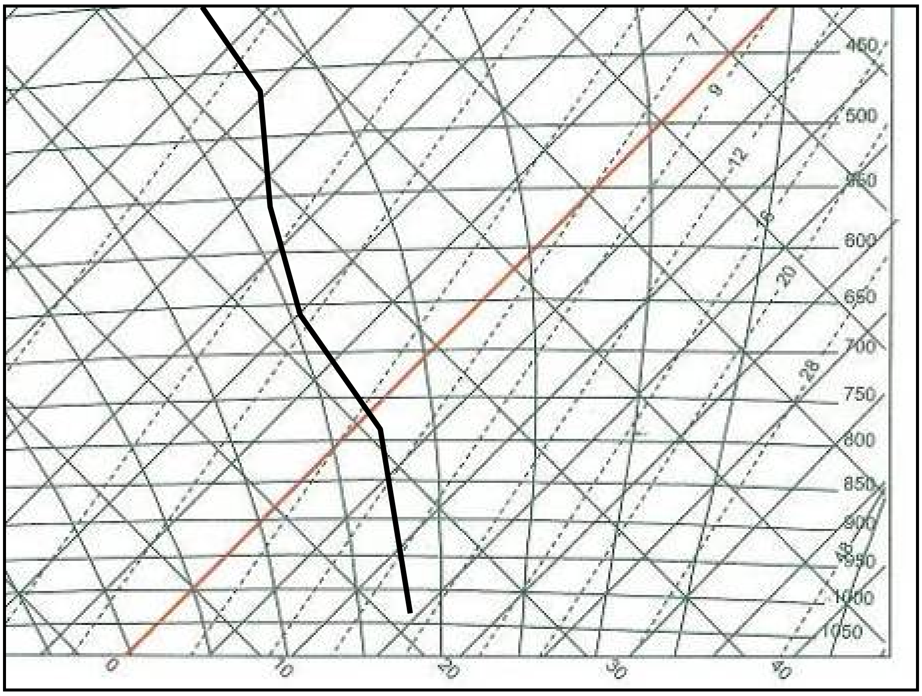
Figure 13. Inversion.

Neither an isothermal nor an inversion can be regarded as normal behaviour for the atmosphere and possibly indicates something interesting happening.

Causes of a super-adiabat

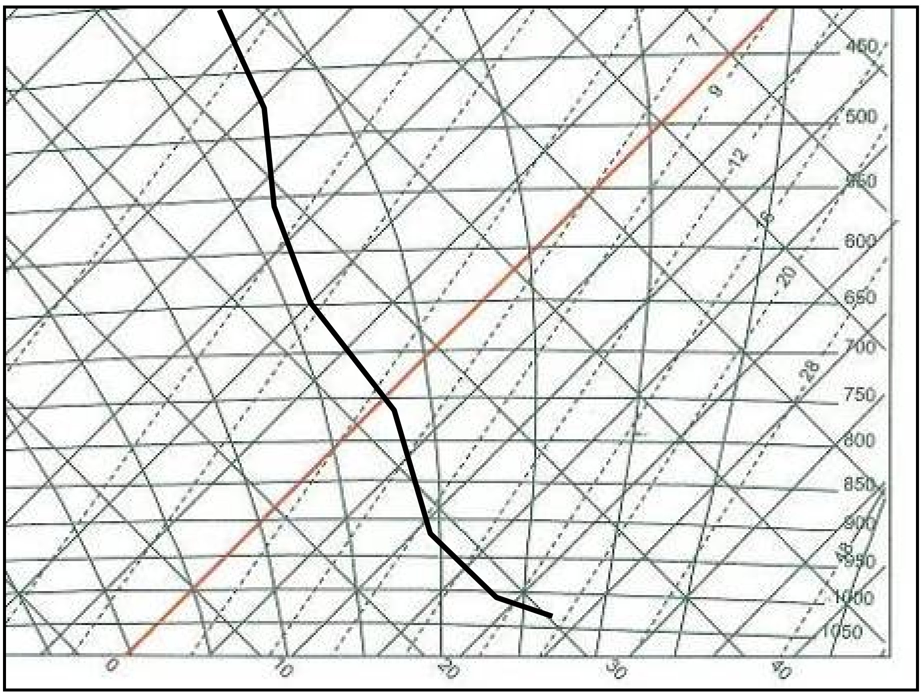
A super-adiabat is caused when there is differential heating between the surface of the earth and the air mass immediately above it.

