Asian J. Energy Environ., Vol. 9, Issue 3 and 4, (2008), pp. 215-230

# Regression Models for Forecasting Fog and Poor Visibility at Donmuang Airport in Winter

S. Ruangjun[1,*] and R. H. B. Exell[2]

[1]Weather Division (Beside Military Airport, Wing 6),
Paholyothin Road, Donmuang, Bangkok, Thailand
[2]The Joint Graduate School of Energy and Environment,
King Mongkut's University of Technology Thonburi, Bangkok, Thailand
*Corresponding author: ruangjun31@yahoo.com

**Abstract:** A method has been developed for predicting visibility over Donmuang Airport at 07:00 a.m. in winter from surface meteorological observations at 01:00 a.m. and 05:00 a.m. using multiple linear regression. Data from the Thai Meteorological Department weather station at Bangkok International Airport and The Royal Thai Air Force in December, January and February were used. For each month two models were found: one containing all the available surface observations, and one omitting the insignificant observations. The model forecast consists of the probabilities of fog, poor visibility, and good visibility, respectively.

**Keywords:** Fog, visibility, forecast, Donmuang Airport, Bangkok, winter.

 

# Introduction

Widespread fog causes problems of safety for air, sea and land traffic due to low visibility. In particular, when fog occurs over airfield runways and taxiways, pilots and air traffic control personnel are concerned about the risk of accidents. In Thailand, fog occurs over airfields in winter, producing low visibility and a low ceiling over the ground. Therefore, there is a need for research on fog forecasting so that reliable warnings of low visibility due to fog can be issued to pilots.

The World Meteorological Organization (WMO) reports “fog” (with symbol FG) when visibility is less than 1,000 meters, and “mist” (with symbol BR) when visibility is from 1,000 to 9,000 meters [1]. Weather records show that fog occurs as the surface temperature approaches the dew point temperature and the relative humidity is more than 75 percent. Under these conditions visibility may be reduced to less than 1 km. The creation of these conditions at a specific location depends on many factors, including the synoptic situation, the wind speed and direction, the stability of the atmosphere, the air temperature and the dew point temperature. At Donmuang Air Force Base, latitude 13° 55’ N, longitude 100° 36’ E, about 20 km north of the city of Bangkok, and 45 km north of the coast of the Gulf of Thailand, fog sometimes occurs near the surface and produces poor visibility in the morning in winter (December to February).

A report by Vinai Thongphasuk (2002) [2] describes the formation of fog over Donmuang Airport in the northeast monsoon season during the periods 9-11 February 1999 and 13-16 February 2000. The conditions favorable for fog at sunrise were found to be as follows:

(i) Pressure falling in a high pressure area over Thailand.

(ii) An easterly wind above the surface with speed 5 knots.

(iii) A clear sky during the night.

(iv) Upper air soundings at 07:00 a.m. at Bang Na about 30 km south of Donmuang showed a temperature inversion near the surface and stable air above.

(v) Dew point at the surface was almost equal to the air temperature giving a relative humidity almost 100 %.

The minimum visibility in thick fog was 50 meters at 06:00 a.m. and 150 meters at 06:30 a.m.

The objective of the research reported in this paper was to find a model for forecasting fog at dawn over Donmuang Airport during the winter months of December, January and February using routine surface meteorological observations made during the preceding early morning hours.

Data from the meteorological stations of the Royal Thai Air Force (RTAF) and the Thai Meteorological Department (TMD) at Donmuang Airport were used in a linear regression model from which probability values were calculated for fog (visibility less than 1 km), poor visibility (1 km to 4.8 km) and good visibility (over 4.8 km).

Complete results are given in [3], and selected results using data from the Thai Meteorological Department are given in [4]. This paper compares the models constructed using data from the Thai

Meteorological Department and the Royal Thai Air Force, and discusses the question of whether or not different forecasting models should be used in different months.

