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A Preliminary Study On Take-Off Data Forecasting

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A Preliminary Study On Take-Off Data Forecasting

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1.0 Introduction

Take-off data are provided to all international flights taking off at Penang International Airport by Bayan Lepas Meteorological Office in its standard flight documentation to the airlines operating at the airport not later than 3 hours before the take-off time. Currently, simple techniques are practised by the Office to produce the take-off data that consist of five components namely, surface wind direction and speed, surface air temperature and dew point, and surface air pressure. Generally, the dew point and surface air pressure are relatively easier to forecast compared to the other components. Wind direction is particularly difficult to forecast accurately during a thunderstorm, most probably due to the effect of the downdraught winds. Similarly, the forecast of air temperature becomes challenging when rain occurs which can cause the temperature to drop by a varying amount according to the air temperature before the rain, the intensity and duration of the rain. In order to ensure the take-off data issued always meet the forecast accuracy targets as set and for continual forecast improvement as expected, it is necessary to carry out a study to analyse the temporal variations of the four components of the take-off data, forecast performance of the current techniques, and to identify potential forecasting aspects for improvements.

2.0 Data

The half-hourly data for year 2008 of Bayan Lepas Meteorological Station used in this study comprise actual observation data of surface wind direction and speed, surface air temperature and dew point, and surface air pressure provided by the Climate Division and Bayan Lepas Meteorological Office of Malaysian Meteorological Department

3.0 Analysis

Graphs were plotted to perform the analyses using the Microsoft Excel or Open Office v3.0.

3.1 Surface Wind Direction and Speed

To study the characteristics of the surface wind, the data were analysed on the monthly basis to examine the temporal variation of wind speed on fair weather days and on bad weather days; percentage distribution of wind direction; and forecast accuracy of wind

direction. In order to filter out randomness in surface wind direction at low speed, a minimum speed of 8 knots is arbitrarily chosen to determine and analyse the wind directions. Hereafter, it is referred to as the dominant wind speed.

For forecast accuracy evaluation purpose, a wind direction forecast is accurate if it is within + or – 30 degrees of the observed value, and for a wind speed forecast, it is accurate if it is within + or – 5 knots of the observed value, up to 25 knots, and within + or – 20% of the observed value if more than 25 knots. In addition, wind speed less than 5 knots is considered insignificant and excluded for forecast accuracy assessment. Based on the evaluation criteria, the required level of forecast accuracy to achieve for each of the take-off data components is 90%.

3.2 Surface Air Pressure

The half-hourly data for surface air pressure were analysed on the monthly basis to assess the forecast accuracy of all the forecasts made at every half an hour intervals, i.e. 0000, 0030, 0100, 0130, 0200 and so on. The forecast accuracy was assessed for each of the months and for four different forecast issue times. A simple forecast model based on persistency was used to forecast the surface air pressure, and was given by:

$$P_{t+3.5} = P_t + [P'_{t+3.5} - P'_t], \text{ where}$$

$P_{t+3.5}$ Forecast air pressure at t + 3.5 hours today i.e. 3.5 hours before take-off time,

P_t Observed air pressure at time t today,

$P'_{t+3.5}$ Observed air pressure at t + 3.5 hours yesterday, and

P'_t Observed air pressure at time t yesterday.

For forecast accuracy assessment, a surface air pressure forecast is considered as accurate if it is within + or – 1 hPa of the observed value. Based on this, the minimum target forecast accuracy level required to be achieved is 90%.

3.3 Surface Air Temperature

The half-hourly data for surface air temperature were analysed monthly to examine the diurnal variations on fair weather days and on rainy days separately. As on fair weather days, the diurnal variation of air temperature can be expected to follow a similar pattern, a simple forecast model like the one in 3.2 was used to produce the air temperature forecasts for the take-off data, and the forecast accuracy was assessed on the monthly basis.

A surface air temperature forecast is considered as accurate if it is within + or – 1 °C of the observed value. The target forecast accuracy level required to be achieved is 90%.

3.4 Dew Point

Graphs (not shown) were plotted to analyse the diurnal variation of dew points. The diurnal variation of dew points was smaller compared to the surface air temperature. Thus, the forecast model based on persistency in 3.2 was again applied here to produce forecast dew points for the take-off data. Forecasts were computed every half-hourly and 3.5 hours before the take-off times. The forecast accuracy was examined on the monthly basis.

A dew point forecast is assessed as accurate if it is within + or – 1 °C of the observed value. The target forecast accuracy level was set at 90%.

4.0 Results and Discussion

4.1 Surface Wind Speed and Direction

It was found out that on fair weather days the surface wind speeds demonstrated strong diurnal variations resulting from strong surface heating during the day for all the months (**Fig. 1a & 1b**), i.e. the surface winds were stronger during the day and reached a maximum around 2 to 4 p.m. for January till October, around 11 a.m. and 4 p.m. (two distinct peaks) for November and around 10 a.m. to 1 p.m. for December. Usually the surface wind speeds were below the dominant speed throughout the year. In general, the night time wind speeds were higher during the northeast monsoon season (November to March), especially in the predawn and early morning in December.

On bad weather days, **Fig.2a – 2c** showed that the surface wind speeds increased significantly up to and exceeding the dominant speed with occurrence frequencies of 14.3% to 58.8%, 58.3% to 100%, and 0% to 25% one hour before, during, and one hour after the rain/thunderstorm events respectively. The non occurrences and relatively lower frequencies after the events demonstrated the wind speeds decreased rapidly to below the dominant speed. This result indicated the effect of a gust front and/or a downburst associated with the rain/thunderstorms in strengthening the surface winds. It was noted that seemingly the winds during the rain/thunderstorms were the strongest during the southwest monsoon season (May to September) and weakest in the first two months (November and December) of the northeast monsoon season.

In **Fig. 3a & 3b**, the most dominant surface wind direction is southwest, i.e. 56.3% of the time in the year, followed by northeast (26.6%), together they added up to 82.9%. The surface southwesterly winds were dominant from March to October, i.e. the period including the last month of northeast monsoon, inter-monsoons and southwest monsoon. The dominance of surface northeasterly winds in January, February, November and December during the northeast monsoon was consistent with the low-level prevailing wind direction in those months. It is interesting to note that the northeasterly winds from March to October were much less common (11.1%) and as low as 2.3% in July compared to 31.5% and as high as 40.2% in January for the southwesterly winds from November to February. The explanation could be due to the geographical position of Penang island located on the western side of Peninsular Malaysia and therefore, sheltered from the northeasterly winds from November to February and normally not strong enough (especially in January and February) to stop the sea breezes (westerly) blowing in the afternoon. Land breezes (easterly) are usually much weaker than sea breezes, and are exposed to the opposing prevailing low-level westerly winds from the open seas from May to September.