Under anticyclonic conditions during the summer months, the surface of the earth can be warmed very quickly, whereas the air mass above it takes much longer to warm up. Below are two typical profiles, one for midnight and the other for midday, showing how quickly the land can be heated compared to the atmosphere immediately above it.



Midnight ascent

Figure 14. Example of the midnight ascent showing no super-adiabatic layer.



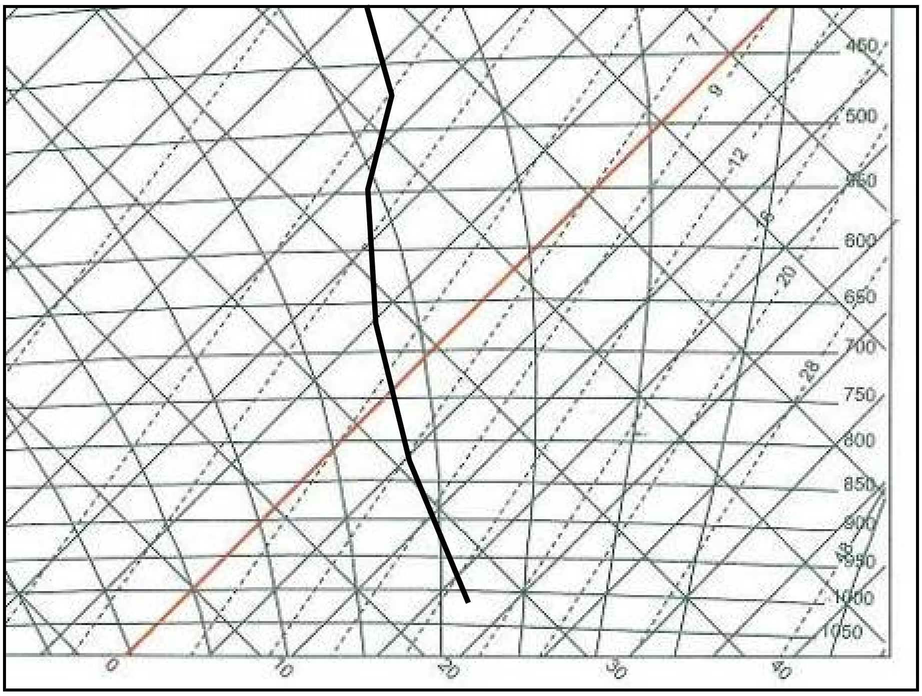
Midday Ascent

Figure 15. Example of the midday ascent showing a super-adiabatic layer.

