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APPENDIX A

DEFINITIONS

The definitions below were obtained from the American Meteorological Society (AMS) Glossary of Meteorology (1989), or the United Kingdom Meteorological Office (UKMO) Meteorological Glossary (1991).

Adiabatic (process): A thermodynamic change of the state of a system in which there is no transfer of heat or mass across the boundaries of the system. In this process, compression (as in sinking of air) results in warming, expansion (as in rising air) in cooling and meteorologically speaking the process is often considered to be reversible (AMS 1989).

Advection: The process of transport of an atmospheric property solely by the mass motion of the atmosphere (AMS 1989).

Altimeter: An instrument for determining the altitude (generally of an aircraft) with respect to a datum level. The two main types are a (i) radio altimeter and (ii) a pressure altimeter (UKMO 1991).

Anabatic wind: A local wind that blows up a slope which is heated by sunshine. It is a feature which is much less common than its converse, the Katabatic wind (UKMO 1991).

Backing: The changing of the wind direction in an anticlockwise direction in either hemisphere. The opposite is veering of the wind (UKMO 1991).

Baroclinic: A baroclinic atmosphere is one in which surfaces of pressure and density (or specific volume) intersect at some level or levels. The atmosphere is always, to some extent, baroclinic. Strong baroclinicity implies the presence of large horizontal temperature gradients and thus of strong thermal winds (UKMO 1991).

Barotropic: The hypothetical atmosphere in which surface of pressure and density, or specific volume, coincide at all levels (UKMO 1991).

Boundary layer: That layer of a fluid adjacent to a physical boundary in which the fluid motion is much affected by the boundary and has a mean velocity less than the free-stream value. The depth of the boundary layer in the earth's atmosphere varies markedly with static stability, from a few hundred metres in stable conditions to 1 or 2 kilometres in convective conditions (UKMO 1991).

Col: (Also called saddle point, neutral point.) In meteorology, the point of intersection of a trough and a ridge in the pressure pattern of a weather map. It is the point of relatively lowest pressure between two highs and the point of relatively highest pressure between two lows (AMS 1989).

Convergence: See Divergence.

Coriolis force/parameter: An apparent force on moving particles in a non-inertial co-ordinate system. The Coriolis forces per unit mass arises solely from the earth's rotation and is equal to **-2Ω x V**, where **Ω** is the angular velocity of the earth and **V** is the relative velocity of the particle. The parameter is twice the component of the earth's angular velocity about the vertical**, 2 Ω sin φ**, where **Ω** is the angular speed of the earth and **φ** is the latitude (AMS 1989).

Dew-point temperature: The temperature to which the air must be cooled in order that it shall be saturated with respect to water at its existing pressure and humidity mixing ratio (UKMO 1991).

Diabatic: A diabatic thermodynamic process is one in which heat enters or leaves the system. Meteorological examples are evaporation, condensation and emission and absorption or radiation. The established term "non-adiabatic" is generally preferred because it emphasises the nature of the process involved (UKMO 1991).

Dines compensation: That property of the atmosphere whereby the sign of the divergence is reversed at least once in a vertical column. This implies that the sign integrated divergence from the earth's surface to the top of the atmosphere, and the associated surface pressure tendency, are small residuals of much larger contributions. In general, a single change of the sign occurs in the troposphere, and regions of convergence and divergence are separated by a level of zero divergence which is usually at around 600 hPa (UKMO 1991).

Diurnal variation: The changes of value, for example of a meteorological element, within the course of a solar day, more specifically the systematic changes that occur within the average day (UKMO 1991).

Divergence: The divergence of the flux of a quantity (e.g. radiation or momentum) expresses the time rate of depletion of the quantity per unit volume. Negative divergence is termed convergence and relates to the rate of accumulation. In meteorology, divergence (or convergence) is mostly used in relation to the velocity vector and so refers to the flux of air particles themselves. The divergence of velocity is a three dimensional property which expresses the time rate of expansion of the air per unit volume (UKMO 1991).

