Aust. Met. Mag. 29 (1981) 1-7 551.509.323(94)

Prediction of mean monthly 9 am dew-point temperature for any site in mainland eastern Australia

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(Manuscript received July 1980; revised November 1980)

Monthly mean values of 9 am dew-point temperature were studied using a total of 494 mainland Australian weather stations east of 141° longitude. The area was divided into four regions and multiple regression techniques were used to relate 9 am mean dew-point to latitude, longitude, elevation and distance to sea. Many stations for which dew-point predictions might be required record rainfall. For areas where the use of rainfall as an independent variable improved the prediction, alternative relationships which included rainfall were also calculated.

Introduction

The studies described here were part of a forestry land evaluation project. A frequent problem with investigating tree growth is the lack of meteorological data from existing or potential forest sites. The nearest recording station is often situated at a post office. This is usually separated by several kilometres in distance and many metres in elevation from the forest.

Dew-point is the temperature to which air must be cooled at constant pressure for the moisture present to provide saturation. It is a more conservative measure of atmospheric moisture than relative humidity which can show considerable diurnal variation (Linacre and Hobbs 1977). In this study relationships to predict monthly mean values of 9 am dew-point temperature (shortened below to 'mean 9 am dew-point') have been calculated.

Dew-point may be used to calculate potential evapotranspiration, an important factor in predicting plant growth rates. For example, Nayava, McMahon and Nix (in prep.) related 9 am dew-point to elevation, latitude and rainfall in Nepal. They then used the dew-point values along with other data to provide estimates of potential evapotranspiration. A similar approach has been used in the Upper Murrumbidgee River Valley by Edwards and Johnston (1978).

The relationship between dew-point and the previous night's minimum temperature has been investigated by Gentilli (1955). He demonstrated a clear linear relationship between these variables for monthly mean values for stations in the Plains, East and Pacific coast of the USA, but a much poorer relationship when values from the slopes and plateaux of the USA were included.

The methodology used here to estimate mean 9 am dew-point is similar to that applied by Johnson, Kalma and Caprio (1976), who studied mean air temperature variation at 22 stations in and around the south coast area of New South Wales. They used multiple regression techniques to predict monthly mean air temperature at any site within the area. They also reviewed previous work of this type from North America and Australia.

Analysis and results

All the climatic data used in the analyses were taken from Bureau of Meteorology (1975). A computer tape version of this publication prepared by the Bureau was used to access the data.

Stations north of 39.5° latitude and east of 141.0° longitude were included in the study. This area contained 494 stations with the necessary climatic data (see Fig. 1). The records cover some 15 to 17 years from the time when processing these data in computer compatible form was begun in January 1957. Some idea of the temporal and spatial variations in mean 9 am dew-point can be gained from Figs 2 and 3.

Fig. 1 Location of the sites used in the study.