## Materials and Method

The models tested in this research for predicting fog at Donmuang airport were multiple linear regressions using surface meteorological observations at the International Airport. Data for December 1997–2001 and January, February 1999–2003 were used for constructing the regression models; data for December 2003 and January–February 2004 were used for testing the regression models.

The independent variables were values at 01:00 and 05:00 a.m. of the following observations:

(i) T, Screen air temperature (ºC)
(ii) Td, Dew point temperature (ºC)
(iii) C, Cloud cover (oktas)
(iv) T – Td, Dew point depression (ºC)
(v) W, Surface wind speed (knots)
(vi) X, The direction of surface wind
(vii) W SIN X, E-W component of surface wind (knots)
(viii) W COS X, N-S component of surface wind (knots)
(ix) $\mathrm{Log}_{10}$ vis, The logarithm to base 10 of surface visibility (km)
(x) P, Pressure (inches of mercury)
(xi) $\Delta$P, Pressure change in the last 24 hours (inches of mercury)
(xii) RH, Relative humidity (percent)

The logarithm of the visibility is chosen instead of the visibility itself for two reasons. The first, the extinction and scattering of light passing though the atmosphere are multiplicative with respect to distance, and second, small changes in visibility at a short distance are more important than the same changes in visibility at long distances. The logarithm therefore gives a natural scale for visibility which is expanded at short distances.

Use of $\log_{10}$ vis instead of the actual visibility, which in all reports falls between 100 m and 10 km, transforms the observations into the interval –1 to +1. Since $\log_{10}(1) = 0$ and $\log_{10}(4.8270) = 0.6837$, we have $\log_{10}$ vis < 0 for fog, $0 \leq \log_{10}$ vis $\leq 0.6837$ for poor visibility, and $\log_{10}$ vis > 0.6837 for good visibility.

The SPSS program version 9.0 was used with the variables defined above to find multiple linear regression equations relating the dependent variable to the independent variables. The full regression equations used for representing $(\log_{10} \text{vis})_{\text{forecast}}$ at 07:00 a.m. from the observations at an earlier time (01:00 a.m. and 05:00 a.m.) had the form:

$$\log_{10} \text{vis} = a_0 + a_1 T + a_2 C + a_3(T - Td) + a_4 W \text{ SIN } X + a_5 W \text{ COS } X + a_6 \log_{10} \text{vis} + a_7 P + a_8 \Delta P$$

The coefficients $a_0, \ldots, a_8$ were obtained by the “ENTER” method of the SPSS program. Another set of coefficients for a simplified regression equation omitting non-significant terms was obtained by the “STEPWISE” method of the program.

Values of the multiple correlation coefficient (R), the multiple coefficient of determination ($R^2$), and the standard error of estimate (S) were also given in the program outputs.

The standard error of estimate (S) is a measure of the scattering of the observed values of the dependent variable $y_i = \log_{10} vis_i$ about the corresponding values $y_{est,i} = a_0 + a_1T_i + \ldots + a_8 \Delta P_i$ estimated from the regression equation. We assume that the scattered values have a normal distribution at each point with mean $y_{est,i}$ and standard deviation S.

This normal distribution has been used to calculate for each set of observations specifying the values of the independent variables the probabilities of fog, poor visibility, and good visibility as follows.

Let $y_{est,i}$ be a predicted value of $\log_{10}$ vis using one of the regression models, and let S be the standard error of estimate of the model. Let $Z = (\log_{10} vis - y_{est,i})/S$ be the corresponding standardized values of $\log_{10}$ vis for this distribution. Also let $Z_0 = 0$ and $Z_1 = 0.6837$ be the standard values corresponding to vis = 1 km, and vis = 4.8 km, respectively. Then the probabilities of fog, poor visibility and good visibility are given respectively by

$$
\begin{aligned}
P\{\text{fog}\} &= P\{Z < Z_0\} = \mathrm{erf}(Z_0), \\
P\{\text{poor visibility}\} &= P\{Z_0 \le Z \le Z_1\} = \mathrm{erf}(Z_1) - \mathrm{erf}(Z_0), \\
P\{\text{good visibility}\} &= P\{Z > Z_1\} = 1 - \mathrm{erf}(Z_1).
\end{aligned}
$$