Causes of an inversion

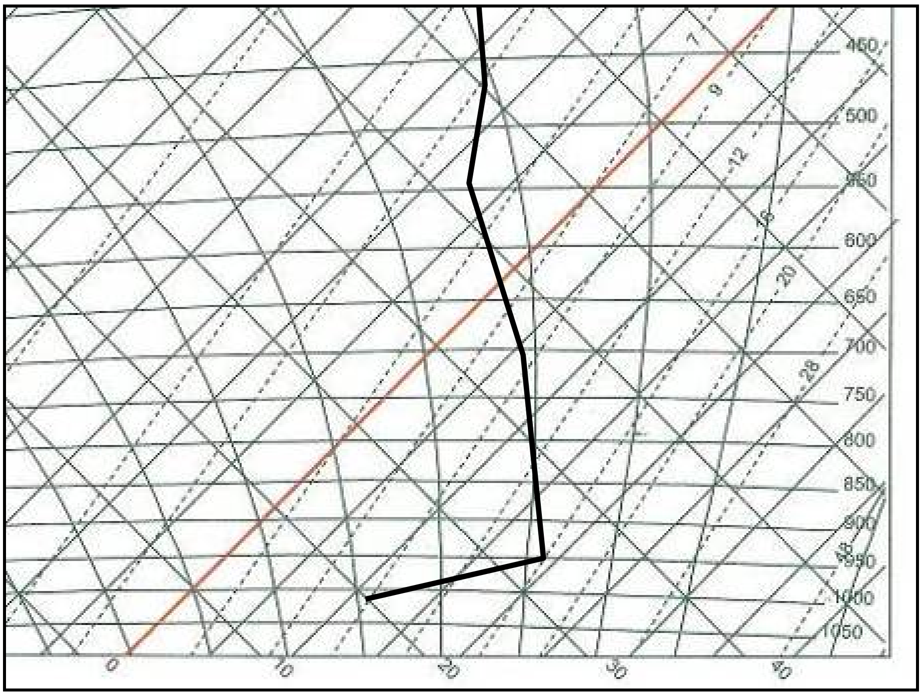
1. Night time cooling of the air mass

As with the super-adiabatic, air is a poor conductor of heat and as such, cools down more slowly than the surface it is immediately above. Consequently, under clear anticyclonic conditions at night, the land cools down very quickly but the atmosphere above takes longer to cool, thus creating an inversion. Below are two typical profiles, one for midday and the other for midnight, showing how quickly the land is cooled compared to the atmosphere immediately above it.



Midday ascent

Figure 16. Example of the midday ascent showing no inversion layer.



Midnight Ascent

Figure 17. Example of the midnight ascent showing an inversion layer.

2. Approaching warm front

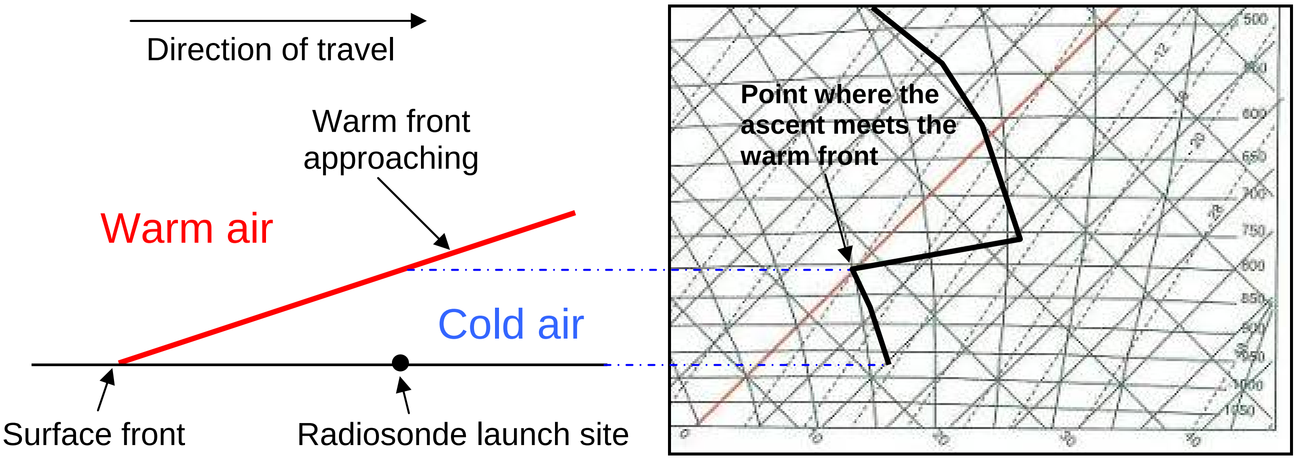


Figure 18. Inversion caused by an approaching warm front.

The above diagram represents a typical ascent that would be plotted with an approaching warm front. The launch site is sitting in a cold returning polar maritime air mass and, typically, the temperature falls away with height corresponding to the characteristics of that air mass. As the radiosonde ascends it eventually meets the warm front with its associated tropical air mass. Being much warmer than the polar air mass it is replacing, the temperature now increases to take on the characteristics of this new tropical air mass before resuming its normal decrease with height scenario, but this time of the new air mass.

Stability

There are three types of stability at work in the atmosphere, these are:

- An absolutely unstable atmosphere
- An absolutely stable atmosphere
- A conditionally unstable atmosphere