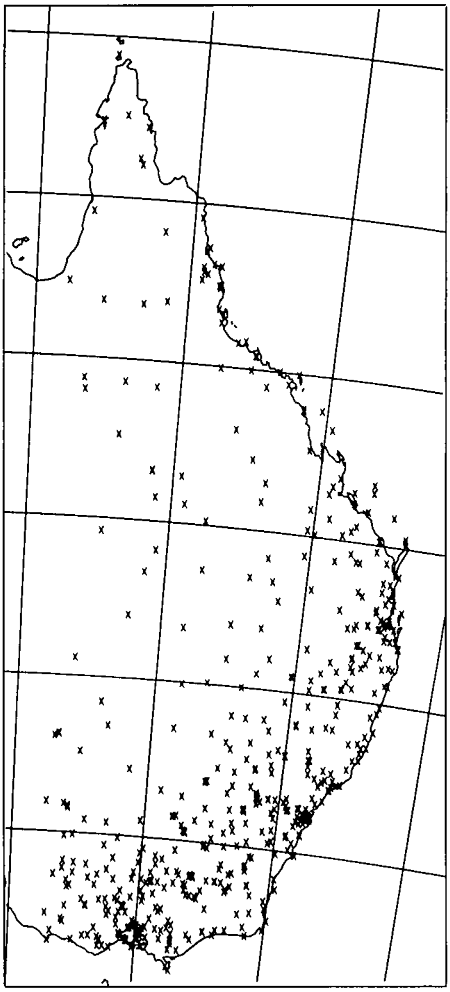
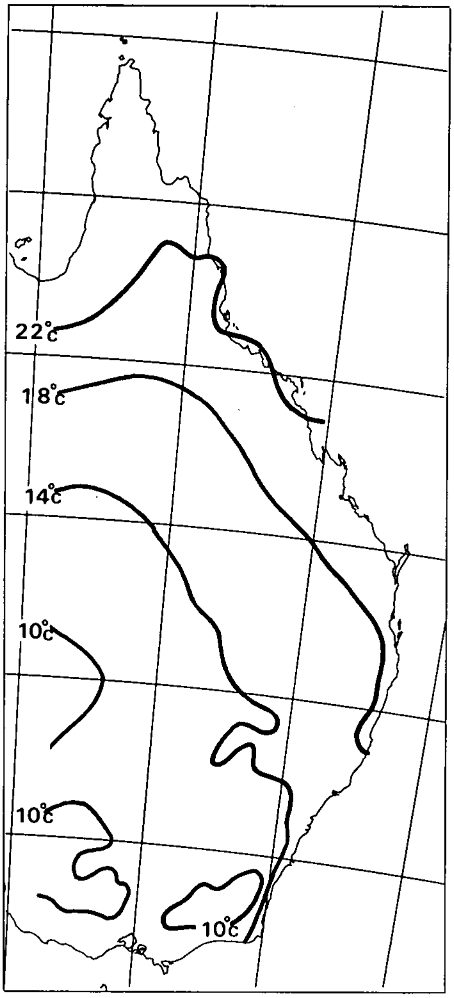
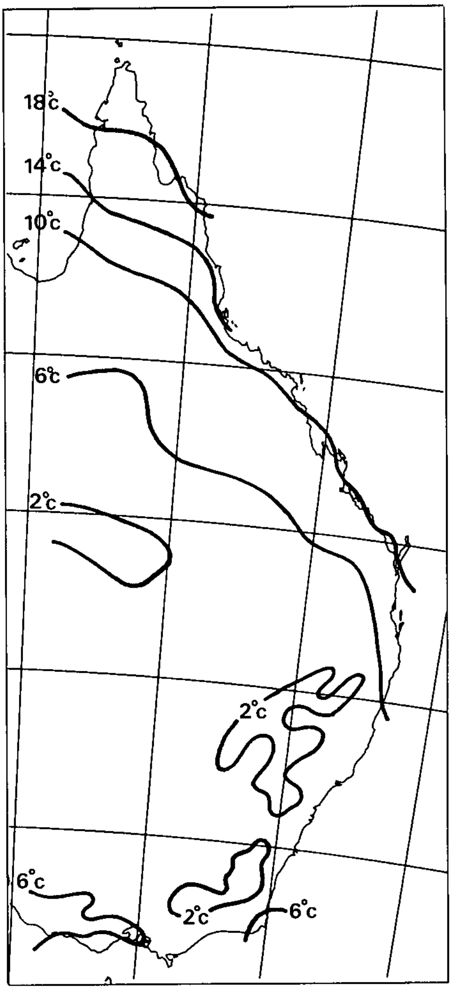


Fig. 2 January mean 9 am dew-point temperature approximate isolines.



