1994

Weather forecasting verification at Lome International Airport, Togo, West Africa

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**Weather forecasting verification at Lome International Airport,
Togo, West Africa**

Attitso, Koffigan Sitsope, M.S.

San Jose State University, 1994

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Ann Arbor, MI 48106**

**WEATHER FORECASTING VERIFICATION AT LOME
INTERNATIONAL AIRPORT, TOGO, WEST AFRICA**

**A Special Project
presented to
The Faculty of the Department of Meteorology
and Environmental Studies
San Jose State University**

**In Partial Fulfillment
of the Requirements for the Degree
Master of Science**

**by
Koffigan S. Attitso
August, 1994**

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APPROVED FOR THE DEPARTMENT OF METEOROLOGY
AND ENVIRONMENTAL STUDIES

A handwritten signature in dark ink, appearing to read "P. F. Lester", written over a horizontal line.

Peter F. Lester

A handwritten signature in dark ink, appearing to read "Douglas M. Sinton", written over a horizontal line.

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Frank R. Schiavo

APPROVED FOR THE UNIVERSITY

A handwritten signature in dark ink, appearing to read "M. Lou Lewandowski", written over a horizontal line.

Abstract

WEATHER FORECASTING VERIFICATION AT LOME INTERNATIONAL AIRPORT, TOGO, WEST AFRIC

by Koffigan S. Attitso

This project presents the weather forecast verification at the International Airport of Lome during critical times of fog and thunderstorm activity. The study examines the accuracy of weather forecasts made during the two primary wet and dry seasons of 1992 and 1993. Forecasts of ceiling, visibility, and wind are compared with the observational data for three hour time blocks. Forecast accuracy is evaluated by comparing differences between Forecast and observed data to ICAO standards and by examining the root - mean - square error (RMSE) as a function of forecast period. Forecast skill is computed on the basis of contingency tables. The results show forecast errors as function of forecast periods of three to 24 hours. RMSE reveal an error minimum for the Forecast period 9 h - 12 h, corresponding to 1500 - 1800 UTC. This result is likely due to persistent meteorological conditions that are well - known to forecasters from local climatological studies. The contingency tables showed a slight forecaster bias toward prediction of conditions that were worse than observed. In general, the results of this pilot study indicate areas for possible forecast improvement . However, a larger data sample must be examined before precise conclusions can be reached.

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1) INTRODUCTION

Weather affects many commercial activities which depend on accurate weather forecasts for safety and economy. For example, International Airline operations in Lome, Togo, West Africa can be adversely affected by fog and thunderstorms which occasionally occur in that location. Safety is of great concern and delays are costly. An important element in judging the usefulness of forecasts is forecast verification. Weather forecast verification is the formal process of comparing the predicted weather with the observed weather within the same time period.

Many studies have been done on forecast verification (Panofsky and Brier 1968; Murphy and Daan 1985; Murphy 1991; Gordon 1992 and 1993). Panofsky and Brier (1968) have presented several scientific, economic and administrative reasons for monitoring the accuracy of weather forecasts. Verification can be used to discover the weaknesses of forecasting systems in order to decide where research emphasis is needed. The main purpose of verification is to improve weather forecasts for the protection of property and of life. Also from an administrative point of view, verification can be used to determine the relative ability of different forecasters.

The International Airport at Lome is the focus of this study. Maps of the area are shown in figures 1 - 3. Lome airport is 20 meters above sea level on the West African coast. It has a tropical climate with two primary wet

and dry seasons and two transition periods. The main wet season is from May through July with thunderstorms and is followed by the less severe rainy season from August through October. The main dry season is from February Through April preceded by the less dry season from November through January.

An important aviation weather forecast problem that is difficult to assess quantitatively is morning fog day time haze. The phenomena occur in the November-January transition period. Another problem is the occurrence of thunderstorms in May-June, during the wet season. Of particular interest are associated low ceilings, strong gusty winds, and downbursts.

Lome airport is an important center for airline operations and accurate forecasts are vital. However, there have not been any systematic verifications of forecasts originating from Togo, therefore the assessment of the value of forecasts is difficult if not impossible. Also improvement of forecasting skills is difficult without knowledge of the accuracy of the weather forecasts. Take-offs and landings can be delayed for many hours due to the weather. The weather conditions may also require diversions of aircraft to the neighboring countries. These situations constitute a real problem for the airline companies and for passengers.

The purpose of this study is to verify the weather forecasts at the International Airport of Lome especially at the critical times of fog and thunderstorm activities. Verifications are made for four critical aviation weather parameters: wind direction, wind speed, visibility and ceiling.

Figure 1 : AFRICA

Figure 2 : WEST AFRICA

Figure 3: TOGO

II) VERIFICATION METHODOLOGY

A) Data

Data from weather forecasts and from weather observations constitute the two different groups of data. The forecasts are Terminal Aerodrome Forecasts (TAFs). The actual verifying weather observations from the aerodrome are the METeorological Aerodrome Reports (METARs).

1) Terminal Aerodrome Forecasts (TAFs)

The information included in the TAF and the way in which it is expressed are defined by the International Civil Aviation Organization (ICAO) and the World Meteorological Organization (WMO). The full TAF code and its breakdown are listed in the Appendix A. The forecasts are prepared at 0400 UTC (TAF 0606), 1000 UTC (TAF 1212), 1600 UTC (TAF 1818), and at 2200 UTC (TAF 0024). In this study, the TAFs prepared at 0400 UTC have been used because airline companies rely upon them for planning their daily operations.

