A Modified Algorithm for Minimum Temperature Forecasts in Belize

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Abstract

Overnight low temperatures in Belize are presently being forecasted with the minimum of objectivity. Occasionally forecasters use climatology as a basis for such predictions while others use the so called "gut feeling" as a predictor. Although there are some minimum temperature forecast algorithms available none was ever developed specifically to suit the orographic, topographic and other moderating effects in Belize. This research is the primary attempt at importing an external formula and adjusting it to suit the environs of coastal Belize. The Boyden Formula developed in he United Kingdom provides relatively more accurate values of nightime low temperatures than techniques that are presently being utilised. The final outcome of this research is a formula applicable to forecasting low temperatures in Belize.

1. INTRODUCTION

Present maximum and minimum temperature forecast techniques in Belize range from purely climatological means application to the more subjective personal feeling approach. The latter, as is largely known, is dependent on the temperament and the likely mood swings of the forecaster. In this age of modern, sophisticated technology and with the permeance of super computers it is almost imperative that some deviation occurs for the latter approach to forecasting high and low temperatures.

The focus of this paper is on the adjustment of a minimum temperature algorithm familiar to most forecasters here at The Belize Weather Bureau - namely the Craddock & Pritchard formula and the Boyden algorithm. The second section of this paper deals with the description and definition of the two aforementioned formulae. Next follows the section dealing with the data acquisition and the methodology involved in obtaining a database for this research. The fourth section covers the results and findings. It is further subdivided into subsections concerning a performance comparison of the two algorithms, the formula adjustment and the wind direction correction. The fifth section involves a comparison of the modified algorithm with present minimum temperature forecasting techniques presently being utilised at the Belize Weather Bureau.

2. Forecast Algorithms

The focus of this paper is the alteration of a minimum temperature forecast formula to suit predictions of such temperatures in Belize. The Craddock & Pritchard along with the Boyden formula are both very well known by forecasters at the Belize Weather Bureau. Both were developed in the United Kingdom but with some alterations can be rendered applicable to this region.

The Craddock & Pritchard Formula (C&PF) was derived from the combined data fron 16 stations in England all more than 10 miles inland. It is only applicable in nights when no fog is expected. It states that:

$$TMin = (0.316 \times T18) + (0.548 \times Td18) - 1.24 + k$$

TMin = Minimum temperature forecasted (°C)
T18 = 1800 UTC screen temperature (°C)
Td18 = 1800 UTC dew point temperature (°C)
k = constant obtained from Table 1

Table 1 *Values of k*

Mean geos wind speed	Mean cloud amount (oktas)			
	0 to 2	2+ to 4	4+ to 6	6+ to 8
knots		° C		
0 - 12	-2.2	-1.7	-.6	0
13 - 25	-1.1	0	0.6	1.1
26 - 38	-0.6	0	0.6	1.1
39 - 51	1.1	1.7	2.8	

The Boyden Formula (BF) is defined by the following equation:

$$TMin = \frac{1}{2}(Tw + Td) - c$$

where Tw = Wet bulb temperature at time of maximum temperature (°C)

Td = Dew point temperature at time of maximum temperature (°C)

c = constant from Table 2

Table 2. *Values of c*

Sfc wind speed	Low cloud amount (oktas)		
	< 2	2 - 6	> 6
knots	°C	°C	°C
0	2	1	-0.5
1 - 2	1.5	0.5	-0.5
3 - 5	1	0	-1
6	0.5	-0.5	-1
7	-0.5	-0.5	-1
8	-1.5	-1.5	

Surface wind direction and speed have a profound influence on nocturnal temperature falls. In Belize west and north-westerly winds exert a cooling effect and the northeasterlies are responsible for significant moisture advection which has a moderating effect on nightime temperatures. Winds with more southerly components have lower moisture content and higher temperatures. The general effect of the latter is higher minimum temperatures during the time of the year that these winds are prevalent. The impact of wind direction on nightime low temperatures will be discussed further in the section dealing with correction factors.

If the concept is accepted that surface wind speeds are largely dictated by downward momentum transfer from the top of the Eckman Layer or the geostrophic level then the C&PF offers more flexibility as pertaining to the wind speed parameter than does the BF. In Belize particularly during the months of March and April the magnitude of the nightime wind velocities often times exceed the maximum depicted in Table 2.