To obtain good relationships for predicting climatic factors it is important to use data from areas which experience broadly similar weather patterns. For this study four areas were defined on the basis of dominant and subdominant weather sytems operating across eastern Australia. These regions were based upon unpublished analyses carried out by H. A. Nix. The zones were greatly simplified to facilitate the accessing of data from a single computer data file sorted on latitude. The areas were between the following latitudes: 10.0°-24.0°, 22.0°-30.0°, 27.0°-34.0°, and 34.0°-39.5°. Because weather systems boundaries are not sharply defined some overlap was allowed and therefore some stations appeared in two analyses for the same dependent variable. There were 59,

Fig. 3 July mean 9 am dew-point temperature approximate isolines.



121, 180 and 213 stations respectively in each group.

The latitude, longitude and elevation of each station was taken from the computer tape. Distances to the sea were estimated from the *Climatological Working Chart of Australia* produced by the Bureau of Meteorology.

Multiple regression equations were calculated for mean 9 am dew-point for the stations in each of the four regions described above. Distance to sea was used in some preliminary analyses, but as the $\log_{10}$ transformation of distance to sea was found to be more effective it alone was used in the analyses presented here. For similar reasons the inverse of rainfall was used in preference to untransformed rainfall data. Latitude, longitude, elevation and $\log_{10}$ distance to sea were transformed by subtracting their mean value in each group. This was to reduce the correlation between linear and quadratic terms. The mean logarithmic distance to sea cannot be directly converted to the corresponding mean distance for each group. The mean distances for the four groups were 98, 182, 180 and 143 km respectively. The following independent variables were tested:

(1) latitude — mean latitude (decimal degrees);
(2) longitude — mean longitude (decimal degrees);
(3) elevation — mean elevation (m);
(4) $\log_{10}$ (distance to sea (km) + 1) — mean $\log_{10}$ (distance to sea (km) + 1);
(5) 1/mean monthly rainfall (mm);
(6-15) all first order interactions between variables 1, 2, 3 and 4.

All quadratic terms of variables 1, 2, 3 and 4.

Interactions related to the inverse of rainfall were omitted to reduce the cost of computation.

For each area a stepwise multiple regression was carried out for each of the first six months of the year. The results of these analyses were used to select the most important independent variables. A maximum of five independent variables were chosen to fit the same model for each month.

Inverse rainfall was included in the analyses as many stations (including most forest headquarters) record rainfall, but do not have dew-point records. When inverse rainfall was used an alternative analysis was also carried out excluding rainfall. This relationship could be applied in areas where rainfall data were not available.

The results of the analyses are shown in Tables 1 to 6. Because of the overlap between some of the areas, a site for which a prediction is required may occur in two regions. In this case it is recommended to use the relationship for the zone which places the site furthest from the edge of the zone.

Discussion

Despite the inclusion of several interaction and quadratic terms the stepwise regressions selected the linear terms much more frequently. Elevation and longitude were included in all six sets of equations. Latitude appeared in five sets of relationships and was replaced by its squared term in the remaining set (see Table 6, variable X4). The distance to sea was also included in five sets of equations. No interaction terms were used. The only quadratic terms, elevation and latitude, appeared in Table 6.

Both R^{2*} and residual mean square (RMS) shown in Tables 1 to 6 to demonstrate the goodness of fit of the equations. The R^2 values indicate that the models accounted for a large proportion of the variance, in most cases more than 80 per cent. This measure suggested that the least successful analyses were the calculations for the area from 34.0° to 39.5°. These analyses, shown in Table 6, only accounted for an average of 74 per cent of the variance in each month.

However, the size of the residual mean square values should also be considered. The square root of the RMS provides a standard error indicating how well the regression fits the data. For example, the standard error associated with the January equation in Table 6 is $\sqrt{1.320} = 1.149$.

The mean of the 12 RMS values from Table 6 is in fact lower than that from any of the other tables shown here. This indicates that there was relatively little variation in the dew-point data for the region. For example, the mean and standard deviation of dew-point for January in this area were 11.6 and 1.9 respectively.