By merely using the preceding day's wind directions of corresponding times as the present day's wind direction forecasts, the forecast accuracy result was shown in **Fig. 4**. The forecast accuracy was high, i.e 83% (December) to 90% (May). Such high accuracy was consistent with the persistent nature of the tropical weather conditions.

4.2 Surface Air Pressure

As Penang is located in the equatorial region, thus rarely directly affected by a tropical cyclone which is close enough to cause its surface air pressure to change rapidly and substantially. Hence, the expected daily pressure pattern is one that strongly exhibiting a diurnal cycle resulting from the regular day/night cycle in the insolation of the atmosphere, gravitational field pull of the Moon, and non-linear interactions between tides and planetary waves. Such a daily pressure pattern is highly predictable and a simple forecasting model based on persistency is expected to be useful.

Overall, the surface air pressure forecast accuracy using the model given in 3.2 was found to be high and often exceeded the target accuracy of 90% and accuracy dropped slightly if forecasts were issued earlier (**Fig. 5**). For forecasts issued 3.5 hours before the take-offs, the forecast accuracy exceeded the target accuracy except for July (88.4%) and September (89.7%); the highest forecast accuracy was 95.7% (November). In **Fig. 6**, the average forecast accuracy for the year exceeded its target level for forecasts issued 3.5, 4.0 and 4.5 hours before take-offs, and just managed for forecasts issued 5 hours before take-offs.

4.3 Surface Air Temperature

The graph of average diurnal variation in air temperature (not shown) for Bayan Lepas indicates most rapid increase between 8 a.m. and 10 a.m. followed by an increasingly slower increase until the time of the maximum (around 2 p.m.) and a similar reversal until 8 p.m.. The air temperature decreased at a slower and almost uniform rate from 8 p.m. until 8 a.m. the following day. **Fig. 7** shows that the average forecast accuracy for air temperature on fair weather days varied from 73.2% in October to 90.6% in June and an overall average of 84.1%. A fair weather day means no rain or trace amounts occurred on the particular day. The forecast accuracy would be lower if any two consecutive days were much different in sky cloudiness especially during daytime. The variation in air temperature on rainy days was highly unpredictable due to various factors, such as timing, duration and intensity of the rain, and more so during the day when the temperature range is bigger as compared to the night. The variation was also dependent on the air temperature just before the occurrence of the rain, e.g. if heavy rain occurred in the early morning when the air temperature is usually close to the minimum, say 23 or 24 °C, the drop in temperature immediately after the rain could be

just 2 degrees or so, whereas if the rain occurred in a hot afternoon, the drop could be much more, say from 30 to 25 °C. When rain is expected, the radar rain echoes provide the most useful weather information when forecasting the air temperature for take-off data.

4.4 Dew Point

Dew points indicate the amount of moisture in the air. Higher dew points means more moisture in the air compared to lower ones. From plotted graphs (not shown), the average dew point was minimum around 7.30 a.m., maximum around 4 p.m. and holding almost at this level till 11 p.m. and thereafter, it dropped gradually to a minimum the following morning. From **Fig. 8**, the average forecast accuracy for dew point varied from 68.8% in February to 86.6% in November and average 80.6%. The low forecast accuracy for February was unexpected.

5.0 Conclusion

Surface wind speed increased significantly up to and exceeding the dominant speed before and during rain/thunderstorm events, and decreased rapidly to below the dominant speed after the events. The most dominant surface wind direction was southwest (56.3% time of the year), followed by northeast (26.6%). The surface southwesterly winds were dominant from March to October and were replaced by northeasterly winds in November, December, January and February. Diurnal variation patterns were demonstrated by the surface air pressure, air temperature on fair days and dew point.

The average forecast accuracies of forecasting the four components in take-off data based on persistency were high, i.e. 83 to 90% for surface wind direction, 92.9% for surface air pressure, 84.1% for surface air temperature (fair weather days only) and 80.6% for surface dew point. As the results were based on one year data, more years of data need to be analysed for more valid results.

Forecasts based on persistency alone may not achieve the target accuracy set. Hence, forecasts may need to be adjusted based on the latest weather conditions observed, knowledge and experiences of the forecasters. As forecast accuracy can be expected to

drop in situations when persistency cannot be applied effectively, research priority should be given to such areas.

References

Atkinson G.D. 1971. Forecasters Guide To Tropical Meteorology.

Azizan A.S., Lim J.T. 2004. Weather and Climate of Malaysia.