It was noted, however, that BF after some adjustments was more applicable to minimum temperature (TMin) forecasts along coastal areas. The C&PF while a thorough investigation was not performed, appears to be bias towards forecasting inland TMins. A forthcoming paper by the same author will address this subject.

3. Data and Methodology

The period 15th July 1994 through 12th July 1995 formed the database for this research. Data from the Weather Bureau station was used due to the consistency in the observations and the representativeness of the station to coastal temperature regimes. It was the author's intent to use a minimum of 3 years observations, however, unforeseen circumstances limited the scope of the research to a year's worth of data.

From nightime observations average surface winds and cloud coverage were obtained. Assuming that for the vast majority of times TMin occurs near or shortly before 0900 UTC the 0300, 0600, 0900 and at times 1200 UTC surface observations were utilised in Tables 1 and 2.

Considering that there would not be a noteworthy change in geostrophic wind speeds within a 3 hour period the 1200 UTC upper air sounding was used to obtain a measure of the geostrophic wind speed used in the C&PF. In this same formula 1800 UTC screen and dew point temperatures from the previous day were utilised.

The BF uses wet bulb and dew point temperatures at the time of occurrence of the maximum temperature. Since only hourly observations are available the 2100 UTC values for the previously mentioned parameters were substituted. This was based on the assumption that daytime maximum temperatures usually occur around 2100 UTC or slightly earlier.

To reiterate, the main function of this study was to adjust a suitable minimum temperature algorithm to suit forecasting of such a parameter. in Belize. To attain this objective appropriate regression equations along with correlation coefficients were obtained using the SYSTAT application package. Hence the primary approach is a purely statistical one which later lends itself to meteorological applications.

4. Results

(a) Performance Evaluation

C&PF along with BF were subjected to the same statistical analyses to determine the fitness of the data. A least squares regression analysis showed a correlation coefficient (r) of 0.775 for C&PF and 0.814 for BF. A value of 1.0 would be indicative of a ' perfect fit' or a perfect correlation between the observed and forecasted parameters while a value of 0.0 would suggest no relationship whatsoever.

C&Pf show substantially lower mean minimum temperatures (19.4°C) than BF (23.6°C). This reality would seem to suggest greater applicability to forecasting inland low temperatures forecasts. The extreme (max and min) TMin forecasted by BF is significantly higher than those calculated using C&PF. This again supports the notion of the applicability of C&PF in the forecasting of inland TMins. Based on the above premise it would appear that BF would be the algorithm more suited to coastal TMin forecasts while the other to inland areas.

(b)Adjusted Boyden Formula (ABF)

Since the BF offers a better correlation between forecast and observed TMins along the coasts it will be adopted throughout this paper as the algorithm which will be adjusted to suit forecasting such temperatures in Belize.

The following figure (Fig 1) is a scatter plot of the BF forecasts vs observed minimum temperatures. From this plot equations to a regression line can be obtained.

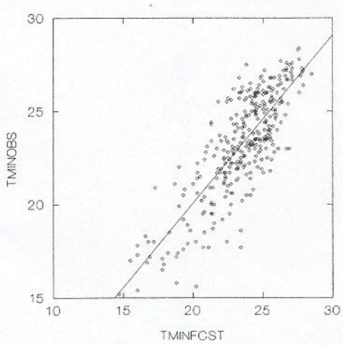

Figure 1

Correction for inflation, deflation and bias is achieved simply by means of regression. If we let FOld = original BF forecasts

FNew = corrected BF forecasts

s = slope of regression line

i = intercept

then FNew = (s×FOld) + i

For this study s was found as evident, from Fig 1, to be 0.904 and i as 1.990 The Adjusted Boyden Formula (ABF) now becomes

FNew = (0.904 × FOld) + 1.990.

It is worthwhile to note that when the ABF was applied to the same data set the correlation coefficient attained a value of 0.831. This exemplifies a much better relationship between the ABF forecasts and the observes TMin.