An absolutely unstable atmosphere

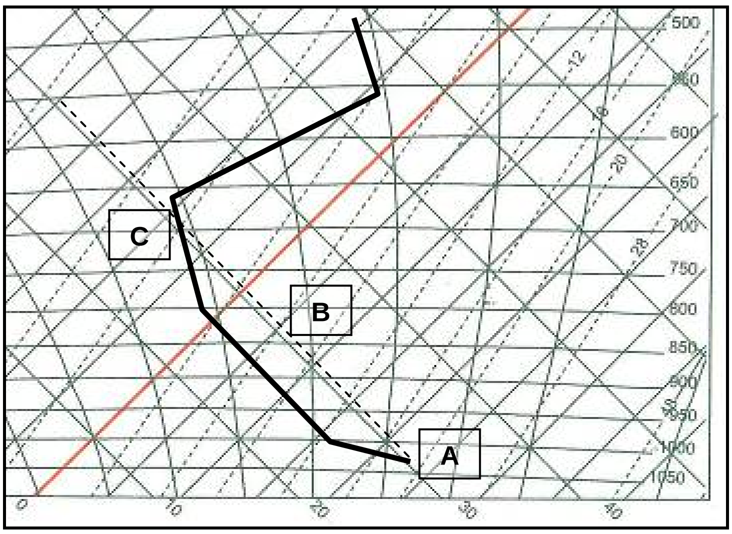


Figure 19. An absolutely unstable atmosphere.

If a parcel of dry air rises, its temperature will follow the appropriate DALR line of the tephigram. Initially its temperature at A is T_1. It is forced to rise until it reaches a lower temperature T_2 at height B and then released. The temperature in the atmosphere given by the ELR (solid line) is lower than (or to the left of) that of the parcel. The parcel is buoyant and will rise like a hot air balloon until it reaches height C.

At this height the temperature of the air T_3 will be the same as the environment. Therefore it is no longer buoyant and will stop rising. Neither will it fall; otherwise it would become buoyant again. If dry air does this, then the atmosphere is said to be **absolutely unstable**.

An absolutely stable atmosphere

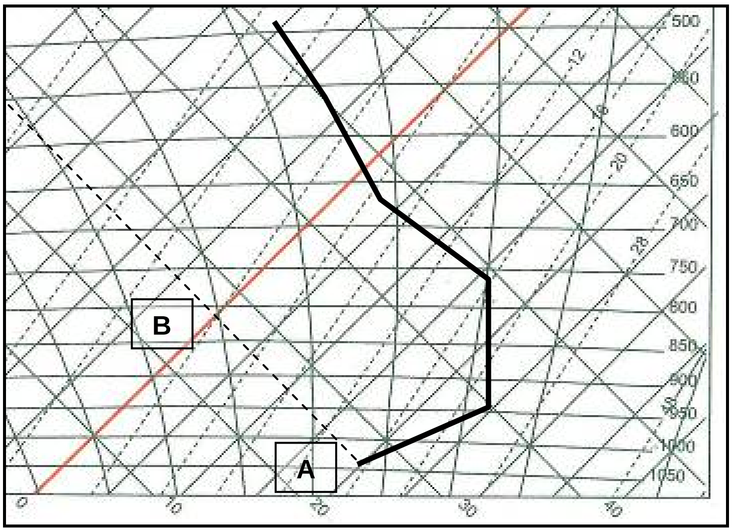


Figure 20. An absolutely stable atmosphere.

If we raise a parcel of air from height A to height B then at height B the temperature of the atmosphere given by the ELR, is higher than, or to the right of that of the parcel. The parcel is negatively buoyant and will fall back to height A. In this case the atmosphere is said to be **absolutely stable**.