Riehl H. 1954. Tropical Meteorology. 1-118

Riehl H. 1979. Climate and Weather in the Tropics. 250-313

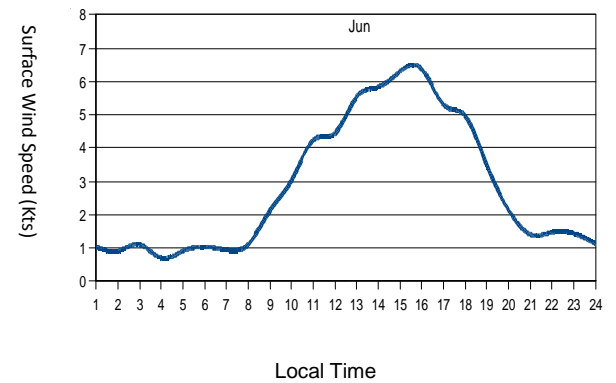
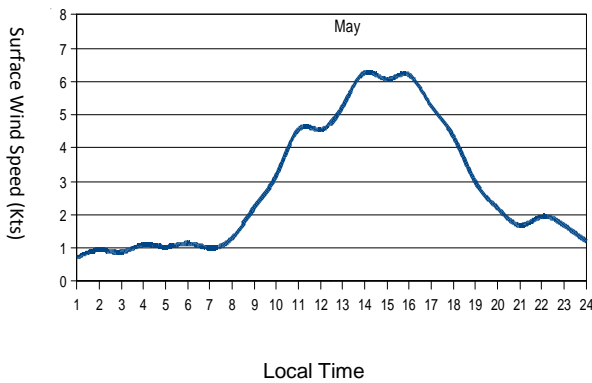
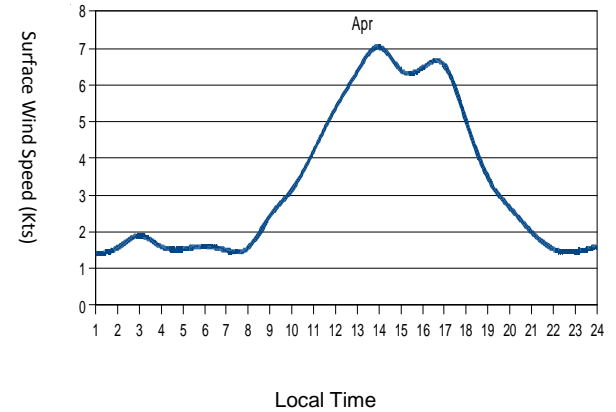
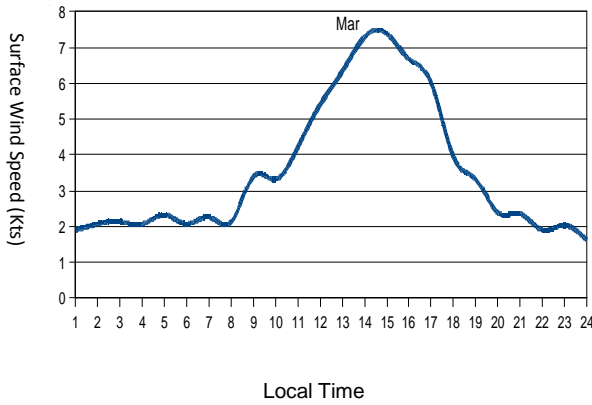
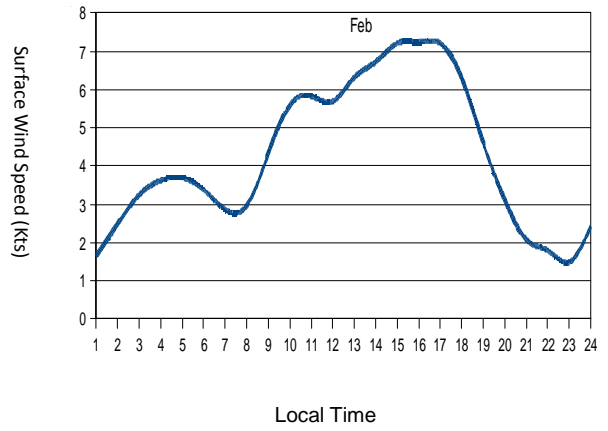
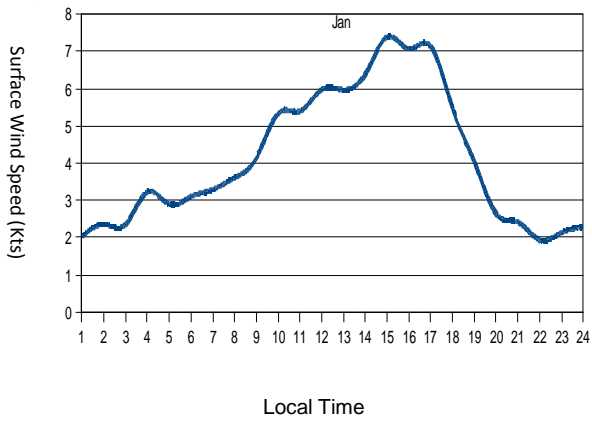


Fig. 1a: Average surface wind speed (smoothed) for fair weather days January - June 2008

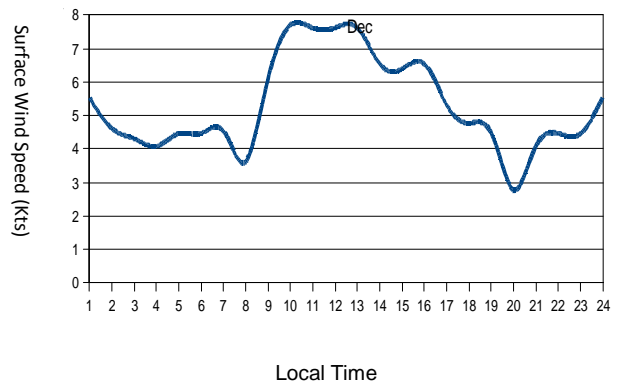
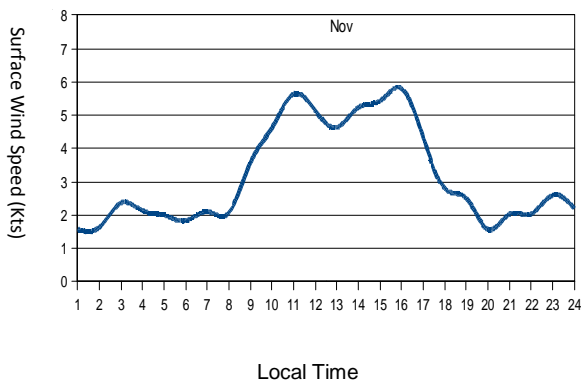
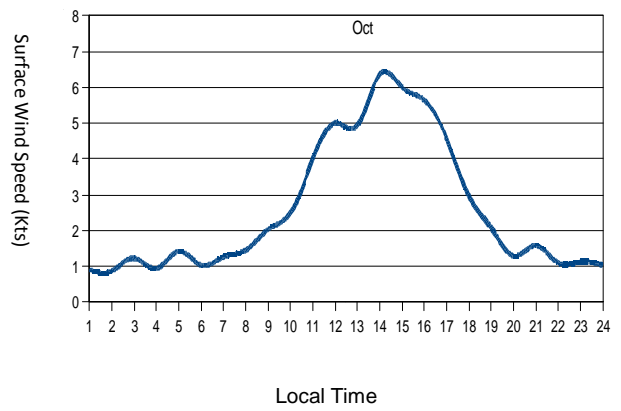
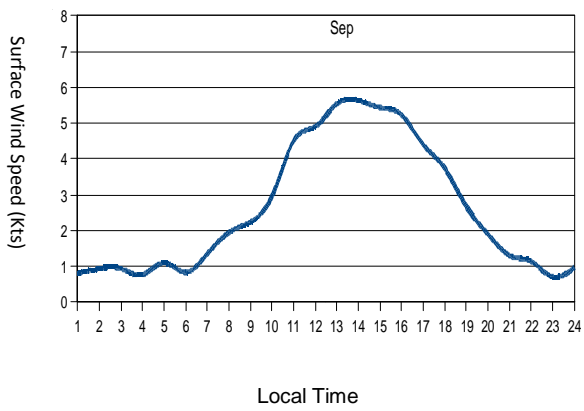
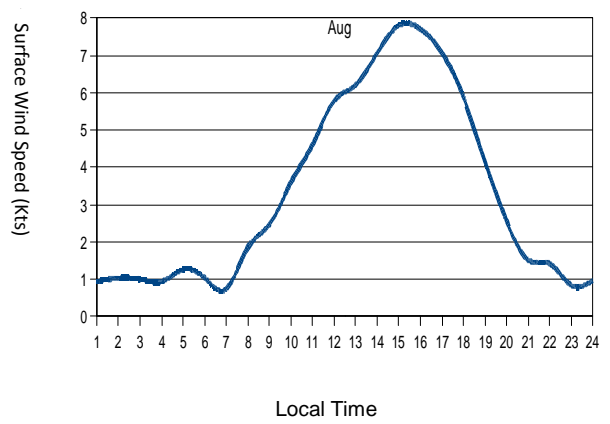
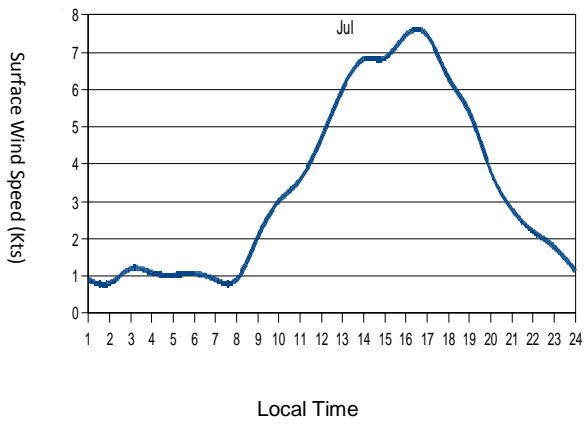