## Results

Here we present the regression models found from combined data covering the winter period December through February. The model names and specifications are listed in Tables 1 and 2. The actual regression equations found from the input data were as follows:

TMD-111:

$\mathrm{Log}_{10}\,\mathrm{vis}(0700) = -19.534 - 0.004T + 0.106C + 0.019(T - Td) + 0.01W\,\mathrm{SIN}\,X + 0.007W\,\mathrm{COS}\,X + 1.219\,\mathrm{Log}_{10}\,\mathrm{vis}(0100) + 0.641P + 0.340\,\Delta P$

TMD-511:

$\mathrm{Log}_{10}\,\mathrm{vis}(0700) = -28.0374 + 0.008T + 0.207C + 0.025(T - Td) - 0.011W\,\mathrm{SIN}\,X - 0.001W\,\mathrm{COS}\,X + 1.008\,\mathrm{Log}_{10}\,\mathrm{vis}(0500) + 0.925P + 0.334\,\Delta P$

TMD-121:

$\mathrm{Log}_{10}\,\mathrm{vis}(0700) = -26.082 + 0.109C + 0.022(T - Td) + 0.010W\,\mathrm{SIN}\,X + 1.215\,\mathrm{Log}_{10}\,\mathrm{vis}(0100) + 0.856P$

TMD-521:

$\mathrm{Log}_{10}\,\mathrm{vis}(0700) = -27.455 + 0.014Td - 0.042W\,\mathrm{SIN}\,X - 0.008RH + 1.009\,\mathrm{Log}_{10}\,\mathrm{vis}(0500) + 0.927P + 0.01W$

RTAF-111:

$\mathrm{Log}_{10}\,\mathrm{vis}(0700) = -29.813 + 0.016T + 0.031C + 0.021(T - Td) + 0.004W\,\mathrm{SIN}\,X + 0.024W\,\mathrm{COS}\,X + 1.843\,\mathrm{Log}_{10}\,\mathrm{vis}(0100) + 0.944P + 0.494\,\Delta P$

RTAF-511:

$\mathrm{Log}_{10}\,\mathrm{vis}(0700) = -19.482 - 0.008T + 0.071C + 0.02(T - Td) + 0.003W\,\mathrm{SIN}\,X + 0.018W\,\mathrm{COS}\,X + 1.416\,\mathrm{Log}_{10}\,\mathrm{vis}(0500) + 0.637P + 0.558\,\Delta P$

RTAF-121:

$\text{Log}_{10}\,\text{vis}(0700) = -25.728 + 0.114W\ \text{SIN}\ X + 0.025W\ \text{COS}\ X + 1.886\ \text{Log}_{10}\,\text{vis}(0100) + 0.823P$

RTAF-521:

$\text{Log}_{10}\,\text{vis}(0700) = -28.762 + 0.073W\ \text{COS}\ X + 1.436\ \text{Log}_{10}\,\text{vis}(0500) + 0.940P + 0.036W$

**Table 1.** Model properties using data from the Thai Meteorological Department.

| Properties | Model | | | |
|---|---|---|---|---|
| | TMD-111 | TMD-511 | TMD-121 | TMD-521 |
| Input data time | 0100 | 0500 | 0100 | 0500 |
| Method of Analysis | ENTER | ENTER | STEPWISE | STEPWISE |

**Table 2.** Model properties using data from the Royal Thai Air Force.

| Properties | Model | | | |
|---|---|---|---|---|
| | RTAF-111 | RTAF-511 | RTAF-121 | RTAF-521 |
| Input data time | 0100 | 0500 | 0100 | 0500 |
| Method of Analysis | ENTER | ENTER | STEPWISE | STEPWISE |

Figures 1 to 8 show the results of the model tests as plots of the forecast values of $\log_{10}$ vis versus the actual values of $\log_{10}$ vis at 07:00 a.m.