Dry adiabatic lapse rate (DALR): The rate of decrease of temperature with height of a parcel of dry air lifted adiabatically through an atmosphere in hydrostatic equilibrium. The rate is 0.98°C per 100 metres, or approximately, 3°C per 1000 feet (UKMO 1991 and AMS 1989).

Equivalent potential temperature: The (isobaric) equivalent temperature (T_c) of a moist air sample is the temperature that would be attained on the assumption of condensation at constant pressure of all the water vapour in the sample, all the latent heat released in the condensation being used to raise the temperature of the sample. The equivalent potential temperature (θ_e) is found on an aerological diagram by progressing along the dry adiabatic line from T_c to the 1000 hPa level (UKMO 1991).

Environmental lapse rate: The rate of decrease of temperature with elevation (AMS 1989).

Friction layer: The atmospheric layer, extending from the earth's surface to about 600 m (2000 feet) above ground in which the influence of surface friction on air motion is appreciable (UKMO 1991).

Geopotential metre (gpm): Geopotential is the potential energy acquired by a unit mass on being raised through a unit distance in a field of gravitational force of unit strength. Dynamically, a dynamic height unit, on average over the world, is a better measure of height in the atmosphere than is geometric height (UKMO 1991).

Gust: A sudden brief increase in the speed of the wind. This may be vertically or horizontally AMS 1989).

Haboob: Many variant spellings, including habbub, habub, haboub, hubbob, hubbub.) A strong wind and sandstorm or duststorm in northern and central Sudan, especially around Khartoum, where the average number is about 24 a year. The name comes from the Arabic word habb, meaning “wind.” Haboobs are most frequent from May through September, especially in June, but they have occurred in every month except November. Their average duration is three hours; they are most severe in April and May when the soil is driest. They may approach from any direction, but most commonly from the north in winter and from the south, southeast, or east in summer. The average maximum wind velocity is over 13 m s^{-1} (30 mph) and a speed of 28 m s^{-1} (62 mph) has been recorded. The sand and dust form a dense whirling wall that may be 1000 m (3000 ft) high; it is often preceded by isolated dust whirls. During these storms, enormous quantities of sand are deposited. Haboobs usually occur after a few days of rising temperature and falling pressure (AMS 1989). Also, the name derived from the Arabian habb meaning to blow, applied to a duststorm in the Sudan north of about 13°N. Such storms occur from about May to September and are most frequent in the afternoon and evening (UKMO 1991).

Hadley circulation: A direct thermally driven and zonally symmetric circulation under the strong influence of the earth's rotation, first proposed by George Hadley in 1735 as an explanation for the trade winds. It consists of the equator ward movement of the trade winds between about latitude 30° and the equator in each hemisphere, with rising wind components near the equator, pole ward flow aloft, and, finally, descending components at about latitude 30° again (AMS 1989).

Hydrostatic equilibrium: The state of a fluid whose surfaces of constant pressure and constant mass (or density) coincides and are horizontal throughout (AMS 1989).

Instrument landing system: (Abbreviated ILS.) A navigational aid used to facilitate the landing of an aircraft in instrument weather at an airport. The instrument landing system consists of two parts: 1) a directional guide to bring the plane to the correct runway; and 2) a glide path to bring the plane down at the correct glide angle or slope to touch the runway at the correct point (AMS 1989).

Isotherm (isothermal): Of equal or constant temperature, with respect to either space or time (AMS 1989).

Jet stream: Relatively strong winds concentrated in a narrow stream in the atmosphere. For the purposes of this dissertation it refers to the jet stream in the upper troposphere. The jet stream as a narrow current of air, generally near the tropopause, thousands of kilometres long, about hundreds of kilometres wide and a few kilometres deep, with strong vertical and horizontal wind shear (UKMO 1991).

Katabatic wind: On a “radiation night” of clear skies and weak pressure gradient, log-wave radiation from the earth’s surface causes a layer of cold air to form near the surface of the ground with an associated temperature inversion. If the ground is sloping, the air close to the ground is colder than air at the same level but at a horizontal distance. Down slope gravitational flow of the colder and denser air beneath the warmer and lighter air produces the Katabatic, or drainage, wind (UKMO 1991).