A conditionally unstable atmosphere

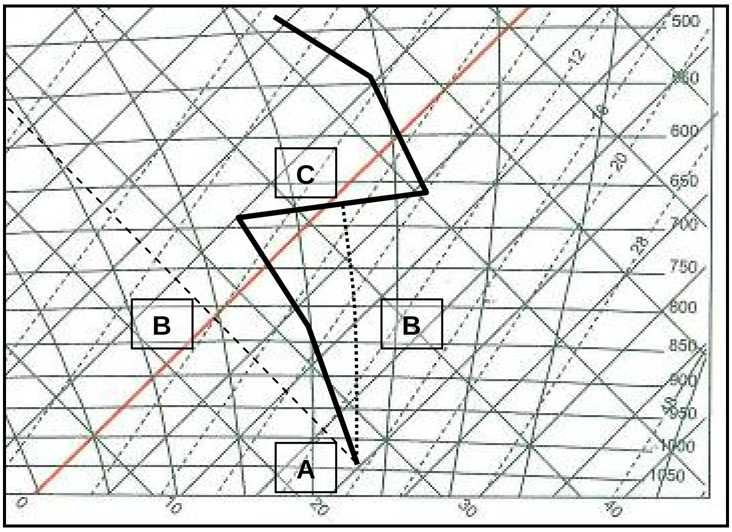


Figure 21. A conditionally unstable atmosphere**.**

Here we will consider two parcels of air, one dry and the other saturated. When forced to rise, the parcels will cool at different rates, the dry parcel of air will cool along the DALR and the saturated parcel of air will cool along the SALR. When these parcels of air reach height B they are at different temperatures to each other. The dry parcel is cooler than the environmental atmosphere (left of the ELR) and will fall back to A. The atmosphere is stable to dry air.

However, the saturated parcel of air is warmer (to the right of the ELR) and will continue to rise to height C before being stopped by an inversion. The atmosphere is unstable to saturated air. In this case the atmosphere in **conditionally unstable**. This is probably the most common state found in the troposphere.

Different layers in the atmosphere can have different stabilities at the same time. Knowledge of stability is most important, particularly in relation to the forecasting of convective cloud and precipitation.

Uses of the tephigram

Apart from identifying the stability of the atmosphere, the tephigram can be used for a number of other purposes. These include:

- Finding the liquid water content and the relative humidity of the air
- Finding the convective cloud bases and tops
- Identifying layer cloud
- Identifying the wet-bulb potential temperature
- Forecasting the temperature at which radiation fog could form

Finding the liquid water content and the relative humidity of the air

- Liquid water content of the air

Plot the dewpoint temperature on the tephigram and then draw a line from the dewpoint temperature to the bottom of the tephigram parallel to the humidity mixing ratio (HMR) line. The figure along this line will give you the amount of liquid water (in grams) which is present in one kilogram of air.

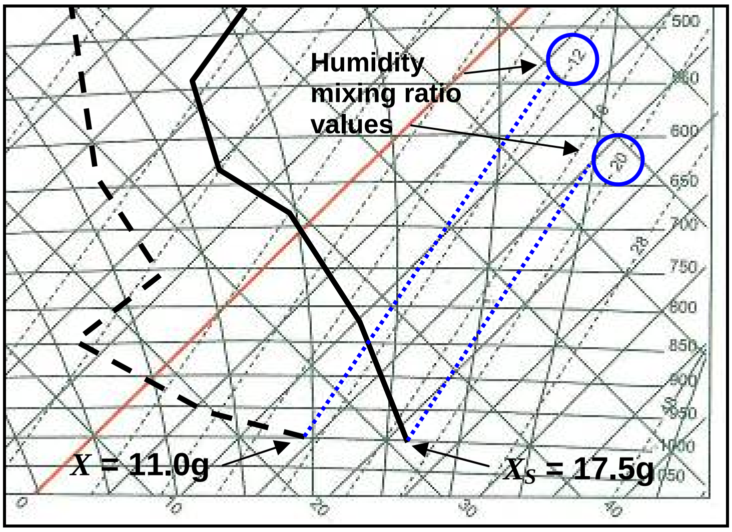


Figure 22. Finding the liquid water content of the air .

In this example, the dewpoint temperature at the earth's surface (surface pressure 1000 mb) is 14 °C and is plotted on the tephigram in the dashed line. A line is then drawn from the dewpoint along the humidity mixing ratio line and in this instance the amount of liquid water in this parcel of air is 11.0g per kilogram of air. It is usually denoted by the symbol X.

- Relative humidity

A similar construction could be drawn from the dry bulb temperature. The value found would then represent the maximum amount of water the air can hold, it could be thought of as the highest dew-point that is possible. This is usually denoted by the symbol, X_S.

The ratio of the mass of actual liquid water content to maximum liquid water content is known as relative humidity (RH). Relative humidity is usually expressed as a percentage by multiplying the ratio X/X_S by 100, thus:

$$\frac{X}{X_S} \times 100 = \text{RH}$$ - from the above diagram the RH at the surface would be:

$$\frac{11.0}{17.5} \times 100 = \mathbf{62.8\%}$$

Identifying convective cloud bases and tops

In order to determine the likely base and top of any convective clouds we can replicate a rising parcel of air on the tephigram. Rising unsaturated air cools at the DALR, but while it's rising and cooling it is not losing any moisture. These features can be shown on the tephigram by drawing a line parallel to the DALR starting at the surface dry bulb temperature. This represents the path the rising air will take. If we draw another line, this time parallel to the HMR starting at the surface dewpoint, this will represent the fact rising air does not gain or lose any moisture. Where these two lines meet determines the height at which the air has cooled enough to become saturated, this is known at the '**Normand's Point**' and represents the condensation level or convective cloud base.