Fig. 1b: Average surface wind speed (smoothed) for fair weather days July - December 2008

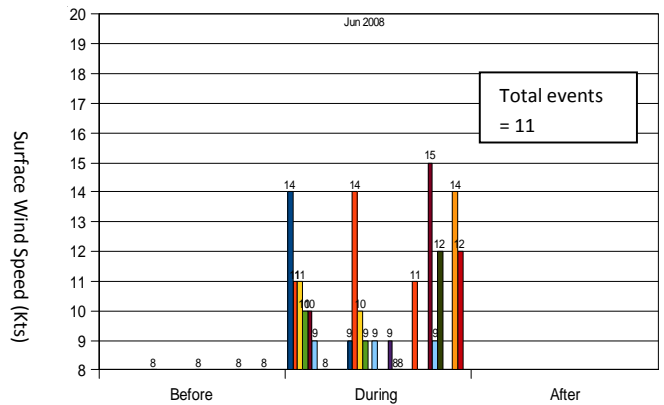
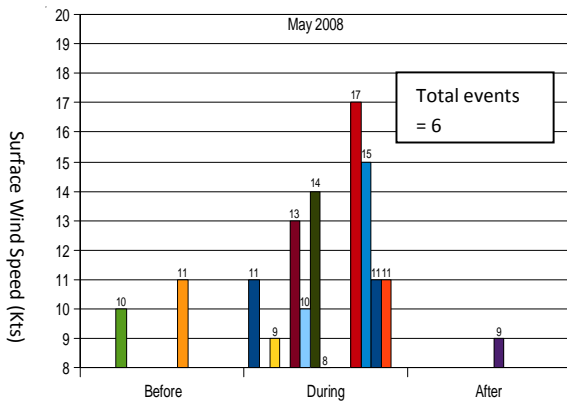
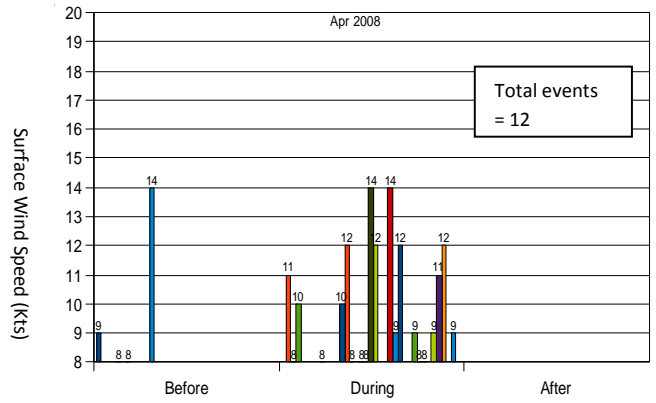
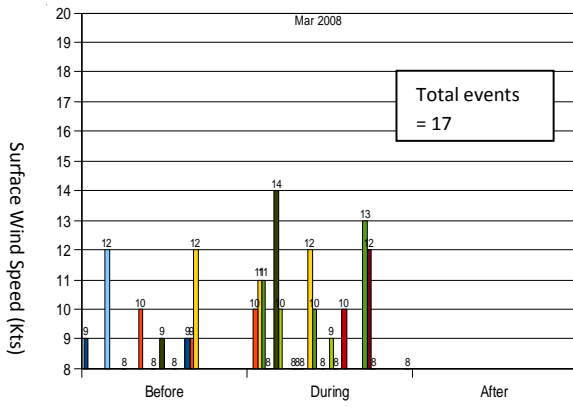
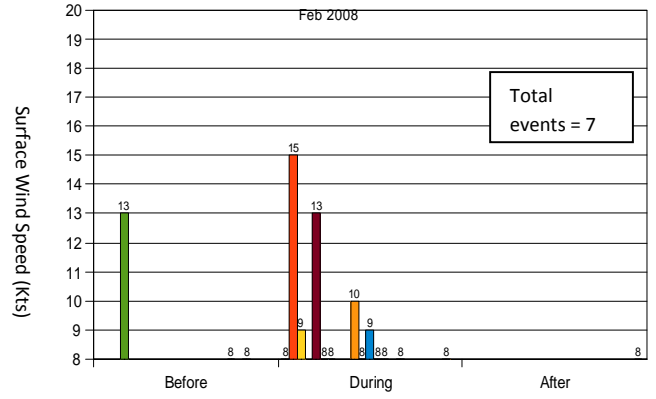
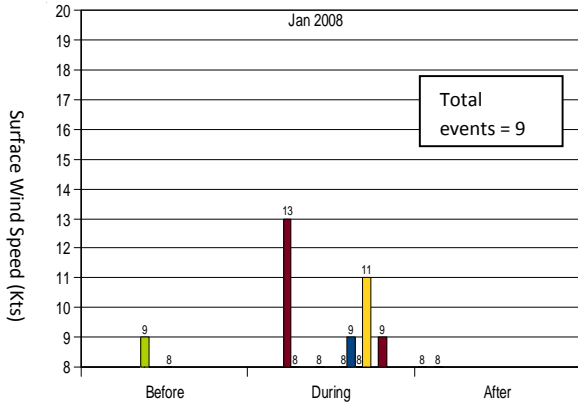