The highest RMS value shown in the tables was 2.385, which occurred with an R^2 value of 89.1 in July in Table 1. However, the corresponding standard error of 1.5°C was considered to be acceptably low. It is interesting to note that in all tables, except Table 6, the July RMS value was the worst, often by a large margin.

The four climatic regions used were simply defined by latitude and longitude in contrast to more complex classifications of Australia's major climatic zones (Gentilli 1971; McBoyle 1971). However, the generally low RMS and high R^2 values obtained indicate that the regions used were adequate for the analysis.

The seasonal variation in the magnitude of the regression coefficients in each table reflects some of the mechanism of factors affecting dew-point. Coote and Cornish (1958) have discussed such variation in coefficients in relation to factors affecting rainfall in South Australia.

Seasonal changes in factors affecting mean 9 am dew-point can be examined, for example, in Table 1. The change in the constant coefficient 'a' for each month reflects seasonal change in the level of dew-point over the region. Examination of the coefficients for latitude indicates that increasing latitude decreases dew-point in this region. By comparing the monthly coefficients it can be seen that this gradient is more pronounced in winter than in summer (see also Figs 2 and 3). The effect of increasing longitude is similarly enhanced in wintertime, but in this case increasing longitude increases dew-point in each month.

Increasing elevation is shown in Table 1 to decrease mean 9 am dew-point. In contrast to latitude and longitude the effect is reduced in winter. However, the seasonal change is relatively small when compared with the seasonal change in the effects of latitude and longitude.

Interpreting seasonal changes in the coefficients related to rainfall is complicated by the fact that the rainfall values themselves vary. The coefficients shown in Table 1 are highly correlated (R^2 = 98 per cent) with the mean monthly rainfalls for the 59 stations used in the analysis. However, in all months decreasing rainfall lowers the mean 9 am dew-point.

The trends in the other regions may similarly be assessed by examining the coefficients in Tables 2 to 6.

Though the accuracy of the equations presented here has not been independently tested, the large number of stations used, the generally high proportion of variance accounted for, and low residual mean square values obtained, suggest they should be useful for cautious prediction.

To improve the relationships a more detailed consideration of the conditions at each site, including its local relief and the proximity of large inland areas of water, would probably be necessary.

Although a study of the relationships between dew-point and minimum temperature was outside the objective of the present study, the opportunity was taken to calculate regressions between the two variables for the most southerly (34.0°-39.5°) and northerly (10.0°-24.0°) regions in the analyses. The mean of 12 monthly percentages of

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$$*R^2 = 100 \times \frac{(\text{Total MS} - \text{Residual MS})}{\text{Total MS}}$$

Table 1. Regression coefficients for mean 9 am dew-point (10.0°-24.0° S)

(1/rainfall included as an independent variable)
Y = a + b(X1) + c(X2) + d(X3) + e(X4)
Y = mean dew-point (9 am) (°C)
X1 = 1/rainfall (mm)
X2 = elevation above mean sea level (m) — 131.8
X3 = latitude — 19.24
X4 = longitude — 146.19

	a	−b	$-cx10^3$	−d	e	R^2	RMS
January	22.683	264.756	5.726	0.330	0.187	91.8	0.380
February	23.132	243.783	4.912	0.279	0.148	81.6	0.532
March	22.233	198.192	5.046	0.436	0.268	91.4	0.506
April	19.580	61.779	4.337	0.897	0.669	95.0	0.569
May	16.452	15.397	3.487	1.429	0.981	93.7	1.023
June	13.903	4.337	3.710	1.509	0.992	93.1	1.171
July	12.141	0.841	3.631	1.686	1.274	89.1	2.385
August	13.448	3.037	4.589	1.741	1.405	93.7	1.494
September	14.487	2.272	5.975	1.479	1.181	91.2	1.602
October	17.069	17.102	6.370	1.152	0.952	92.1	1.022
November	18.673	23.038	6.749	1.038	0.910	90.4	1.165
December	21.020	120.542	5.520	0.722	0.598	90.2	0.751