Boxes labelled H represent hits (correct forecasts). Boxes labelled M represent misses (failures to predict fog or poor visibility). Boxes labelled F represent false alarms (actual visibility better than predicted).

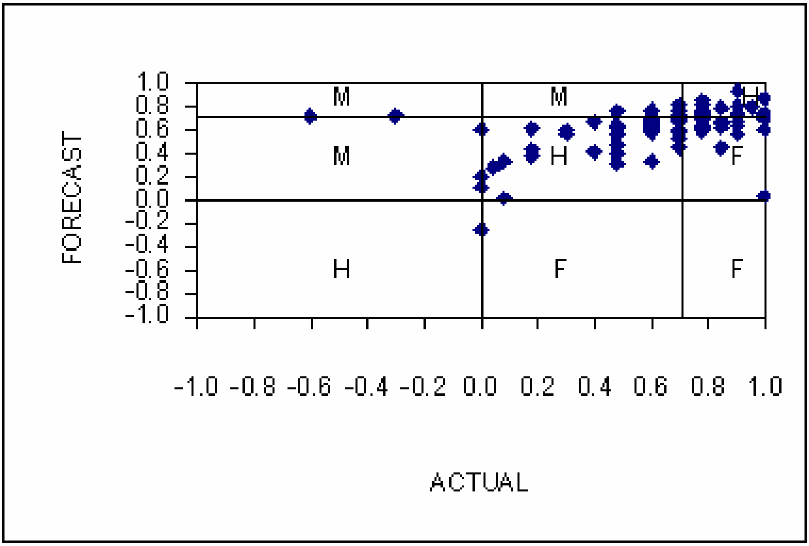


**Figure 1.** TMD-111 Model. Forecast $\log_{10}$ vis versus actual $\log_{10}$ vis.

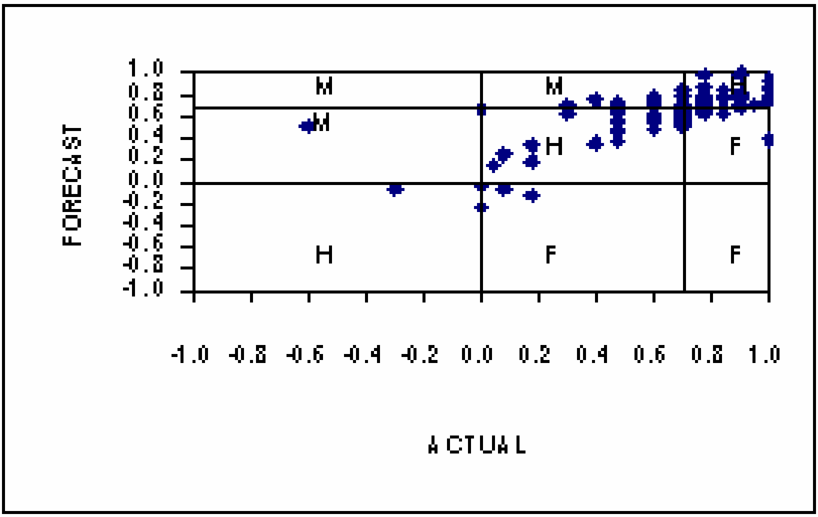


**Figure 2.** TMD-511 Model. Forecast $\log_{10}$ vis versus actual $\log_{10}$ vis.

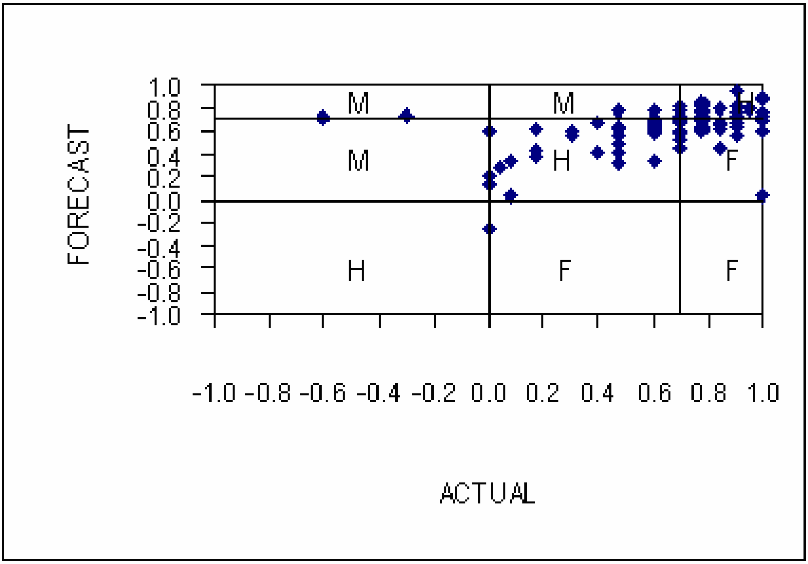


**Figure 3.** TMD-121 Model. Forecast $\log_{10}$ vis versus actual $\log_{10}$ vis.

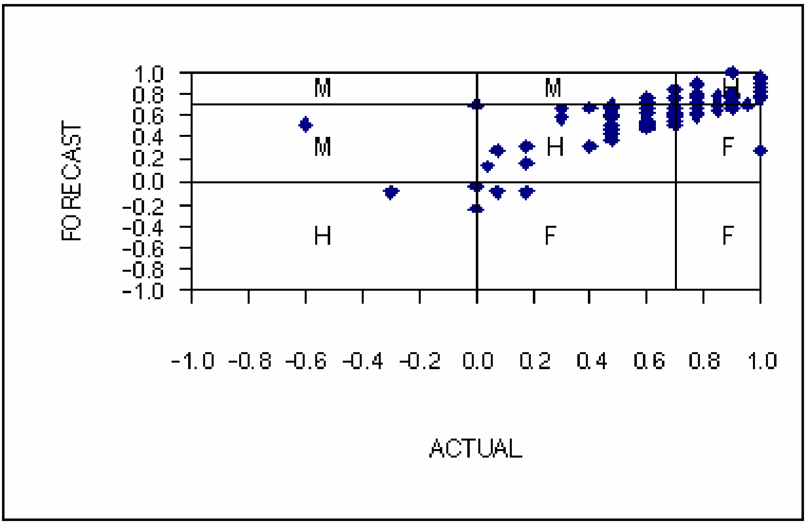


**Figure 4.** TMD-521 Model. Forecast $\log_{10}$ vis versus actual $\log_{10}$ vis.

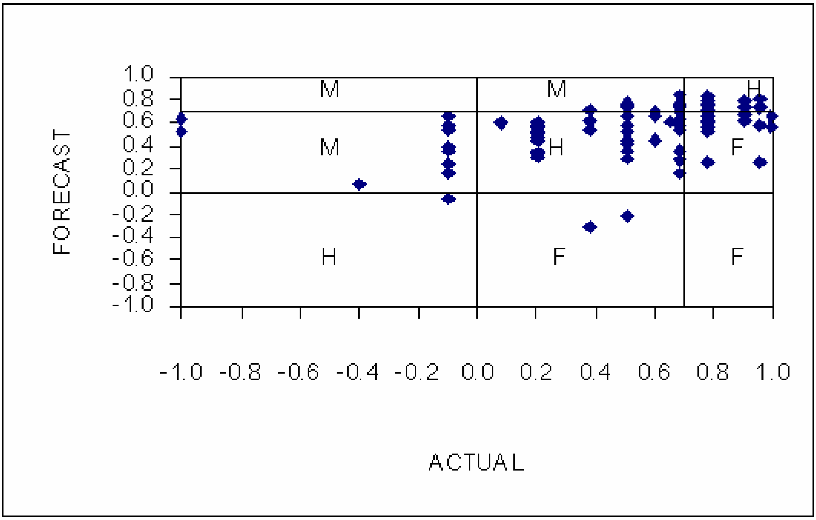