2) METeorological Aerodrome Reports (METARs).

Similar to the TAF, METAR code is also defined by ICAO and WMO. The full METAR code and its breakdown are also given in the Appendix A. METARs are reports of the actual state of the atmosphere at the terminal and are made at every 30 minutes intervals. Besides regular METARs some

SPECIALS reports (SPECI) are made if weather conditions change significantly between two regular report times (See Appendix A).

3) Data Base

Verification data were obtained from Lome, courtesy of the Forecasting Center of Togo. These data are for the following time periods: November 15, 1992 to December 14, 1992 which will be for the fog and haze problem, and May 15, 1993 to June 13, 1993 for the thunderstorms problem.

B) Data Processing.

The verification used in this study compares the predicted TAFs with the observed METARs and SPECI within the same time period to determine Forecast errors.

The present TAFcode is that it allows forecasts of GRADUal change (GRADU) from one set of conditions to another over a period of hours or a RAPID change (RAPID) at a given hour. The TAF also allows some possible alternative that may occur TEMPOrarily (TEMPO), but never for the majority of the time. The TAF forecast period is 24 hours. Because the present code allows these often ambiguous "Change Groups" (GRADU, RAPID, and TEMPO), the direct comparison of observed weather conditions at a single time with its corresponding weather forecasts is often difficult. The TEMPO and INTER groups were interpreted to obtain possible worst-case forecast values. Any PROBability (PROB)

qualification on likelihood of alternative conditions was ignored in this study.

In view of these difficulties, the reduction of the TAF data to a suitable form was necessary before any verification process. Prior to this TAF interpretation step, TAFs and METARs were quality assured by correcting or removing any obviously incorrect information.

1) TAFs Interpretation

In this step, the coded TAFs were interpreted and reduced to a quantitative hourly dissection form, in order to obtain for each hour values of the following elements:

- * Wind Speed
- * Wind Direction
- * Visibility
- * Ceiling

In order to accomplish hourly dissection of the TAFs, linear interpolation was used to obtain values at intermediate hours. For example, if the wind direction and wind speed were forecast for 0900 UTC and 1100 UTC, the appropriate values from the TAF at 1000 UTC were obtained by assuming a linear variation of each parameter from 0900 UTC to 1100 UTC.

2) Time blocks and comparisons.

After the interpretation and the hourly dissection of the TAFs, the next step was to obtain minimum or worst values of forecast and observed conditions within a given time period defined as a "time block." The time block is the period of time over which forecasts and observations are compared. In the current study, the procedure outlined by (Gordon,1993) was followed. Three hour time blocks were used. Gordon justifies the use of three hour time blocks as follows: *" One way of looking at the choice of three hours is that, if TEMPO reduction in visibility is forecast, then there should be a high probability of its occurring at least once in three hour period, or it should not have been forecast "* (Page 254-255).

Forecasts are compared to the observational data by checking the worst forecast conditions against the worst observed for time blocks of three hours. The following specific criteria were applied:

- * **Visibility:** minimum value of visibility within the time block.
- * **Wind speed :** highest wind speed within the time block.
- * **Wind direction:** direction associated with the highest wind speed.
- * **Ceiling :** Up to 750 m, the height of the lowest layer of cloud covering more than four oktas (4/8). If no cloud is forecast, or if forecast coverage is less than four oktas, the ceiling is set to 750 m.

If forecast cloud coverage is more than four oktas and the height is more than 750 m, the ceiling is also set to 750 m. These conditions satisfy the criteria for Visual Flight Rules (VFR) in use in Togo; that is, for VFR the ceiling must be equal to or greater than 750 m.

All data tabulated in time blocks are presented in appendix B.

The procedures described in the preceding paragraphs are summarized in Table 1.

TABLE 1

Data processing procedure for verification of 0400 UTC 24- hour TAFs with METARs

For each day of the 60-day sample :

- 1) Preliminary Quality Assurance (QA) Check.**
- 2) TAFs and METARs separated into three- hour time blocks.**
- 3) Worst conditions selected for each three- hour block.**
- 4) Forecast error computed for each time block.**
- 5) Results tabulated into spreadsheet .**
- 6) Verification Statistics computed.**

iii) RESULTS AND DISCUSSION

A) ICAO Criteria

The International Civil Aviation Organization, Annex 3 (1992) presents the current guidance on the operationally desirable accuracy of forecasts. Table 2 shows the relevant criteria for the verifications for International Airport of Lome. These criteria were applied to the worst observed and worst forecast wind direction, wind speed, minimum ceiling and visibility for each time block. The percent of forecasts at Lome that were within the ICAO limits are also given in table 2.

Note that the visibility forecasts for the May-June sample and the ceiling forecasts for November-December sample satisfied the ICAO criteria. The most problematic forecasts were visibility, wind speed and direction forecasts for November-December period. The latter ranged from 10% to 12% below ICAO criteria.

B) Contingency Tables

The contingency tables for ceiling and visibility were prepared from all time block samples. Results are presented in Table 3 and 4 for ceiling, and Tables 5 and 6 for visibility. For the sample 1992 case the frequency of forecast visibilities in the greater than 8000 m category (40.8 %) is greater than that observed (37.5 %) and that for 5000 m to 8000 m (25.4 %) is

equal to that observed (25.4 %). The frequency of forecast visibility for 3000 m to 5000 m category (17.9 % is less than that observed (21.2 %). This indicates a slight negative bias to the forecasts for that period; that is, forecasted visibilities showed a systematic error toward lower than observed values.