Fig. 2a : Dominant surface wind speed for all rainfall events January – June 2008

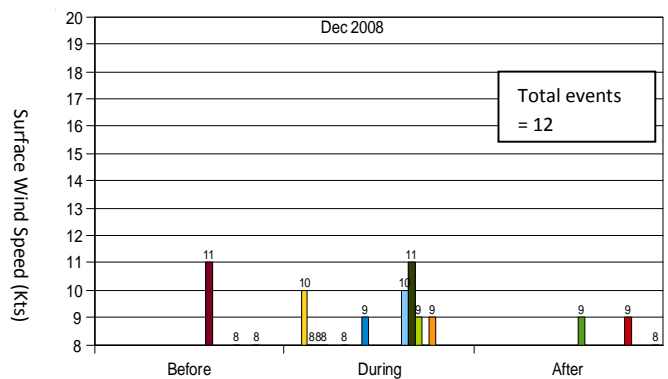
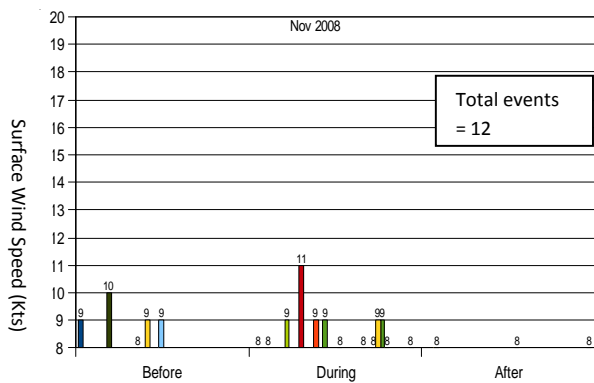
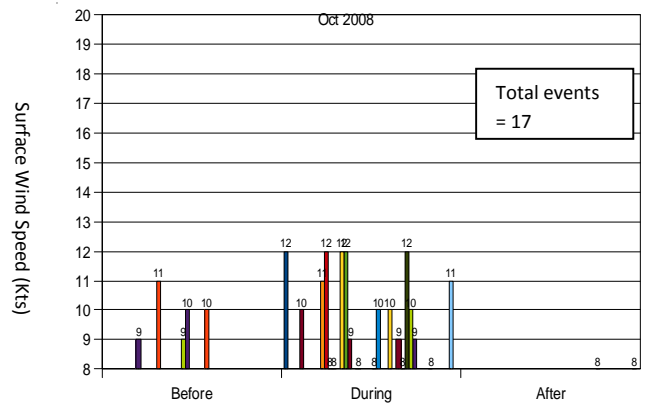
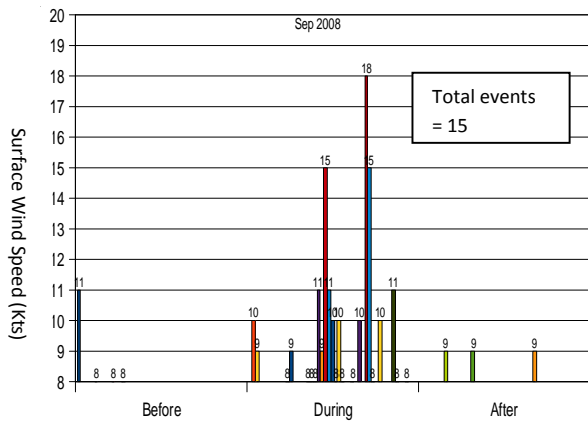
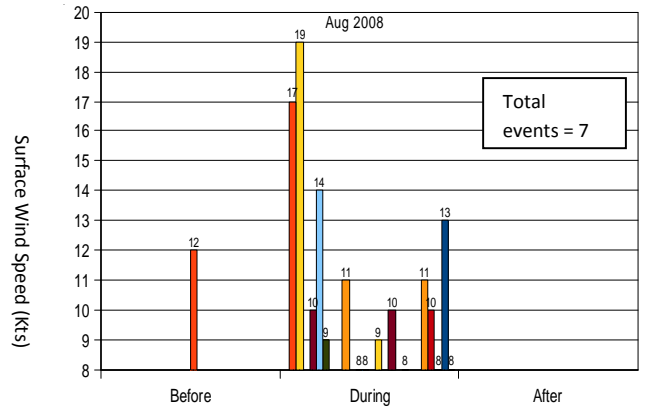
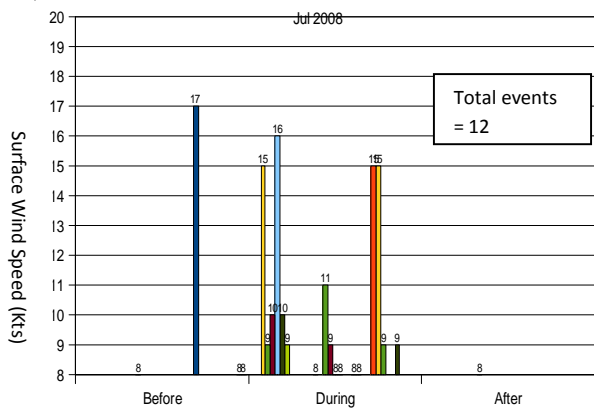