K Index: (Also called George's index, 1960). A stability index that is a measure of thunderstorm potential based on temperature lapse rate, moisture content of the lower troposphere, and the vertical extent of the moist layer. The K index is determined by the following equation:

$$K = (850 \text{ hPa } T - 500 \text{ hPa } T) - 850 \text{ hPa } Td - (700 \text{ hPa } T - 700 \text{ hPa } Td),$$

where T is the temperature and Td is the dew-point in degrees Celsius at the pressure levels indicated. The higher (positive) the K index, the greater the likelihood of thunderstorm development (AMS 1989).

Lifted Index: This index, developed by Galway (1956), is

$$L = (T_L - T_{500}),$$

so is nominally identical to the Showalter index, except that the parcel being lifted (dry-adiabatically to saturation and then moist-adiabatically to 500 hPa) is defined by the dry adiabat running through the predicted surface afternoon temperature maximum and the mean mixing ratio in the lowest 900 m of the sounding. If no further heating is expected, as with a sounding taken in the late afternoon, then the mean potential temperature in the lowest 900 m of the sounding defines the dry adiabat used for the parcel. Numerous variations, focused on how the lifted parcel is defined, have been used since the original definition. The values of this index tend to be somewhat lower than those of Showalter, and the interpretation depends to some extent on how the lifted parcel is defined (AMS, 1989).

Nashi: Also spelled N’aschi. The Arabic name for a north-easterly wind that occurs in winter on the Iranian coast of the Arabian Sea, especially near the entrance to the gulf and also on the Makran coast. It is probably of the bora type, though less strong, representing the outflow of cold air from central Asia. The N'aschi is part of the Asiatic monsoon system (AMS, 1989).

Numerical weather prediction (also numerical forecasting): The forecasting of the behaviour of atmospheric disturbances by the numerical solution of the governing fundamental equations of hydrodynamics, subject to observed initial conditions, performed with the aid of high-speed computing devices (AMS 1989).
Okta: Unit, equal to area of one eight of the sky, used in specifying cloud amount (UKMO 1991).

Pascal: The SI derived unit of pressure. One pascal (Pa) is equal to 1 newton m^{-2}. The kilopascal (kPa) is the preferred unit for atmospheric pressure, but the more familiar millibar (mb) is the unit of pressure generally used by meteorologists (in the USA, Author), by international agreement; 1 mb = 1 hPa (hectopascal). For a typical sea level pressure, 102.345 kPa = 1023.45 hPa = 1023.45 mb (AMS, 1989).

Potential temperature: The temperature a parcel of dry air would have if brought adiabatically from its initial state to the (arbitrarily selected) standard pressure of 1000 hPa (AMS 1989).

Runway visual range (RVR): The maximum distance in the direction of take-off, or landing, at which the runway, or the specified lights delineating the runway can be seen from a position on the centreline at a height corresponding to the average eye-level of the pilot at touchdown (UKMO 1991).

Saturated adiabatic lapse rate (SALR): The rate of decrease of temperature with height of a parcel of saturated air lifted in a saturation-adiabatic process through an atmosphere in hydrostatic equilibrium. The saturation-adiabatic process is maintained at saturation by the evaporation or condensation of water substance, the latent heat being supplied by or to the air, respectively. The rate is about half of the DALR, that is, about 1.5°C per 1000 feet (UKMO 1991 and AMS, 1989).

Showalter stability index: An index given by

$$S = (T_{500} - T_L)$$

where T_L is the temperature (°C) of a parcel lifted from 850 hPa to 500 hPa, dry-adiabatically to saturation and moist adiabatically above that. As the index decreases to zero and below, the likelihood of showers and thunderstorms is considered to increase (Showalter, 1947) (AMS, 1989).

Statically stable (static stability): The stability of the atmosphere in hydrostatic equilibrium with respect to vertical displacements. The criterion for stability is that a displaced parcel of air be subjected to a buoyant force opposite to its displacement. For example a parcel displaced upward becomes colder than its new environment and will attempt to sink back to its original level once the disturbing force ceases (AMS 1989).