C) RMSE

RMSE is defined as follows. If in a series of N forecasts, F_i represents the i -th forecast and O_i the corresponding observation, then

$$RMSE = \sqrt{\frac{\sum (F_i - O_i)^2}{N}}$$

RMSE for ceiling , visibility, wind speed and direction were computed for both samples.

Results are presented in Figures 4 and 5 for wind speed, 6 and 7 for wind direction, 8 and 9 for visibility, and 10 and 11 for ceiling.

TABLE 2

Operationally desirable accuracy of aerodrome forecast (TAFs) as given in ICAO Annex 3.

Forecast Element	Operationally Desirable Accuracy of Forecast		Actual % of Forecasts within Desirable range for Lome	
	Range	% of Forecasts	Nov.- Dec. 1992	May - June 1993
Wind Direction	+ 30 degree	80 %	70 %	78 %
Wind Speed	+ 5 kt up to 25 kt	80 %	68 %	75 %
	+ 20 % above 25 kt			
Visibility	+ 200 m up to 700 m	80 %	70 %	93 %
	+ 30 % 700m to 10000m			
Ceiling Height	+ 30 m up to 120 m	70 %	90 %	66 %
	+ 30 % 120m to 750m			

TABLE 3 : Contingency Table for Ceiling (meters) : Nov.- Dec.1992

		Observed Ceiling (meters)				Total	Fraction%
		<300	300 to 500	>500 to 700	>700		
Forecast Ceiling	<300	0	0	0	0	0	0
	300-500	0	12	3	14	14	5.8
	>500-700	0	0	0	3	3	1.2
	>700	0	10	7	206	223	92.9
	Total	0	10	7	223	240	
Fraction		0	4.1	2.9	92.9		

TABLE 4 : Contingency Table for Ceiling (meters) : May- June 1993

		Observed Ceiling (meters)				Total	Fraction%
		<300	300 to 500	>500 to 700	>700		
Forecast Ceiling	<300	0	0	0	0	0	0
	300-500	0	0	3	18	33	13.7
	>500-700	0	0	0	6	6	2.5
	>700	0	21	7	197	201	83.7
	Total	0	33	10	197	240	
Fraction		0	13.7	4.1	82.1		

TABLE 5: Contingency Table for Visibility (KM): Nov.- Dec.1992

		Observed Visibility (KM)						
		<1.5	1.5-3	3-5	5-8	>8	Total	Fraction%
Forecast Visibility	<1.5	0	0	0	0	0	0	0
	1.5-3	0	25	11	2	0	38	15.8
	>3-5	0	11	23	6	3	43	17.9
	>5-8	0	2	8	37	14	61	25.4
	>8	0	0	9	16	73	98	40.8
Total		0	38	51	61	90	240	
Fraction%		0	15.8	21.2	25.4	37.5		

TABLE 6: Contingency Table for Visibility (KM): May-June1993

		Observed Visibility (KM)					Total	Fraction%
		<1.5	1.5-3	3-5	5-8	>8		
Forecast Visibility	<1.5	0	0	0	0	0	0	0
	1.5-3	0	0	0	0	0	0	0
	>3-5	0	0	0	0	5	5	2.1
	>5-8	0	0	0	0	10	10	4.1
	>8	0	0	1	19	205	225	93.7
Total		0	0	1	19	220	240	
Fraction%		0	0	0.4	7.9	91.6		

RMSE TAF - FF

(1992)

Figure 4 : RMSE for Wind Speed

RMSE TAF - FF

(1993)

Figure 5 : RMSE for Wind Speed

RMSE TAF - DD

(1992)

Figure 6 : RMSE for Wind Direction

RMSE TAF - DD

(1993)

Figure 7 : RMSE for Wind Direction

RMSE TAF - VIS (1992)

Figure 8 : RMSE for Visibility

RMSE TAF - VIS

(1993)

Figure 9 : RMSE for Visibility

RMSE TAF - Ceiling (1992)

Figure 10 : RMSE for Ceiling

RMSE TAF - Ceiling (1993)

Figure 11 : RMSE for Ceiling

The RMSE computations and plots show forecast accuracy at three hour intervals during the 24 hour TAF forecast period. An interesting result is that for nearly all variables, there is a significant decrease in RMSE to a minimum between the 3-6 hour and 9-12 hour time blocks. This behavior is in contrast to mid - latitude stations where the error usually increases as forecast period increases (e.g., see Gordon, 1993). The result in this study is also notable in that, most of RMSE values are not exceptionally large in the shorter forecast period, but rather they are exceptionally small in the intermediate periods.

The cause of the minimum in the RMSE curves is most likely related to persistent conditions that are characteristic of tropical regions and are often best defined in the afternoon. For example, for May-June 1993 the consistency of the Southwest wind direction and the speed with the afternoon breeze, the regularity of the afternoon thunderstorms, and the good visibilities and ceilings in the afternoon partially explain the early decrease in RMSE during the day. During November-December 1992, the regularity of the Northeast trade winds, the permanent haze that reduces visibility in the afternoon, and the low frequency of ceilings during the period of study are the most likely cause of the midday RMSE minimum.

VI) CONCLUSIONS

In general, the project has given the weather community in Togo an opportunity to examine accuracy of 24 hours forecasts of wind speed, wind direction, visibility and ceiling. For the first time, it has opened a window for the general application of a verification system to enhance and improve the techniques and current methods of forecasting. Systematic verification provides forecasters tangible information for the identification of sources of forecast errors. It also helps the management such as selecting promising personnel for further training in forecasting, selecting research personnel and rating the efficiency of forecasters. The verification gives important attention to aviation forecasting and the objective evaluation of the accuracy of these forecasts. It is clear that weather forecast verification is a vital component to improving weather forecast services for the growing aviation community in Togo.