Table 2. Regression coefficients for mean 9 am dew-point (10.0°-24.0° S)

(1/rainfall not included as an independent variable)
Y = a + b(X1) + c(X2) + d(X3) + e(X4)
Y = mean dew-point (9 am) (°C)
X1 = log (km from coast + 1) — 1.24
X2 = latitude — 19.24
X3 = longitude — 146.19
X4 = elevation above mean sea level — 131.8

	a	−b	−c	d	$-ex10^2$	R^2	RMS
January	21.339	0.384	0.511	0.264	0.573	89.0	0.505
February	21.881	0.261	0.479	0.252	0.501	82.8	0.658
March	20.864	0.429	0.665	0.372	0.480	88.8	0.660
April	18.424	0.432	1.073	0.821	0.402	93.5	0.738
May	15.898	0.399	1.379	0.978	0.311	93.2	1.114
June	13.661	0.450	1.413	0.917	0.279	92.9	1.208
July	12.051	0.598	1.553	1.111	0.256	89.5	2.295
August	13.077	0.291	1.689	1.425	0.389	93.1	1.642
September	14.220	0.296	1.397	1.135	0.544	90.9	1.666
October	16.305	0.460	1.068	0.925	0.560	91.7	1.079
November	18.220	0.388	1.020	0.861	0.603	90.5	1.144
December	19.932	0.373	0.796	0.585	0.515	89.6	0.803

variance accounted for 43 and 54 per cent for the northern and southern areas respectively. This indicated a similar poor relationship to that obtained by Gentilli (1955) when slopes and plateau stations from the USA were included with data from the Plains, East and Pacific coast areas.

Acknowledgments

I am grateful to H. A. Nix for helpful advice during the analysis. J. D. Kalma, J. F. Angus, R. B. Cunningham and the anonymous reviewers provided useful criticisms of earlier drafts of this paper.

Table 3. Regression coefficients for mean 9 am dew-point (22.0°-30.0° S)

(1/rainfall included as an independent variable)
Y = a + b(X1) + c(X2) + d(X3) + e(X4) + f(X5)
Y = mean dew-point (9 am) (°C)
X1 = 1/rainfall (mm)
X2 = log (km from coast + 1) − 1.77
X3 = latitude − 26.85
X4 = longitude − 150.72
X5 = elevation above mean sea level (m) − 239.2

	a	−bx10^{-2}	−c	−d	e	−fx10^{2}	R^2	RMS
January	19.282	−1.427	0.318	0.476	0.333	0.349	87.1	0.855
February	19.462	−1.253	0.201	0.502	0.347	0.366	86.4	0.913
March	17.131	−0.253	0.364	0.669	0.524	0.384	89.7	0.757
April	14.363	−0.150	0.370	0.668	0.611	0.449	90.9	0.799
May	10.783	−0.087	0.901	0.575	0.445	0.384	86.5	1.125
June	8.683	−0.075	0.667	0.581	0.436	0.379	87.8	0.857
July	7.579	−0.434	1.103	0.607	0.223	0.369	82.7	1.585
August	9.230	−0.428	0.592	0.744	0.372	0.416	86.0	1.346
September	9.368	0.087	0.518	0.680	0.815	0.392	87.9	1.266
October	13.162	−0.268	0.592	0.678	0.626	0.318	90.0	0.900
November	14.379	−0.199	0.536	0.799	0.769	0.348	88.5	1.323
December	17.570	−1.096	0.189	0.620	0.557	0.377	84.6	1.452

Table 4. Regression coefficients for mean 9 am dew-point (22.0°-30.0° S)