Stratosphere: The atmosphere above the troposphere and below the mesosphere. It is characterised by stable atmospheric conditions (AMS 1989).

Superadiabatic lapse rate: An environmental lapse rate greater than the dry-adiabatic lapse rate, such that potential temperature decreases with height (AMS 1989).

Temperature inversion: A layer in which temperature increases with altitude. A typical trait is its marked static stability, so that very little turbulent exchange can occur within it. Strong wind shears often occur across inversion layers (AMS 1989).

Total Totals Index: The index is attributable to Miller (1972). It is defined as the sum of two indices:

$$TT = VT + CT$$

Where VT is the Vertical Totals index, defined by

$$VT = T_{850} - T_{500},$$

A value of about 40 corresponds to a dry-adiabatic lapse rate. For a moist adiabatic lapse rate it is about 20 for T_{850} = 15°C, about 30 for T_{850} = 0°C. The Cross Totals index, CT, is defined by

$$CT = D_{850} - T_{500}$$

So it is strongly influenced by the 850 hPa moisture. Showers and thunderstorms become increasingly likely from TT values of about 30, and severe thunderstorms are considered likely for values of 50 or more (AMS 1989).

Tropopause: The boundary between the troposphere and stratosphere, usually characterised by an abrupt change of atmospheric stability. The change is to more stable conditions compared with those below the tropopause (AMS 1989).
Troposphere: The portion of the atmosphere from the earth's surface to the tropopause. This is the lowest 10 to 20 km of the atmosphere (AMS 1989).

Turbulence: A state of fluid flow in which the instantaneous velocities exhibit irregular and apparently random fluctuations. When encountered by an aircraft in flight it results in bumpy and uncomfortable flying conditions. A common cause of turbulence is wind shear (AMS 1989).

Veering: This is the clockwise change of wind direction in either hemisphere. The opposite is backing of the wind (UKMO 1991).

Wet-bulb potential temperature: The wet-bulb potential temperature (θ_w) at any level is obtained on an aerological diagram as that temperature at which the saturated adiabatic through the wet-bulb potential temperature at the level concerned intersects the 1000 hPa isobar. It is, for practical purposes, conservative for processes such as evaporation or condensation and for both dry adiabatic and saturated adiabatic temperature changes. It is therefore a useful property for air-mass analysis (UKMO 1991).

Wind shear: The local variation of the wind vector or any of its components in a given direction. The shear may be in the vertical or horizontal. In other words, wind shear is a marked change in wind speed and/or direction, either vertically or horizontally, spatially and with respect to time (AMS 1989).

APPENDIX B

CONVERSIONS

Conversions from knots to metres per second and feet to metres from the Handbook of Aviation Meteorology, 1994. London: HMSO Publications Centre. Page 355.

KNOTS TO METRES PER SECOND

1 knot = 0.51479 metres per second

Knots	0	1	2	3	4	5	6	7	8	9
					metres per second					
0	0.0	0.5	1.0	1.5	2.1	2.6	3.1	3.6	4.1	4.6
10	5.1	5.7	6.2	6.7	7.2	7.7	8.2	8.8	9.3	9.8
20	10.3	10.8	11.3	11.8	12.4	12.9	13.4	13.9	14.4	14.9
30	15.4	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.6	20.1
40	20.6	21.1	21.6	22.1	22.7	23.2	23.7	24.2	24.7	25.2
50	25.7	26.3	26.8	27.3	27.8	28.3	28.8	29.3	29.9	30.4
60	30.9	31.4	31.9	32.4	32.9	33.5	34.0	34.5	35.0	35.5
70	36.0	36.6	37.1	37.6	38.1	38.6	39.1	39.6	40.2	40.7
80	41.2	41.7	42.2	42.7	43.2	43.8	44.3	44.8	45.3	45.8
90	46.3	46.8	47.4	47.9	48.4	48.9	49.4	49.9	50.4	51.0
100	51.5	52.0	52.5	53.0	53.5	54.1	54.6	55.1	55.6	56.1