The specific results of the present study suggest that although certain forecasts are quite accurate, efforts should be expended to improve wind speed, wind direction, ceiling and visibility forecast at Togo bring them up to WMO standards.

RMSE indicate that improvements could possibly be made both in the first few hours of the 24 hour TAF forecast period and in the last few. Typically, two types of improvements are required: better observations in the short range, better forecast meteorology in in the long range.

The use of new equipment in weather forecasts such as the Doppler Weather RADAR, weather satellite, and computers with numerical

prediction software will increase the accuracy of weather forecasts in the future. The current work should be considered a pilot study. Quantitative results are tentative and should be interpreted carefully since the data samples were very small. More verifications are needed.

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Appendix A

TAFs and METARS Code Breakdowns

TAF
 KPIT 091720Z 1818 22020KT 3SM -SHRA BKN020 FM20 30015G25KT 3SM
 SHRA OVC015 PROB40 2022 1/2SM TSRA OVC008CB FM23 27008KT
 5SM -SHRA BKN020 OVC040 TEMPO 0407 00000KT 1SM -RA FG FM10
 20010KT 5SM -SHRA OVC020 BECMG 1315 20010KT P6SM NSW SKC

METAR
 KPIT 1955Z 22015G25KT 3/4SM R22L/2700FT TSRA OVC010CB 18/16 A2992

Forecast	Explanation	Report
TAF	Message type: TAF-routine and TAF AMD-amended forecast, METAR-hourly and SPECI-special report	METAR
KPIT	ICAO location indicator	KPIT
091720Z	Issuance time: ALL times in UTC "Z", 2-digit date and 4-digit time for TAF, 4-digit time for METAR	1955Z
1818	Valid period: first 2 digits begins and last 2 ends forecast	
22020KT	Wind: first 3 digits mean true-north direction, nearest 10 degrees, (or Variable); next 2 digits mean speed and unit, KT, (KMH or MPS); as needed, Gust and 2-digit maximum speed: 00000KT for calm; (for reports only, if direction varies 60 degrees or more, Variability appended, e.g., 180V260)	22015G25KT
3SM	Prevailing visibility: in U.S., Statute Miles & fractions: above 6 miles in TAF Plus 6SM. (Or, 4-digit minimum visibility in meters and as required, lowest value with direction)	3/4SM
	Runway Visual Range: R; 2-digit runway designator Left, Center, or Right as needed; "I": Minus or Plus in U.S., 4-digit value, Feet in U.S., (usually meters elsewhere); Variability (and tendency Down, Up or No change)	R22L/2700FT
-SHRA	Significant present, forecast and recent weather: see table	TSRA
BKN020	Cloud amount, height and type: SKy Clear, SCaTtered, BroKeN, OVerCast; 3-digit height in hundreds of feet; and either Towering CUmulus or CumulonimBus. Or Vertical Visibility for obscured sky and height "VV004", or unknown height "VV///". More than one-layer may be forecast or reported. Clear for "clear below 12 thousand feet" at automated observation sites.	OVC010CB
	Temperature: in degrees Celsius; first 2 digits, temperature "I" less 2 digits, dew-point temperature; below zero reported with Minus; e.g., M06	18/16
	Altimeter setting: indicator and 4 digits; in U.S., A-inches and hundredths; (Q-hectoPascals, e.g., Q1017)	A2992

	Supplementary information to report: (Wind Shear in lower layers, LandIng or TakeOff, RunWay, 2-digit designation; REcent weather of operational significance.) ReMark: Automated Observation or AOAugmented: wind shear; recent weather and time; and TORNADO, FUNNEL CLOUD, WATERSPOUT	
FM20	From and 2-digit hour: indicates significant change	
PROB40	PROBability and 2-digit percent: probable condition during 2-digit beginning and 2-digit ending time period	
2022		
TEMPO	TEMPOrary: changes expected for less than 1 hour and in total less than half of 2-digit beginning and 2-digit ending time period	
0407		
BECMG	BECOMing: change expected during 2-digit beginning and 2-digit ending time period	
1315		

Table of Significant Present, Forecast and Recent Weather - Grouped in categories and used in the order listed below: or as needed in TAF, No Significant Weather.

QUALIFIER			
Intensity or Proximity			
- Light	- no sign	- Moderate	- Heavy
VC Vicinity: but not at aerodrome; in U.S., 5-10SM from center of runway complex (elsewhere within 8000m)			
Descriptor			
MI Shallow	EC Patches	DR Drifting	TS Thunderstorm
BL Blowing	SH Showers	FZ Supercooled/freezing	
WEATHER PHENOMENA			
Precipitation			
DZ Drizzle	RA Rain	SN Snow	SG Snow grains
IC Diamond dust	PE Ice pellets	GR Hail	GS Small hail/snow pellets
UP Unknown precipitation in automated observations			
Obscuration			
BR Mist	FG Fog	FU Smoke	VA Volcanic ash
SA Sand	HZ Haze	PY Spray	DU Widespread dust
Other			
SQ Squall	SS Sandstorm	DS Duststorm	PO Well developed dust and whirls
FC Funnel cloud/tornado/waterspout			

Explanations in parentheses "()" indicate different worldwide practices: Ceiling named as the lowest broken or overcast layer, or the vertical visibility. Automated Observations may be Augmented manually for certain weather phenomena. TAFs exclude temperature, turbulence and icing forecasts and METARs exclude trend forecasts. Although not used in U.S., Ceiling And Visibility OK replaces visibility, weather and clouds if: visibility is 10 kilometers or more; no cloud below 1500 meters (5000 feet) or below the highest minimum sector altitude, whichever is greater and no precipitation; and no precipitation, thunderstorm, duststorm, sandstorm, shallow fog, or low drifting dust, sand or snow.