If the temperature of the rising air has been warmer than that of its surroundings all the way up to the Normand's Point, then the air will continue to rise. On passing Normand's Point the air becomes saturated, condensation occurs releasing latent heat, so the air now cools at the slower rate known as the SALR. It will continue to rise until it is no longer warmer than the surroundings, i.e. on the tephigram the rising air has reached the ELR. When this point is reached the parcel of air stops rising. This is known as the parcel top, and represents the height of the top of the cloud.

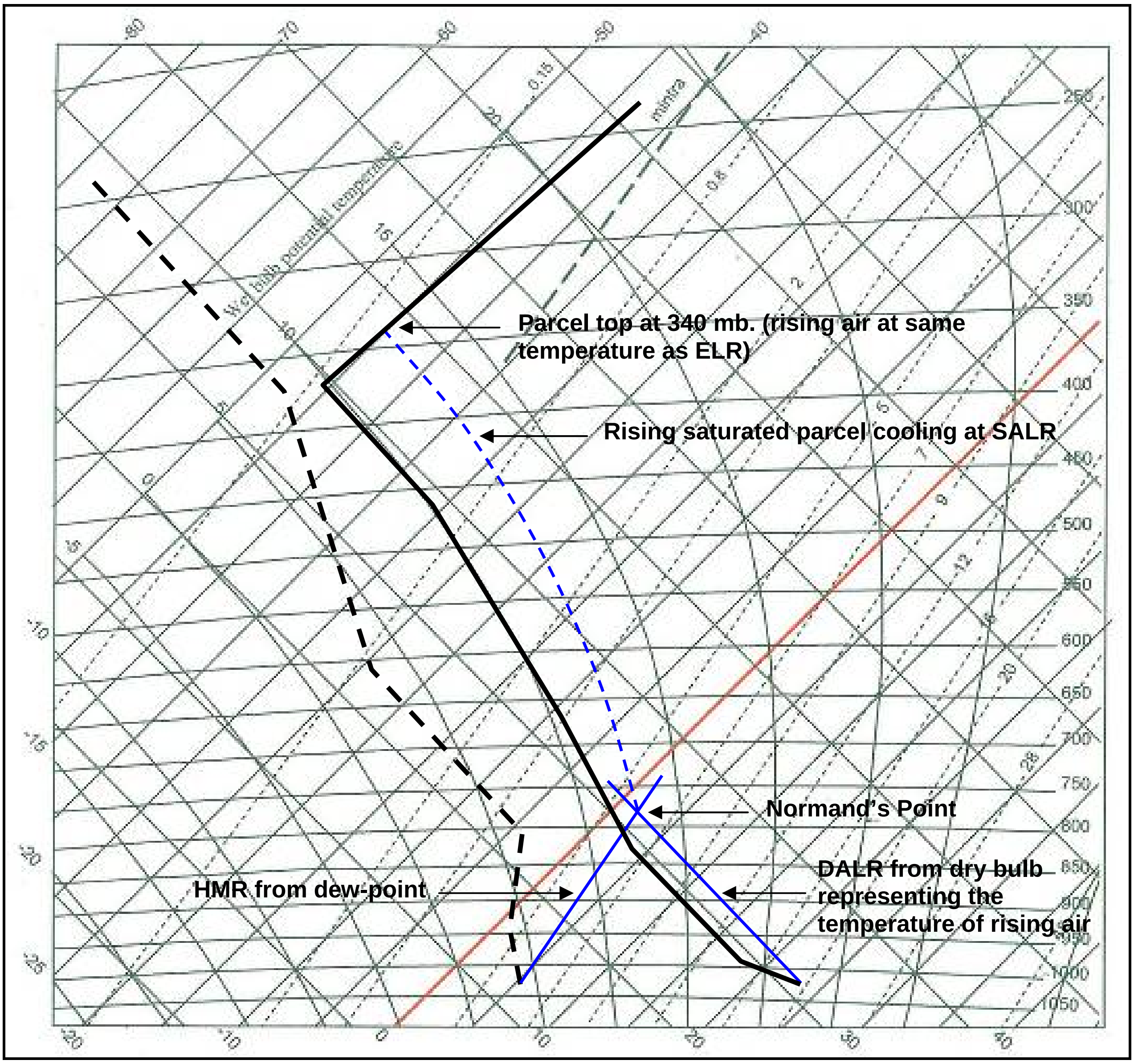


Figure 23. Diagram showing the construction used to identify the base and tops of convective clouds.