FEET TO METRES

1 foot = 0.3048 metres

1000's of feet	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
					metres					
0	0	305	610	915	1219	1524	1829	2134	2438	2743
10	3048	3352	3657	3962	4267	4572	4877	5182	5486	5791
20	6096	6401	6706	7011	7351	7620	7924	8229	8534	8839
					kilometres					
30	9.1	9.5	9.8	10.1	10.4	10.7	11.0	11.3	11.6	11.9
40	12.2	12.5	12.8	13.1	13.4	13.7	14.0	14.3	14.6	14.9
50	15.2	15.5	15.9	16.2	16.5	16.8	17.1	17.4	17.7	18.0
60	18.3	18.6	18.9	19.2	19.5	19.8	20.1	20.4	20.7	21.0
70	21.3	21.6	22.0	22.3	22.6	22.9	23.2	23.5	23.8	24.1
80	24.4	24.7	25.0	25.3	25.6	25.9	26.2	26.5	26.8	27.1
90	27.4	27.7	28.0	28.4	28.7	29.0	29.3	29.6	29.9	30.2
100	30.5									

Note: Metres are rounded off to the nearest whole metre; kilometres are rounded off to the nearest tenth of a kilometre; 500 feet = 152 metres.

Microbar

1 microbar	= one millionth of a bar
1 bar	= 100 000 Pascals (Pa)
100 Pascals	= 1 hectopascal (hPa)
Examples;	0.6 microbars = 0.06 Pa, 35 microbars = 3.5 Pa.

APPENDIX C

FOG INDICES

1 SAUNDERS' METHOD OF CALCULATION OF RADIATION FOG POINT (UKMO 1997).

The method takes account of moisture throughout the cooling layer; it is based on Mk. llb radiosonde profiles; Mk. ill *Td* data may differ.

(i) Select a representative upper-air sounding and find the condensation level from the maximum temperature and the dew point at that time, using Normand's theorem.

(ii) Find the humidity mixing ratio at the condensation level and read off the temperature where the humidity mixing ratio line cuts the surface isobar. This is the expected fog-point temperature.

This procedure needs modification to allow for different types of sounding (see figure below):

(a) *Type I* has a constant dew-point lapse rate except near the ground where the surface dew-point lies on, or to the right of, a downward extension of the upper dew-point curve. *T* is the maximum temperature and Td is the surface dew-point. If there is a superadiabatic, use the value *Tc* instead of *T* to eliminate the superadiabatic section. The pecked lines through *Tc* and the dew point Td meet at the condensation level A. The humidity mixing ratio at this level is at B and the fog point is at C.

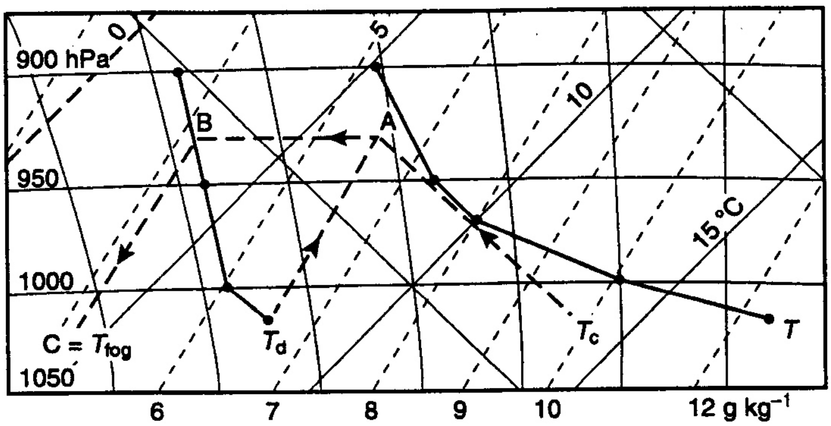
(b) In *Type II* the dew-point lapse rate increases aloft. Point B is found by extrapolating the lower part of the dew point curve above the point at which the lapse rate increases.

(c) In *Type III* the surface dew point lies to the left of the downward extension of the upper dew-point curve, two possibilities are illustrated:
(i) If the temperature lapse in the lowest layers is less than a dry adiabatic, the construction follows the basic principles as for *Type l.*
(ii) If the temperature lapse rate in the lowest layer is equal to or greater than a dry adiabat, then no Normand construction is drawn and the fog point is taken to equal the dew-point.