March 1993
NOAA/PA 93054

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration - National Weather Service

Appendix B

TABULATED DATA

Each page shows one Forecast (F) and Observed (O) parameter tabulated in eight three-hour time blocks.

Group 1: 700 UTC to 900 UTC

Group 2: 1000 UTC to 1200 UTC

Group 3: 1300 UTC to 1500 UTC

Group 4: 1600 UTC to 18 00 UTC

Group 5: 1900 UTC to 2100 UTC

Group 6: 2200 UTC to 2400 UTC

Group 7: 0100 UTC to 0300 UTC

Group 8: 0400 UTC to 0600 UTC

Nov15	Group1		Group2		Group3		Group4		Group5		Group6		Group7		Group8		Group9		Group10		Group11		Group12		Group13		Group14		Group15		Group16		Group17		Group18		Group19		Group20		Group21		Group22		Group23		Group24		Group25		Group26		Group27		Group28		Group29		Group30		Group31		Group32		Group33		Group34		Group35		Group36		Group37		Group38		Group39		Group40		Group41		Group42		Group43		Group44		Group45		Group46		Group47		Group48		Group49		Group50		Group51		Group52		Group53		Group54		Group55		Group56		Group57		Group58		Group59		Group60		Group61		Group62		Group63		Group64		Group65		Group66		Group67		Group68		Group69		Group70		Group71		Group72		Group73		Group74		Group75		Group76		Group77		Group78		Group79		Group80		Group81		Group82		Group83		Group84		Group85		Group86		Group87		Group88		Group89		Group90		Group91		Group92		Group93		Group94		Group95		Group96		Group97		Group98		Group99		Group100																																																																																																																																																																																											
	Nov15	Nov16	Nov17	Nov18	Nov19	Nov20	Nov21	Nov22	Nov23	Nov24	Nov25	Nov26	Nov27	Nov28	Nov29	Nov30	Dec1	Dec2	Dec3	Dec4	Dec5	Dec6	Dec7	Dec8	Dec9	Dec10	Dec11	Dec12	Dec13	Dec14	Dec15	Dec16	Dec17	Dec18	Dec19	Dec20	Dec21	Dec22	Dec23	Dec24	Dec25	Dec26	Dec27	Dec28	Dec29	Dec30	Dec31	Jan1	Jan2	Jan3	Jan4	Jan5	Jan6	Jan7	Jan8	Jan9	Jan10	Jan11	Jan12	Jan13	Jan14	Jan15	Jan16	Jan17	Jan18	Jan19	Jan20	Jan21	Jan22	Jan23	Jan24	Jan25	Jan26	Jan27	Jan28	Jan29	Jan30	Jan31	Feb1	Feb2	Feb3	Feb4	Feb5	Feb6	Feb7	Feb8	Feb9	Feb10	Feb11	Feb12	Feb13	Feb14	Feb15	Feb16	Feb17	Feb18	Feb19	Feb20	Feb21	Feb22	Feb23	Feb24	Feb25	Feb26	Feb27	Feb28	Feb29	Feb30	Mar1	Mar2	Mar3	Mar4	Mar5	Mar6	Mar7	Mar8	Mar9	Mar10	Mar11	Mar12	Mar13	Mar14	Mar15	Mar16	Mar17	Mar18	Mar19	Mar20	Mar21	Mar22	Mar23	Mar24	Mar25	Mar26	Mar27	Mar28	Mar29	Mar30	Mar31	Apr1	Apr2	Apr3	Apr4	Apr5	Apr6	Apr7	Apr8	Apr9	Apr10	Apr11	Apr12	Apr13	Apr14	Apr15	Apr16	Apr17	Apr18	Apr19	Apr20	Apr21	Apr22	Apr23	Apr24	Apr25	Apr26	Apr27	Apr28	Apr29	Apr30	May1	May2	May3	May4	May5	May6	May7	May8	May9	May10	May11	May12	May13	May14	May15	May16	May17	May18	May19	May20	May21	May22	May23	May24	May25	May26	May27	May28	May29	May30	May31	Jun1	Jun2	Jun3	Jun4	Jun5	Jun6	Jun7	Jun8	Jun9	Jun10	Jun11	Jun12	Jun13	Jun14	Jun15	Jun16	Jun17	Jun18	Jun19	Jun20	Jun21	Jun22	Jun23	Jun24	Jun25	Jun26	Jun27	Jun28	Jun29	Jun30	Jul1	Jul2	Jul3	Jul4	Jul5	Jul6	Jul7	Jul8	Jul9	Jul10	Jul11	Jul12	Jul13	Jul14	Jul15	Jul16	Jul17	Jul18	Jul19	Jul20	Jul21	Jul22	Jul23	Jul24	Jul25	Jul26	Jul27	Jul28	Jul29	Jul30	Jul31	Aug1	Aug2	Aug3	Aug4	Aug5	Aug6	Aug7	Aug8	Aug9	Aug10	Aug11	Aug12	Aug13	Aug14	Aug15	Aug16	Aug17	Aug18	Aug19	Aug20	Aug21	Aug22	Aug23	Aug24	Aug25	Aug26	Aug27	Aug28	Aug29	Aug30	Aug31	Sep1	Sep2	Sep3	Sep4	Sep5	Sep6	Sep7	Sep8	Sep9	Sep10	Sep11	Sep12	Sep13	Sep14	Sep15	Sep16	Sep17	Sep18	Sep19	Sep20	Sep21	Sep22	Sep23	Sep24	Sep25	Sep26	Sep27	Sep28	Sep29	Sep30	Oct1	Oct2	Oct3	Oct4	Oct5	Oct6	Oct7	Oct8	Oct9	Oct10	Oct11	Oct12	Oct13	Oct14	Oct15	Oct16	Oct17	Oct18	Oct19	Oct20	Oct21	Oct22	Oct23	Oct24	Oct25	Oct26	Oct27	Oct28	Oct29	Oct30	Oct31	Nov1	Nov2	Nov3	Nov4	Nov5	Nov6	Nov7	Nov8	Nov9	Nov10	Nov11	Nov12	Nov13	Nov14	Nov15	Nov16	Nov17	Nov18	Nov19	Nov20	Nov21	Nov22	Nov23	Nov24	Nov25	Nov26	Nov27	Nov28	Nov29	Nov30	Dec1	Dec2	Dec3