This method of determining the base and tops of convective cloud is known as the Parcel Theory. Rising parcels vary in their degree of buoyancy and not all cloud tops reach the parcel top. They stop at a point where the SALR and ELR have the same rate of cooling, these cloud tops are known as **slice tops**.

The cloud bases found by Normand's theorem are theoretically correct but in reality the rising parcel undergoes a certain amount of mixing with its surroundings. An empirical method to allow for this is to subtract 25 mb from the height (in mb) of the cloud base found from Normand's theorem. This puts the cloud base some 650 to 700 feet higher than it would otherwise be.

Identifying layer cloud

Layer clouds form in stable atmospheres, although they can also form in air that is just conditionally unstable. There is a rough but simple empirical rule for estimating cloud amount, base and top depending on how moist the air is. The method is based on the simple premise that the more saturated the air the more cloud there is likely to be. The following table gives a guide:

Dew-point depression	Amount of cloud
0 to 2 deg. C	Overcast layer cloud
3 to 5 deg. C	Broken thick layers
6 to 10 deg. C	Scattered thin layers
> 10 deg. C	No layer cloud

Table 5. Identifying Cloud Layers Using the Dew Point Depression.

Identifying the wet-bulb potential temperature

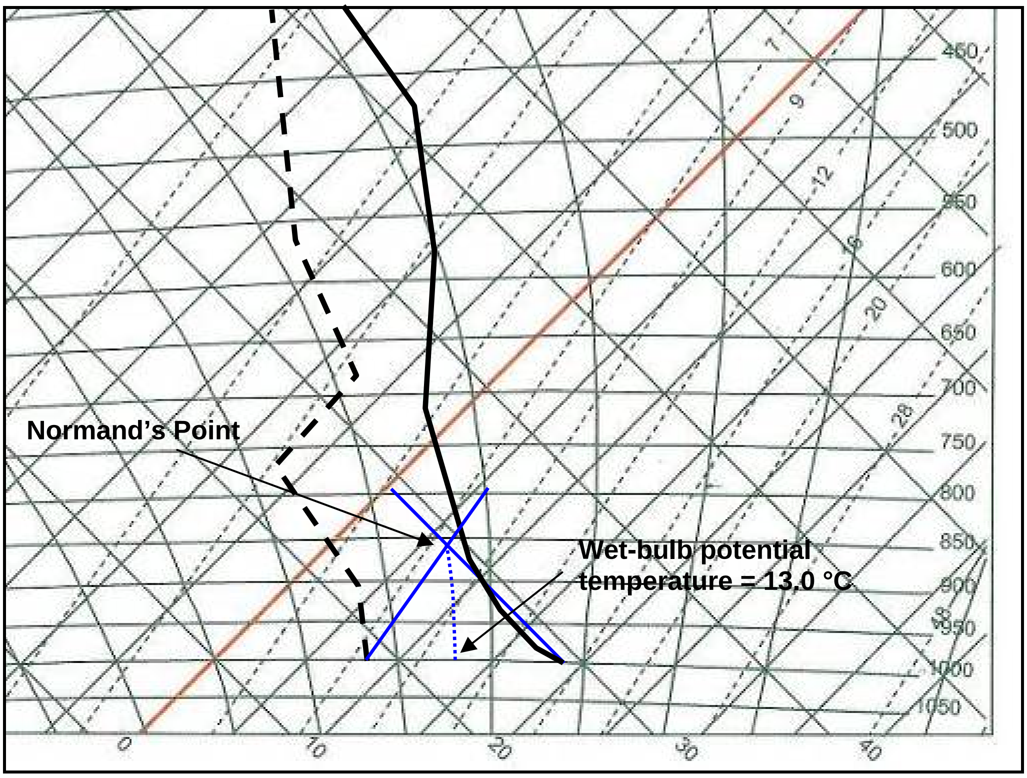


Figure 24. Diagram showing the construction used to identify the wet-bulb potential temperature.