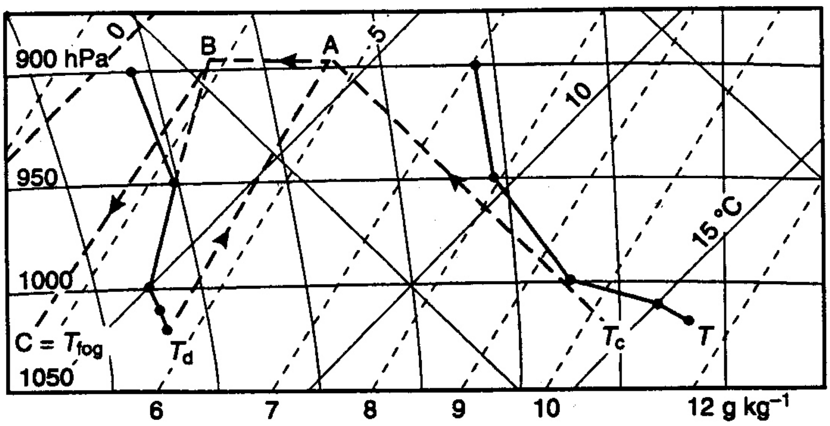
Normally, if the boundary layer is mixed at the time of the midday sounding, extending the mean mixing-ratio through the boundary layer to the surface will give an acceptable fog point. As a rough guide, the afternoon dew point at screen level minus 2˚C gives a good first guess for Tr>- 2˚C.

Notes:
(i) If a subsidence inversion has brought dry air down to within 30 hPa of the ground, use the dew point *(Td)* as the fog-point.
(ii) If rain falls during the afternoon leaving the ground wet, the actual fog point may be higher than the calculated value.

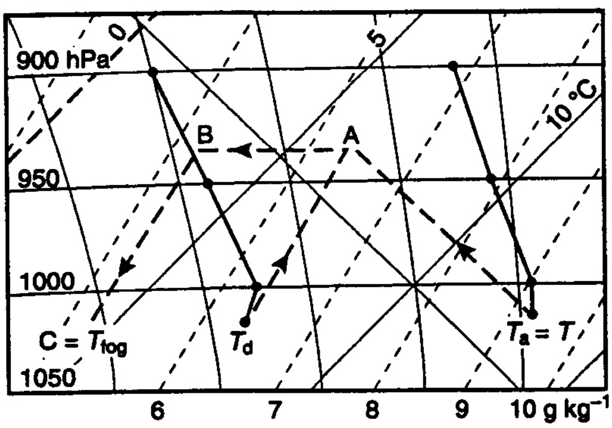
(iii) If a sea-breeze reaches the area later in the day, the fog point may be much higher than calculated; use the coastal dew point.
(iv) The dew-point temperature 60 hPa above the surface nearly always gives a fog-point value close to Saunders' value, exception being *Type /IIb* when the surface dew-point is used.
(v) If the calculated temperature is ≤0˚C, then the actual fog point may well be lower (due to deposition by hoar frost).



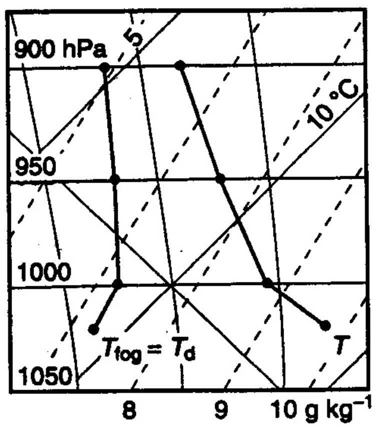
Type I



Type II



Type III(a)



Type III(b)

2 CRADDOCK AND PRITCHARD METHOD (UKMO 1997)

If T_f is the fog point, T_{12} is the screen temperature at 1200 UTC, and T_{d12} is the dew point at 1200 UTC, then

$$T_f = 0.044\ (T_{12}) + 0.844\ (T_{d12}) - 0.55 + A = Y + A.$$

Table 1. Values of Y (°C) corresponding to the observed values of T_{12} and T_{d12}