B-3

Wind Speed: in KT - LOWE INTERNATIONAL AIRPORT - TOGO (1993) GROUP1=7.00 to 9.00 - GROUP2=4.00 to 6.00 UTC(NEXT DAY)

	May15	Group1	Group2	Group3	Group4	Group5	Group6	Group7	Group8	May18	Group1	Group2	Group3	Group4	Group5	Group6	Group7	Group8	May17	Group1	Group2	Group3	Group4	Group5	Group6	Group7	Group8	S
F	6	16	16	16	10	11	6	6	6	7	10	10	10	10	10	10	10	10	4	8	8	8	8	8	8	8	8	8
O	22	4	4	4	18	18	4	4	4	4	6	6	6	6	6	6	6	6	2	8	8	8	8	8	8	8	8	
E	16	12	12	12	5	10	2	2	2	3	4	4	4	4	4	4	4	4	0	0	0	0	0	0	0	0	0	
E2	258	144	144	144	25	100	4	4	4	May19	9	16	16	33	4	38	64	64	May20	0	0	0	0	0	0	0	0	130
F	6	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	May20	0	0	0	0	0	0	0	1158	
O	6	6	10	12	10	10	6	6	6	8	8	10	10	12	4	2	2	2	2	2	6	6	6	6	6	6	6	
E	2	0	2	4	2	2	2	2	2	0	2	2	4	4	4	6	6	6	2	4	4	4	4	4	4	4	78	
E2	4	0	4	4	4	4	4	4	4	May22	0	4	4	16	16	36	36	36	May23	4	16	16	16	16	36	16	16	324
F	7	10	10	10	10	10	10	10	10	4	8	8	8	8	8	8	8	8	8	10	10	10	10	10	10	10	10	
O	6	6	10	12	8	6	2	2	2	6	6	6	6	8	8	8	8	8	6	10	10	10	10	8	8	8	8	
E	1	4	0	2	4	8	8	8	8	2	2	0	0	0	0	2	0	4	0	0	0	2	0	0	2	2	2	
E2	1	16	0	4	4	16	64	64	64	4	4	0	0	0	0	4	0	0	0	0	0	2	0	0	0	0	8	
F	6	8	8	8	25	25	25	25	25	May25	10	10	10	10	10	8	8	8	May26	30	6	7	8	8	8	8	8	
O	6	6	8	8	8	6	2	4	4	6	10	12	12	12	4	2	2	2	6	6	8	8	8	8	8	8	8	
E	2	2	0	0	17	19	23	21	21	4	0	2	2	4	2	4	4	4	24	0	1	0	6	6	6	6	153	
E2	4	4	0	0	0	269	391	520	441	May28	16	0	4	4	16	4	16	4	576	0	1	0	0	36	36	36	36	2413
F	10	10	10	10	9	8	8	8	8	6	10	10	10	10	8	8	8	8	May29	5	10	10	10	7	4	4	4	
O	6	8	10	10	6	6	4	4	4	6	8	16	6	4	2	2	2	2	6	8	10	8	6	6	6	6	6	
E	4	2	0	0	3	2	4	2	2	2	6	4	6	6	36	36	16	16	1	2	2	0	1	2	2	2	2	
E2	16	4	0	0	0	9	4	16	4	May31	4	36	16	36	36	36	16	16	June1	4	4	0	1	4	4	4	4	
F	7	10	10	10	10	10	10	8	8	4	10	10	10	10	4	4	4	4	4	8	10	12	12	4	4	4	4	
O	6	8	10	10	10	6	6	6	6	8	10	12	10	6	2	0	2	2	6	8	6	4	2	2	2	2	2	
E	1	0	0	0	0	4	2	0	4	4	0	2	0	4	2	4	4	4	0	0	0	6	10	2	2	2	2	
E2	1	0	0	0	0	16	4	0	0	June3	16	0	4	0	16	4	4	4	June4	0	0	16	64	100	4	4	4	
F	4	8	12	10	9	5	5	5	5	5	12	12	12	6	5	5	5	5	5	5	10	9	8	8	8	8	8	
O	6	8	10	6	12	6	4	2	4	6	4	10	12	6	2	2	2	2	4	8	8	10	6	6	6	6	6	
E	2	0	2	4	3	3	1	3	1	8	2	0	3	3	3	3	3	3	1	3	2	1	2	2	2	2	2	
E2	4	0	4	16	9	9	1	9	1	64	1	64	4	0	8	8	8	8	1	9	4	1	4	4	39	38	252	
F	12	11	10	10	8	6	6	6	6	14	14	14	14	14	11	8	8	8	5	5	15	15	10	6	5	3	3	
O	4	8	10	12	2	2	2	2	2	4	6	8	10	8	4	4	4	4	4	6	10	10	8	4	4	4	4	
E	6	3	0	2	6	4	4	4	4	10	8	8	4	3	2	2	2	2	1	1	5	5	2	2	2	2	2	
E2	64	9	0	4	36	16	16	16	16	100	64	36	16	9	4	4	4	4	1	1	25	25	4	4	1	1	1	472
F	6	8	10	10	10	10	10	10	10	8	8	8	8	8	8	8	8	8	10	10	10	10	10	8	8	8	8	
O	6	8	10	10	8	2	2	2	2	6	10	12	10	6	10	2	2	2	8	10	8	8	4	4	4	4	4	
E	0	0	0	0	0	2	6	6	6	2	2	2	2	2	2	6	6	6	2	0	2	2	4	2	4	4	4	
E2	0	0	0	0	0	4	64	64	64	4	4	16	4	4	4	4	36	36	4	0	4	4	16	4	16	16	16	
F	4	16	16	16	12	10	6	6	6	8	10	10	10	10	10	10	10	10	8	12	12	12	10	6	6	6	6	
O	6	8	12	10	6	4	4	4	4	8	10	12	10	8	8	8	8	8	8	10	12	10	10	6	4	4	4	
E	4	8	4	8	6	0	0	0	0	0	0	2	0	2	4	4	4	4	2	2	0	0	0	2	2	2	2	
E2	16	64	16	36	36	36	0	0	0	0	0	0	0	0	4	4	16	64	4	4	4	0	0	4	4	4	4	