(1/rainfall not included as an independent variable)
Y = a + b(X1) + c(X2) + d(X3) + e(X4)
Y = mean dew-point (9 am) (°C)
X1 = log (km from coast + 1) − 1.77
X2 = latitude − 26.85
X3 = longitude − 150.72
X4 = elevation above mean sea level − 239.2

	a	−b	−c	d	−ex10^{2}	R^2	RMS
January	17.983	0.253	0.652	0.598	0.326	85.7	0.948
February	18.223	0.224	0.678	0.562	0.356	84.8	1.017
March	16.802	0.454	0.682	0.550	0.376	89.5	0.776
April	14.008	0.465	0.676	0.641	0.446	90.8	0.815
May	10.579	0.952	0.575	0.465	0.381	86.6	1.118
June	8.504	0.709	0.581	0.454	0.374	87.9	0.854
July	6.521	1.174	0.610	0.409	0.348	82.3	1.621
August	7.785	0.663	0.652	0.636	0.393	84.2	1.519
September	9.653	0.528	0.690	0.767	0.400	88.0	1.259
October	12.661	0.522	0.686	0.736	0.311	90.0	0.902
November	14.050	0.482	0.824	0.848	0.342	88.6	1.317
December	16.298	0.059	0.778	0.832	0.339	84.0	1.507

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Table 5. Regression coefficients for mean 9 am dew-point (27.0°-34.0° S)

Y = a + b(X1) + c(X2) + d(X3) + e(X4)
Y = mean dew-point (9 am) (°C)
X1 = latitude — 31.04
X2 = longitude — 150.32
X3 = elevation above mean sea level (m) — 299.7
X4 log (km from coast + 1) — 1.89

	a	−b	c	−dx10^2	−e	R^2	RMS
January	15.528	0.340	0.650	0.369	0.364	85.3	1.176
February	16.144	0.151	0.677	0.395	0.345	85.0	1.111
March	14.411	0.294	0.523	0.409	0.687	88.2	0.876
April	11.722	0.250	0.553	0.433	0.490	88.2	0.843
May	8.361	0.369	0.262	0.412	0.933	84.0	1.028
June	6.589	0.288	0.242	0.404	0.860	85.7	0.772
July	4.389	0.264	0.103	0.342	1.087	64.7	1.919
August	5.828	0.209	0.307	0.415	0.484	78.2	1.108
September	7.644	0.258	0.472	0.447	0.469	82.2	1.238
October	10.511	0.239	0.648	0.399	0.338	85.5	1.092
November	11.561	0.319	0.622	0.354	0.689	86.6	1.113
December	13.767	0.326	0.765	0.391	0.275	84.6	1.458

Table 6. Regression coefficients for mean 9 am dew-point (34.0°-39.5° S)

Y = a + b(X1) + c(X2) + d(X3) + e(X4) + f(X5)
Y = mean dew-point (9 am) (°C)
X1 = elevation above mean sea level (m) —279.2
X2 = (X1) (X1)
X3 = log (km from coast + 1) — 1.87
X4 = (latitude — 36.51) (latitude — 36.51)
X5 = longitude — 146.02

	a	−bx10^2	−cx10^6	−d	ex10	fx10	R^2	RMS
January	11.515	0.256	1.073	0.766	1.377	4.110	64.8	1.320
February	12.483	0.265	1.277	0.517	1.655	4.248	63.1	1.357
March	10.953	0.288	1.155	0.641	2.138	3.090	73.0	0.877
April	9.150	0.312	1.840	0.729	1.547	1.539	76.6	0.834
May	6.606	0.372	1.042	0.619	1.693	−2.407	81.2	0.669
June	4.863	0.246	2.164	0.868	1.322	−0.705	77.1	0.792
July	4.014	0.231	1.883	0.898	0.857	−1.898	75.1	0.868
August	4.800	0.401	0.795	0.432	0.737	−0.699	81.8	0.619
September	5.912	0.443	0.745	0.311	1.215	−0.483	78.3	0.864
October	8.037	0.404	1.590	0.229	0.680	2.331	76.6	0.823
November	8.633	0.275	1.835	0.744	1.335	2.861	72.9	0.930
December	9.868	0.255	1.262	0.805	1.832	3.411	68.3	1.131

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