Plot the tephigram as normal, and then construct a Normand's Point construction by taking a line up the DALR from the surface dry-bulb temperature and another line up the HMR line from the surface dewpoint. Where these two lines cross, the Normand's Point, extend another line down the SALR back to the 1000 mb level. This is the **wet-bulb potential temperature**.

In our example, the wet-bulb potential temperature is 13.0°C.

Forecasting the temperature at which radiation fog could form

Using the tephigram it is possible to forecast the temperature at which radiation fog could form for a given airmass. Other aspects come into play, such as wind strengths, cloud cover and moisture content of the air, but temperature is one of the key factors in radiation fog formation.

The temperature at which radiation fog forms is called the **fog-point**. On a tephigram it is possible to find the fog-point of a given parcel of air using the Normand's Point construction.

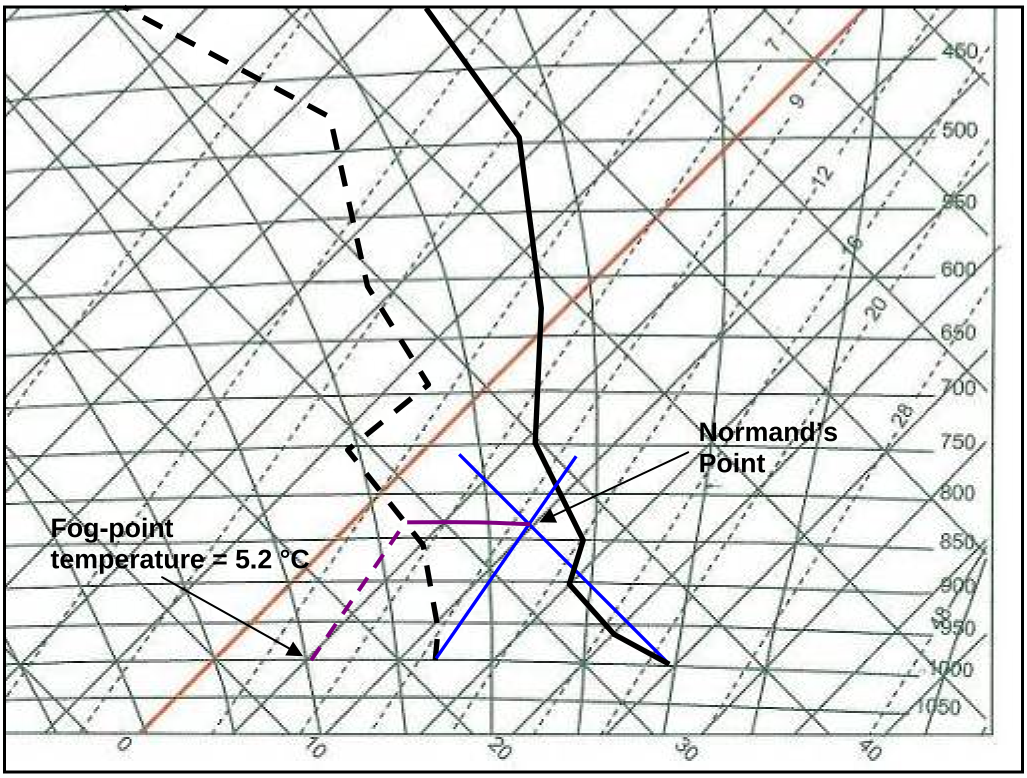


Figure 25. Diagram showing the construction used to identify the Temperature at which Radiation Fog could form.

Plot the tephigram as normal, and then construct a Normand's Point construction by taking a line up the DALR from the surface dry-bulb temperature and another line up the HMR line from the surface dewpoint. Where these two lines cross, the Normand's Point, take a line from the Normand's Point parallel to the isobars until you reach the dewpoint temperature, then project a line from this intersection down the HMR line until you reach the surface. This is the temperature at which, if all other conditions are right, radiation fog could form. This is called the **Fog Point**.

In this instance, fog could form if the overnight temperature dropped to 5.2 °C.

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Email: enquiries@metoffice.gov.uk

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