F = FORECAST(TAF)

O = OBSERVATION(METAR)

E = [F-Q] ABSOLUTE ERROR

E2 = E^E

S = SUM

Visibility: in KM - LOME INTERNATIONAL AIRPORT. TODD (1992) GROUP1 = 7.00 to 9.00... GROUP2 = 4.00 to 6.00 UTC(NEXT DAY)

	Nov 15				Nov 16				Nov 17				Nov 18				Nov 19				Nov 20				Nov 21				Nov 22				Nov 23				Nov 24				Nov 25				Nov 26				Nov 27				Nov 28				Nov 29				Nov 30				Dec 1				Dec 2				Dec 3				Dec 4				Dec 5				Dec 6				Dec 7				Dec 8				Dec 9				Dec 10				Dec 11				Dec 12				Dec 13				Dec 14				Dec 15				Dec 16				Dec 17				Dec 18				Dec 19				Dec 20				Dec 21				Dec 22				Dec 23				Dec 24				Dec 25				Dec 26				Dec 27				Dec 28				Dec 29				Dec 30				Dec 31				Jan 1				Jan 2				Jan 3				Jan 4				Jan 5				Jan 6				Jan 7				Jan 8				Jan 9				Jan 10				Jan 11				Jan 12				Jan 13				Jan 14				Jan 15				Jan 16				Jan 17				Jan 18				Jan 19				Jan 20				Jan 21				Jan 22				Jan 23				Jan 24				Jan 25				Jan 26				Jan 27				Jan 28				Jan 29				Jan 30				Jan 31				Feb 1				Feb 2				Feb 3				Feb 4				Feb 5				Feb 6				Feb 7				Feb 8				Feb 9				Feb 10				Feb 11				Feb 12				Feb 13				Feb 14				Feb 15				Feb 16				Feb 17				Feb 18				Feb 19				Feb 20				Feb 21				Feb 22				Feb 23				Feb 24				Feb 25				Feb 26				Feb 27				Feb 28				Feb 29				Feb 30				Mar 1				Mar 2				Mar 3				Mar 4				Mar 5				Mar 6				Mar 7				Mar 8				Mar 9				Mar 10				Mar 11				Mar 12				Mar 13				Mar 14				Mar 15				Mar 16				Mar 17				Mar 18				Mar 19				Mar 20				Mar 21				Mar 22				Mar 23				Mar 24				Mar 25				Mar 26				Mar 27				Mar 28				Mar 29				Mar 30				Mar 31				Apr 1				Apr 2				Apr 3				Apr 4				Apr 5				Apr 6				Apr 7				Apr 8				Apr 9				Apr 10				Apr 11				Apr 12				Apr 13				Apr 14				Apr 15				Apr 16				Apr 17				Apr 18				Apr 19				Apr 20				Apr 21				Apr 22				Apr 23				Apr 24				Apr 25				Apr 26				Apr 27				Apr 28				Apr 29				Apr 30				May 1				May 2				May 3				May 4				May 5				May 6				May 7				May 8				May 9				May 10				May 11				May 12				May 13				May 14				May 15				May 16				May 17				May 18				May 19				May 20				May 21				May 22				May 23				May 24				May 25				May 26				May 27				May 28				May 29				May 30				May 31				Jun 1				Jun 2				Jun 3				Jun 4				Jun 5				Jun 6				Jun 7				Jun 8				Jun 9				Jun 10				Jun 11				Jun 12				Jun 13				Jun 14				Jun 15				Jun 16				Jun 17				Jun 18				Jun 19				Jun 20				Jun 21				Jun 22				Jun 23				Jun 24				Jun 25				Jun 26				Jun 27				Jun 28				Jun 29				Jun 30				Jul 1				Jul 2				Jul 3				Jul 4				Jul 5				Jul 6				Jul 7				Jul 8				Jul 9				Jul 10				Jul 11				Jul 12				Jul 13				Jul 14				Jul 15				Jul 16				Jul 17				Jul 18				Jul 19				Jul 20				Jul 21				Jul 22				Jul 23				Jul 24				Jul 25				Jul 26				Jul 27				Jul 28				Jul 29				Jul 30				Jul 31				Aug 1				Aug 2				Aug 3				Aug 4				Aug 5				Aug 6				Aug 7				Aug 8				Aug 9				Aug 10				Aug 11				Aug 12				Aug 13				Aug 14				Aug 15				Aug 16				Aug 17				Aug 18				Aug 19				Aug 20				Aug 21				Aug 22				Aug 23				Aug 24				