**Figure 5.** RTAF-111 Model. Forecast $\log_{10}$ vis versus actual $\log_{10}$ vis.

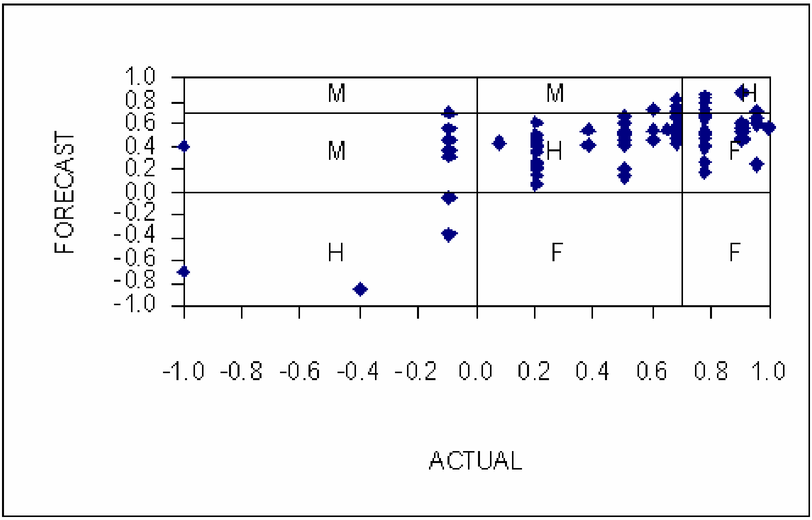


**Figure 6.** RTAF-511 Model. Forecast $\log_{10}$ vis versus actual $\log_{10}$ vis.

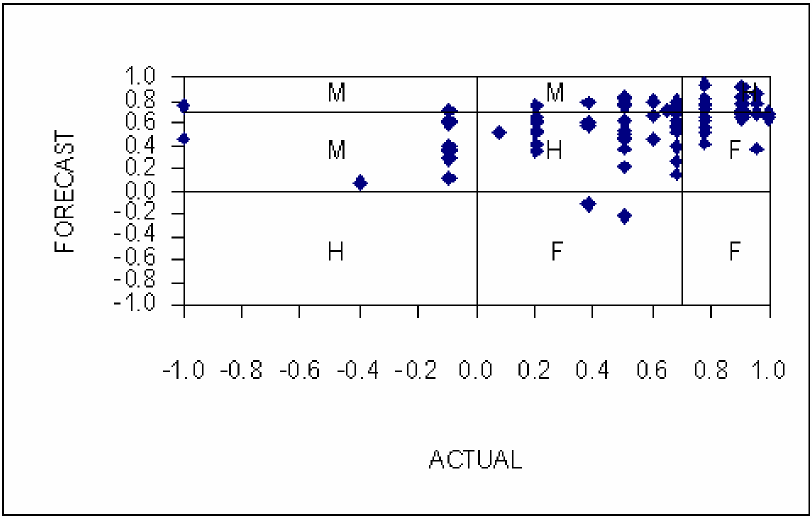


**Figure 7.** RTAF-121 Model. Forecast $\log_{10}$ vis versus actual $\log_{10}$ vis.

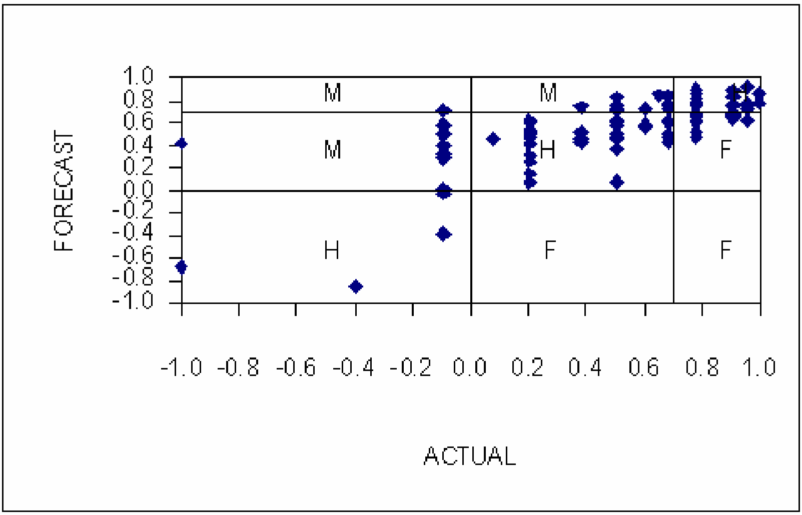


**Figure 8.** RTAF-521 Model. Forecast $\log_{10}$ vis versus actual $\log_{10}$ vis.

Tables 3 and 4 show the correlation coefficients R, and the standard errors of estimate S, found from the data used to construct the eight models. These tables also show the percentages of hits H, misses M, and false alarms F found from the data used to test the models.