(c) Wind Direction Correction Factor (DCF)

In an earlier section entitled 'Forecast Algorithms' mention was made of the effects of wind speed and direction on the fall of nighttime temperatures. The speed parameter was addressed in the original BF through Table 2. Here in this subsection the effects of the direction will be dealt with.

After applying the ABF individual forecasts and observations of TMin were separated based on the average wind direction observed throughout the night. The entire dataset was classified into five separate groups based on the four different quadrants associated with the four cardinal points. The fifth grouping involved the calm wind class. Group 1 entailed those with average directions >360° but < 090°, Group 2: > or = 90° and < or = 180°, Group 3: = or > 270° and = or < 360°. Group 4 involved winds with a south-westerly component i.e. average wind directions >180° and < 270° and finally Group 5 as mentioned earlier were those nights when the wind was calm.

Here in Belize an accurate or so called 'correct' TMin forecast is one in which the relative error (i.e. the difference between the forecast and the observed parameter) is 2°C or less. Meanwhile, a forecast 'bust' is one in which this relative error was greater than the value stated above.

A first for each individual group the bias of the 'busts' were obtained. Then through an iterative process and at times by sheer trial and error a direction correction factor was derived. To be applicable this Direction Correction Factor (DCF) had to have both the effect of reducing the number of 'busts' and at the same time reduce the magnitude of the average relative error. Table 3 gives a depiction of the number of 'busts' without and with DCF. Along with this is the average relative error before and after DCF.

Table 3.
Effects of DCF

Groups	without DCF busts / error	with DCF busts/error	DCF
1	6 / 0.204	6 / 0.329	0.3
2	21 / -0.705	8 / 0.329	+1.1
3	9 / 1.4	3 / 0.577	-1.25
4	1 /N/A	1 /N/A	N/A
5	31/ 0.841	23/ -0.214	-1.05

From the above table it is evident that for Group 1 the correction factor does not reduce the number of busted forecasts and it raised substantially the average relative error. Hence applying the DCF has more negative effects on the forecasts in this group. With only four observations one of which was a 'bust' the search for a correction factor was inconclusive for Group 4.

Also from Table 3 it can be inferred that the BF performs best with winds from a generally north-easterly direction. It yields too low forecasts for winds with a mean south-easterly component. With calm conditions along with winds from an average north-westerly direction the BF forecasts values that are too high and have to be adjusted downwards. The unavailability of a DCF for winds from a general south-westerly direction was due to the fact that data was too sparse to derive a value for a correction factor.

Applying now the DCF to the Adjusted Boyden Formula (ABF) would now yield:

TMin = (0.904 × FOld) + 1.990 + DCF

The above is the best fit to an algorithm for nighttime minimum temperature forecasts in

Belize. DCF values are to be obtained from Table 4 on the following page.

Table 4
Values of DCF

Nightime Wind Direction	DCF
>360° but <090°	0.0
> or = 090° and < or = 180°	+1.1
>180° but <270°	N/A
> or = 270° and < or = 360°	-1.25
calm	-1.05

Although it may appear that using the final version of the ABF would yield values of magnitudes rather close to the FOld values the usage of the finalised version would reduce the probability of a busted forecast.

5. Present Techniques vs Formula

The present forecasting scheme utilised at the Weather Bureau does not yield as much an accurate forecast as using some sort of forecast algorithm as guidance. This is exemplified by the following obtained by the comparison of data from both schemes for the same period.

(1) The correlation coefficient between the present forecasting schemes and the observed TMin yields a value of 0.545 which is considerably less than using any of the available algorithm in any of their forms e.g. BF 0.814, C&PF 0.775. After the application of the DCF the value for r using the BF was substantially raised.

2)The number of forecast 'busts' without the use consistent use of an algorithm amounted to 63 while using the ABF with a direction correction factor only 41. This was a 6.8% reduction in 'wrong' forecasts.

Summary

Through the importation and adjustment of an external formula a suitable algorithm was developed to forecast low temperature in Belize. The results of this study showed that the usage of such an adjusted algorithm consistently outperformed present forecast techniques.

While a total dependence on such a formula is undesirable if performances indicate that results are significantly more consistent than present techniques then such an algorithm should obviously be adopted as a standard for nightime temperature forecasts. Subjectivity would not be totally wiped out since it is not known how the formula would perform in extreme circumstances.

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