Fig. 2b: Dominant surface wind speed for all rainfall events July – December 2008

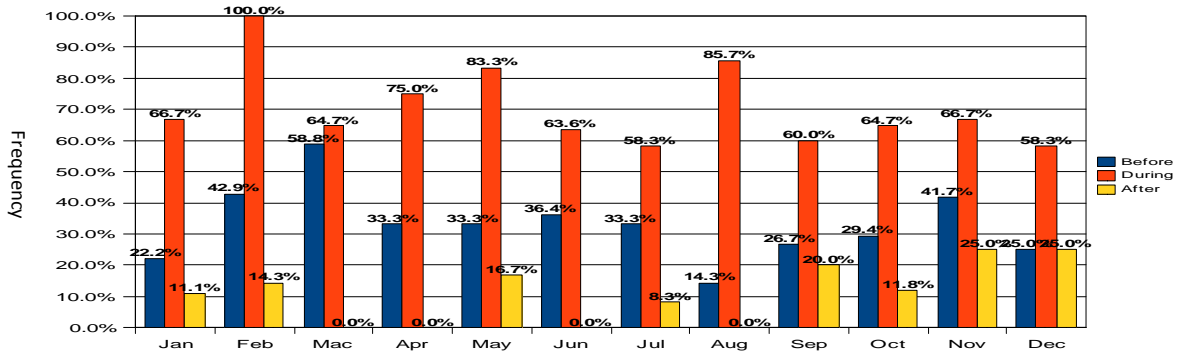


Fig. 2c: Frequency distribution of dominant surface wind speed before, during, and after the rain/thunderstorms in 2008

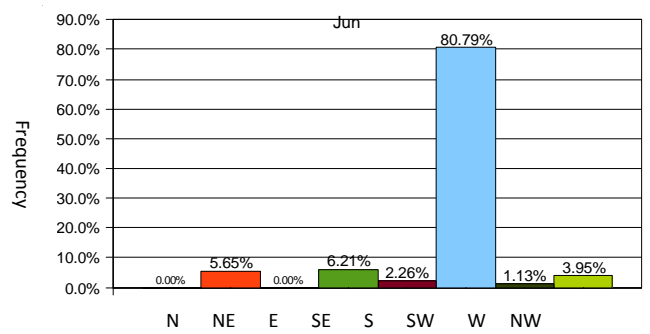
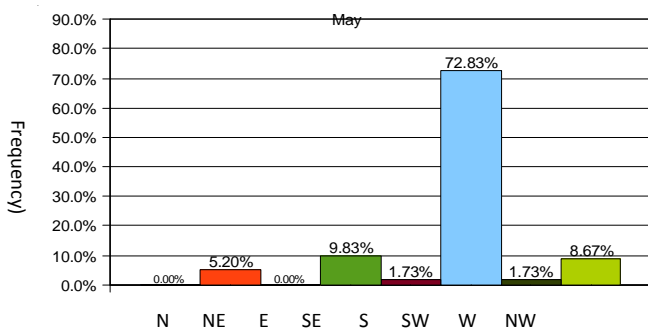
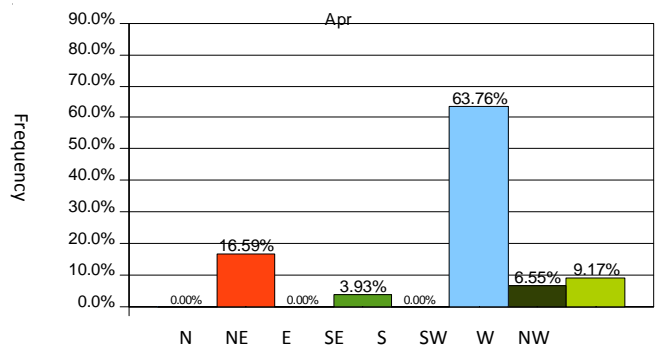
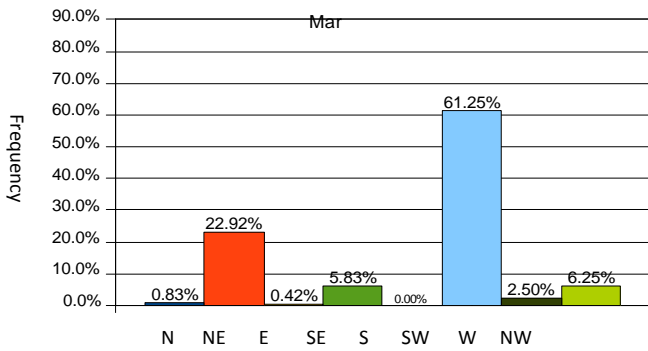
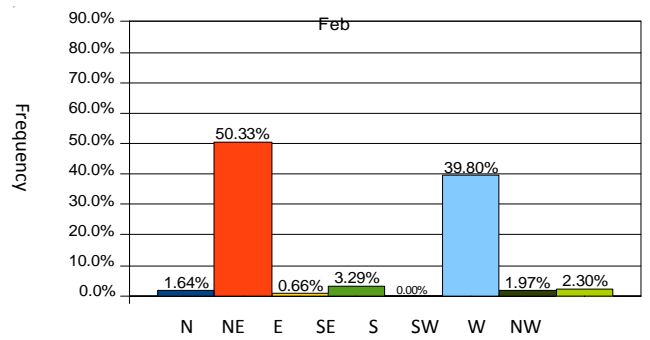
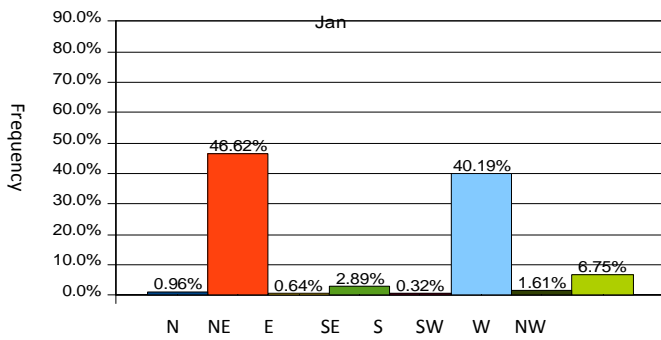