**Table 3.** Comparison of TMD models.

| Model | R | S | H(%) | M(%) | F(%) |
|---|---|---|---|---|---|
| TMD-111 | 0.578 | 0.2574 | 74.57 | 8.47 | 16.95 |
| TMD-511 | 0.763 | 0.2038 | 67.79 | 8.47 | 23.73 |
| TMD-121 | 0.572 | 0.2578 | 71.67 | 5.00 | 23.33 |
| TMD-521 | 0.763 | 0.2035 | 71.70 | 5.66 | 22.64 |

**Table 4**. Comparison of RTAF models.

| Model | R | S | H(%) | M(%) | F(%) |
|---|---|---|---|---|---|
| RTAF-111 | 0.541 | 0.3111 | 66.18 | 17.65 | 16.18 |
| RTAF-511 | 0.625 | 0.2884 | 75.38 | 10.77 | 13.85 |
| RTAF-121 | 0.541 | 0.3085 | 63.49 | 19.05 | 17.46 |
| RTAF-521 | 0.632 | 0.2842 | 70.15 | 19.40 | 10.45 |

Comparison of the models using the results in Tables 3 and 4 suggest that there is little to choose between them. The correlation coefficients are of the order 0.6 and the frequencies of hits are about 70%. The TMD models give slightly fewer misses than the RTAF models, but they also give slightly more false alarms.

Examples of the predicted probabilities of fog, poor visibility and good visibility are illustrated in Figures 9 and 10. In Figure 9 the value of $\log_{10}$ vis(0700) predicted from the meteorological data at 01:00 a.m. was 0.8476, which makes the predicted visibility 7.0 km (good). The probabilities of fog, poor visibility and good visibility were 0.05%, 26.18% and 73.12%, respectively. The actual visibility on this day (8 December 2003) at 07:00 a.m. was 9 km.