T_{d12} \ T_{12}	30	25	20	15	10	5	0	-5	-10
20	17.7	17.4	17.2						
18	16.0	15.7	15.5						
16	14.3	14.1	13.8						
14	12.6	12.4	12.1	11.9					
12	10.9	10.7	10.5	10.2					
10	9.2	9.0	8.8	8.6	8.3				
8	7.5	7.3	7.1	6.9	6.6				
6	5.8	5.6	5.4	5.2	5.0				
4	4.1	3.9	3.7	3.5	3.3	3.0			
2	2.5	2.2	2.0	1.8	1.6	1.4			
0	0.8	0.6	0.3	0.1	-0.1	-0.3	-0.6		
-2	-0.9	-1.1	-1.4	-1.6	-1.8	-2.0	-2.2		
-4	-2.6	-2.8	-3.0	-3.3	-3.5	-3.7	-3.9		
-6	-4.3	-4.5	-4.7	-5.0	-5.2	-5.4	-5.6	-5.8	
-8	-6.0	-6.2	-6.4	-6.6	-6.9	-7.1	-7.3	-7.5	
-10	-7.7	-7.9	-8.1	-8.3	-8.6	-8.8	-9.0	-9.2	-9.4

Table 2. The number A (°C) is an adjustment which depends upon the forecast cloud amount and geostrophic wind speed, as tabulated below.

*Mean cloud amount (oktas)	*Mean geostrophic wind speed (kn)	
	0 - 12	13 - 25
0 – 2	0.0	-1.5
2 – 4	0.0	0.0
4 – 6	+1.0	+0.5
6 – 8	+1.0	+0.5

*Mean of forecast values for 1800, 0000 and 0600 UTC.

Notes:

(a) The equation for T_f was derived from the combined data for 13 widely separated stations in England. There was considerable variation from station to station in their proximity to major smoke sources.

(b). Account was not taken of variations in atmospheric pollution so that, in effect, an average degree of pollution is assumed in using this technique (in contrast to Saunders' method which refers mainly to fog in clean air).

(c). If the minimum temperature is predicted using Craddock and Pritchard' s method it is suggested That:

(i) if T_f is 1 °C or more above T min, forecast fog;

(ii) if T_f is 0.5 °C above to 1.5 °C below T min, forecast a risk of fog;

(iii) if T_f is 2 °C or more below T min, do not forecast fog.

(d). When forecasting for a region, rather than a specific airfield, allow a larger safety margin, since there is always more low-level moisture present near streams and in lush valleys than over flat airfields with trimmed grass.

3 TEST SAMPLE OF FOG INDICES

Table 1. Summer event 2002-07-18/22 and winter 2003-01-08/11 using fog indices. Temperatures rounded to whole degrees

Key:

Saunders = Saunders method.
C & P = Craddock & Pritchard.
850WBPT = 850 wet-bulb potential temperature.
12T/Td = 1200 UTC surface wet-bulb temperature (12T/Td).
00T/12Td = Surface wet-bulb temperature using 0000 UTC temperature and 1200 UTC dew point temperature.
FogT = Temperature at which the fog began.
MnT = Early morning minimum temperature.
V = Calculated fog index temperature.
D = Difference from the temperature at which the fog began.

Date	Saunders		C & P		850WBPT		12 T/Td		00T/12Td		FogT	MnT
	V	D	V	D	V	D	V	D	V	D		
2002-7												
18/19	10	-19	26	-3	20	-9	31	+2	32	+3	29	29
19/20	-8	-39	25	-6	19	-12	31	0	29	-2	31	30
20/21	21	-10	26	-5	19	-12	31	+0	30	-1	31	29
21/22	-5	-34	23	-6	14	-15	28	-1	28	-1	29	29
2003-01												
08/09	9	-3	14	+2	10	- 2	18	+6	15	+3	12	11
09/10	0	-14	12	-3	11	- 4	18	+3	14	-1	15	14
10/11	3	-12	14	-1	14	- 1	18	+3	15	0	15	12