Fig. 3a: Frequency distribution of surface wind direction January - June 2008

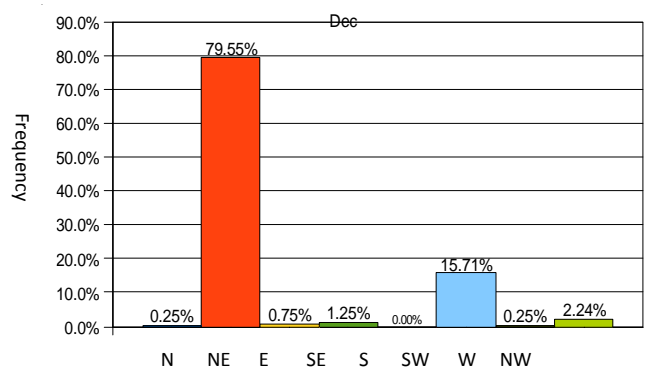
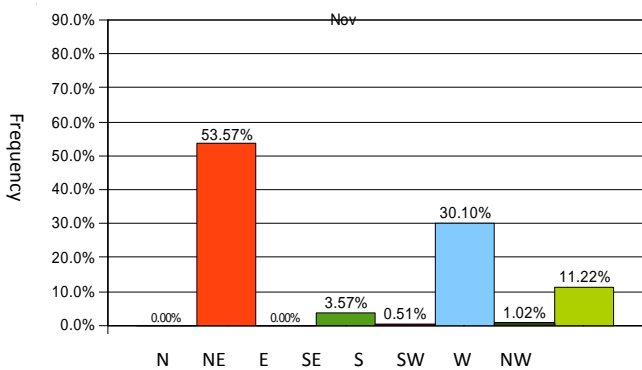
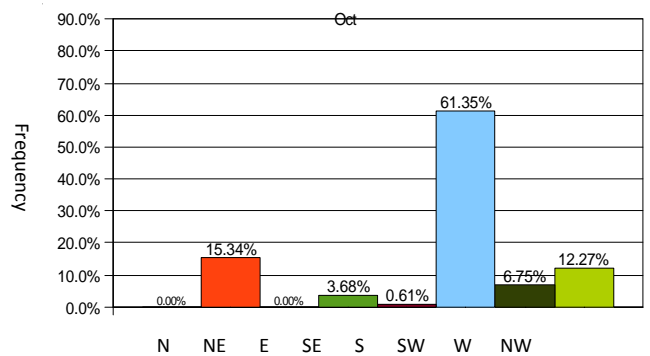
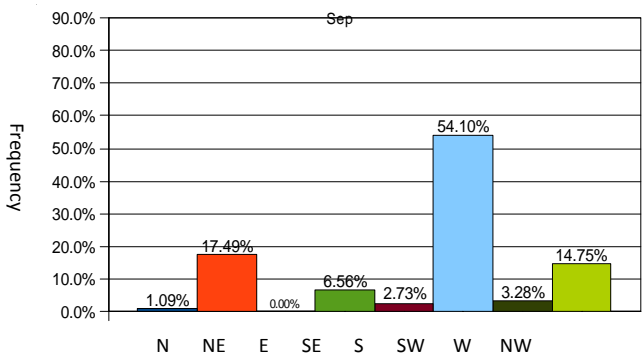
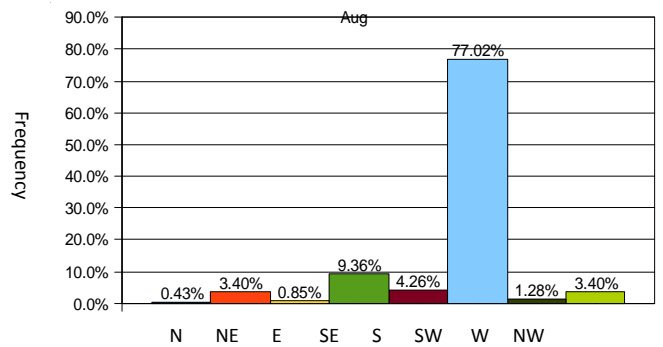
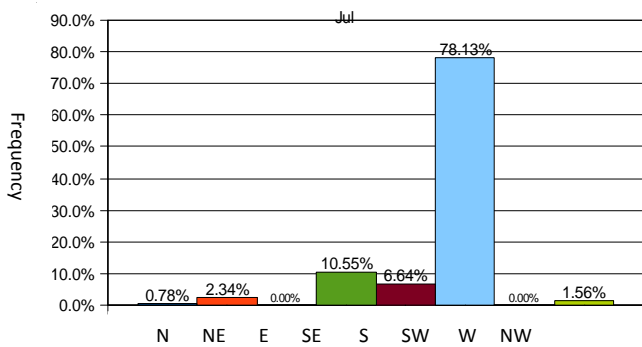


Fig. 3b: Frequency distribution of surface wind direction July - December 2008

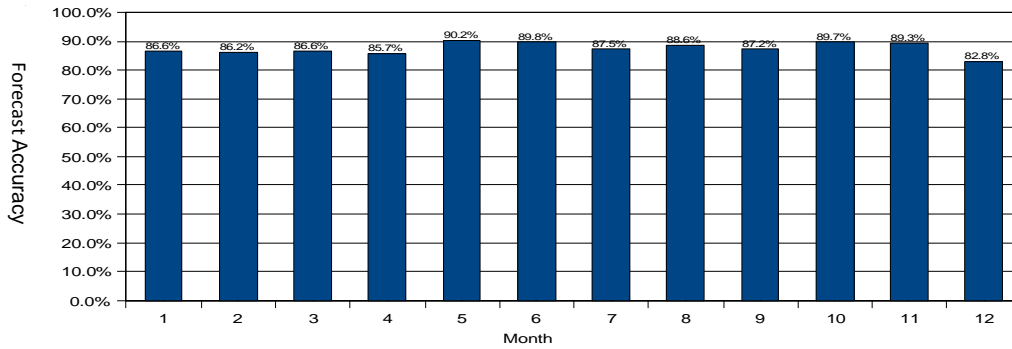


Fig.4 Average forecast accuracy of surface wind direction using corresponding preceding day data in 2008.