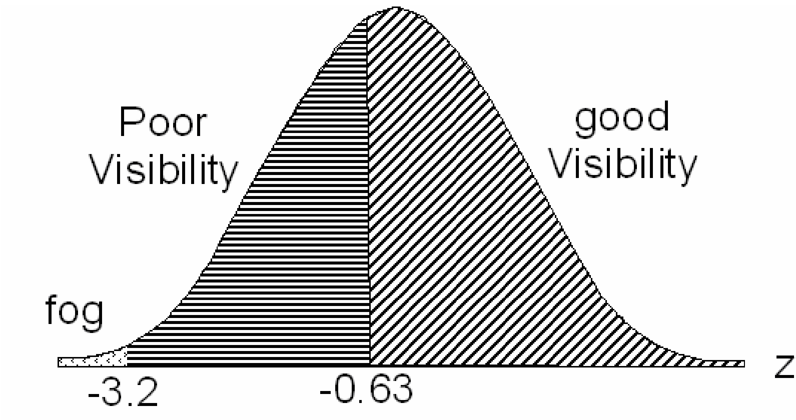


**Figure 9.** Predicted probability classes on 8 December 2003 (with high visibility) using data at 01:00 a.m. in model TMD-111 having standard error of estimate S = 0.2574.

In Figure 10 the value of $\log_{10}$ vis(0700) predicted from the meteorological data at 01:00 a.m. was 0.1323, which makes the predicted visibility 1.4 km (poor). The probabilities of fog, poor visibility and good visibility were 30.36%, 68.04% and 1.61%, respectively. The actual visibility on this day (26 December 2003) at 07:00 a.m. was 1 km.

Details of the calculations for the results presented above may be found in reference [3], including studies of separate models for the different months December, January, and February. The results in these separate models were variable, and indicate that it is not worth using separate monthly models in practice.

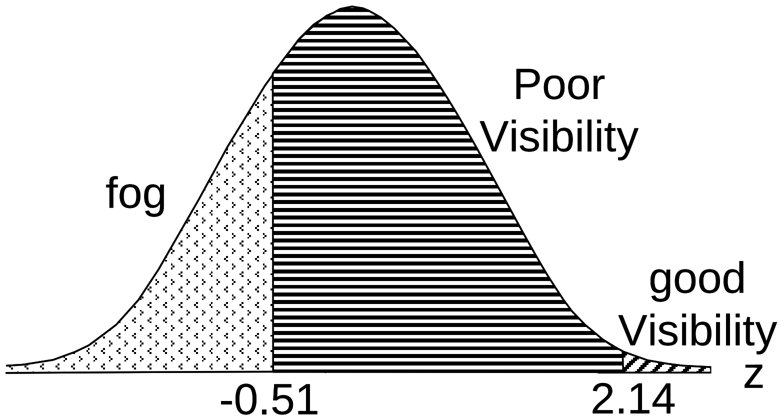


**Figure 10.** Predicted probability classes on 26 December 2003 (with low visibility) using data at 01:00 a.m. in model TMD-111 having standard error of estimate S = 0.2574.

## Conclusion

Fog and poor visibility are difficult to forecast. The models developed in this research are not perfect, but they have been proved to give results that will be of value to forecasters to help them with their visibility predictions. Computer programs are now available in the Royal Thai Air Force Base, Weather Division, by means of which forecasters can obtain probabilities of fog, poor visibility and good visibility at 07:00 a.m. from the weather observations at 01:00 a.m. and 05:00 a.m. at Donmuang Airport.

## Acknowledgments

The authors gratefully acknowledge the contribution of the Royal Thai Air Force and the Thai Meteorological Department.


## References


[1] Suwanpong, S. (1974) *Weather Instrument Handbook*, Thai Meteorological Department, pp. 2–3.

[2] Thongphasuk, V. (2001) *Forecasting Dense Fog Covering Donmuang Aerodrome*, Thai Meteorological Department, pp. 41–42.

[3] Ruangjun, S. (2004) *Fog Formation over Donmuang Air Force Base During Winter*, Master degree thesis, JGSEE, King Mongkut's University of Technology Thonburi.

[4] Ruangjun, S. and Exell, R.H.B. (2004) Forecasting fog at Donmuang Airport in winter, *Proceedings of The Joint International Conference on "Sustainable Energy and Environment (SEE)"*, 1–3 December 2004, Hua Hin, Thailand, pp. 704–706.