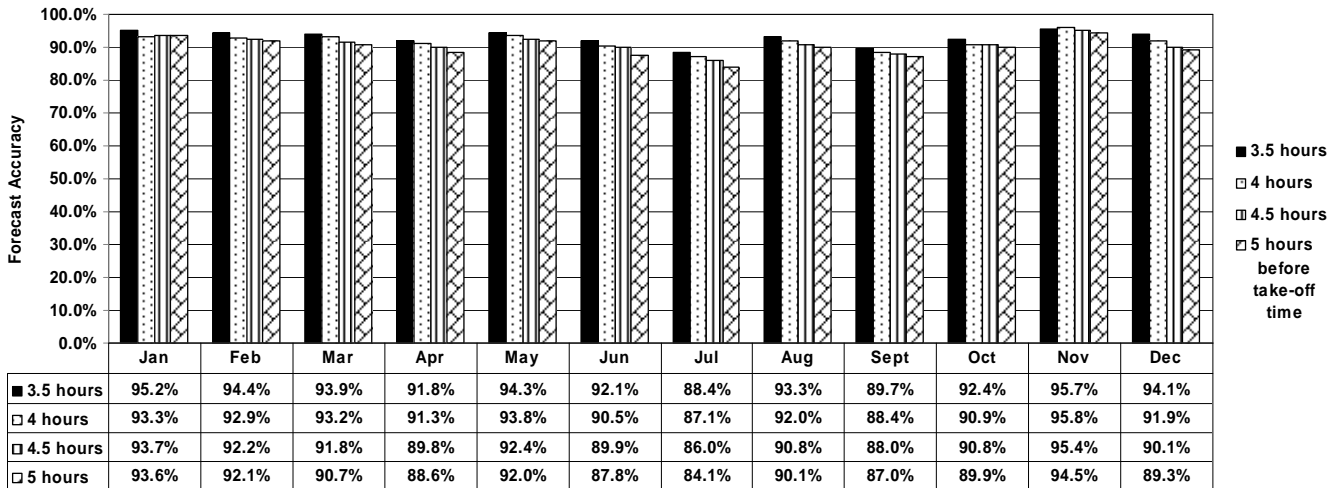


Fig. 5: Average forecast accuracy of surface air pressure issued every half hourly, and 3.5, 4.0, 4.5, and 5.0 hours before take-off times in 2008.

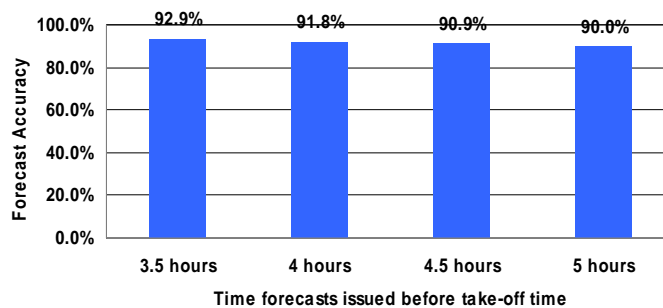


Fig. 6: Average forecast accuracy of surface air pressure in 2008.

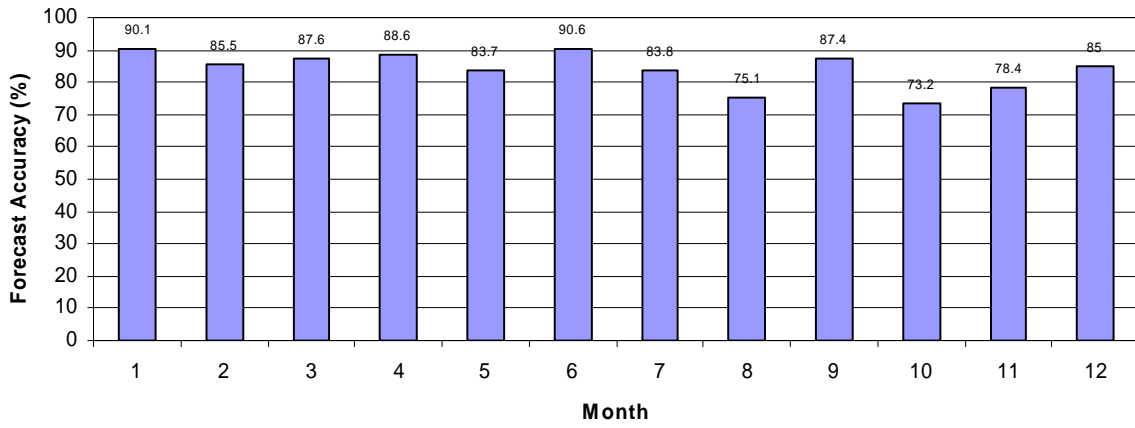


Fig. 7: Average forecast accuracy for surface air temperature on fair weather days in 2008.

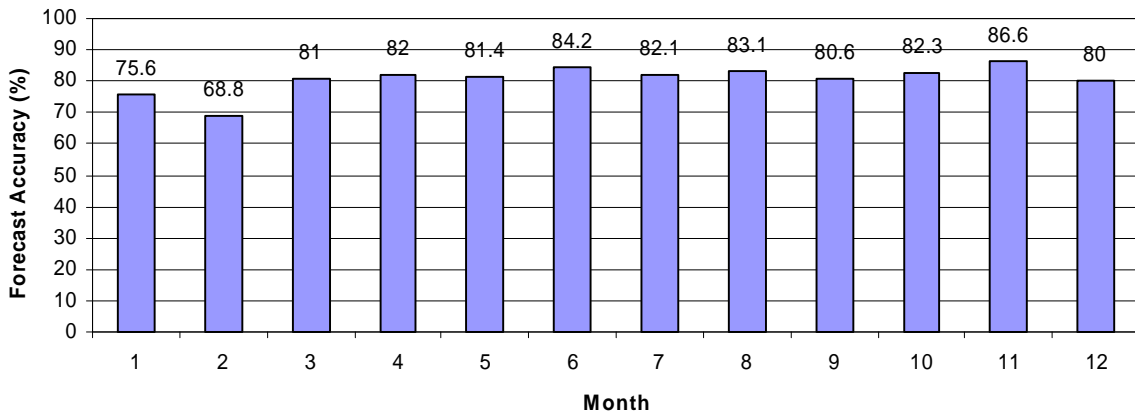


Fig. 8: Average forecast accuracy for surface dew point in 2008.

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