Aug 25				Aug 26				Aug 27				Aug 28				Aug 29				Aug 30				Aug 31				Sep 1				Sep 2				Sep 3				Sep 4				Sep 5				Sep 6				Sep 7				Sep 8				Sep 9				Sep 10				Sep 11				Sep 12				Sep 13				Sep 14				Sep 15				Sep 16				Sep 17				Sep 18				Sep 19				Sep 20				Sep 21				Sep 22				Sep 23				Sep 24				Sep 25				Sep 26				Sep 27				Sep 28				Sep 29				Sep 30				Oct 1				Oct 2				Oct 3				Oct 4				Oct 5				Oct 6				Oct 7				Oct 8				Oct 9				Oct 10				Oct 11				Oct 12				Oct 13				Oct 14				Oct 15				Oct 16				Oct 17				Oct 18				Oct 19				Oct 20				Oct 21				Oct 22				Oct 23				Oct 24				Oct 25				Oct 26				Oct 27				Oct 28				Oct 29				Oct 30				Oct 31				Nov 1				Nov 2				Nov 3				Nov 4				Nov 5				Nov 6				Nov 7				Nov 8				Nov 9				Nov 10				Nov 11				Nov 12				Nov 13				Nov 14				Nov 15				Nov 16				Nov 17				Nov 18				Nov 19				Nov 20				Nov 21				Nov 22				Nov 23				Nov 24				Nov 25				Nov 26				Nov 27				Nov 28				Nov 29				Nov 30				Dec 1				Dec 2				Dec 3				Dec 4				Dec 5				Dec 6				Dec 7				Dec 8				Dec 9				Dec 10				Dec 11				Dec 12				Dec 13				Dec 14				Dec 15				Dec 16				Dec 17				Dec 18				Dec 19				Dec 20				Dec 21				Dec 22				Dec 23				Dec 24				Dec 25				Dec 26				Dec 27				Dec 28				Dec 29				Dec 30				Dec 31				Jan 1				Jan 2				Jan 3				Jan 4				Jan 5				Jan 6				Jan 7				Jan 8				Jan 9				Jan 10				Jan 11				Jan 12				Jan 13				Jan 14				Jan 15				Jan 16				Jan 17				Jan 18				Jan 19				Jan 20				Jan 21				Jan 22				Jan 23				Jan 24				Jan 25				Jan 26				Jan 27				Jan 28				Jan 29				Jan 30				Jan 31				Feb 1				Feb 2				Feb 3				Feb 4				Feb 5				Feb 6				Feb 7				Feb 8				Feb 9				Feb 10				Feb 11				Feb 12				Feb 13				Feb 14				Feb 15				Feb 16				Feb 17				Feb 18				Feb 19				Feb 20				Feb 21				Feb 22				Feb 23				Feb 24				Feb 25				Feb 26				Feb 27				Feb 28				Feb 29				Feb 30				Mar 1				Mar 2				Mar 3				Mar 4				Mar 5				Mar 6				Mar 7				Mar 8				Mar 9				Mar 10				Mar 11				Mar 12				Mar 13				Mar 14				Mar 15				Mar 16				Mar 17				Mar 18				Mar 19				Mar 20				Mar 21				Mar 22				Mar 23				Mar 24				Mar 25				Mar 26				Mar 27				Mar 28				Mar 29				Mar 30				Mar 31				Apr 1				Apr 2				Apr 3				Apr 4				Apr 5				Apr 6				Apr 7				Apr 8				Apr 9				Apr 10				Apr 11				Apr 12				Apr 13				Apr 14				Apr 15				Apr 16				Apr 17				Apr 18				Apr 19				Apr 20				Apr 21				Apr 22				Apr 23				Apr 24				Apr 25				Apr 26				Apr 27				Apr 28				Apr 29				Apr 30				May 1				May 2				May 3				May 4				May 5				May 6				May 7				May 8				May 9				May 10				May 11				May 12				May 13				May 14				May 15				May 16				May 17				May 18				May 19				May 20				May 21				May 22				May 23				May 24				May 25				May 26				May 27				May 28				May 29				May 30				May 31				Jun 1				Jun 2				Jun 3				Jun 4				Jun 5				Jun 6				Jun 7				Jun 8				Jun 9				Jun 10				Jun 11				Jun 12				Jun 13				Jun 14				Jun 15				Jun 16				Jun 17				Jun 18				Jun 19				Jun 20				Jun 21				Jun 22				Jun 23				Jun 24				Jun 25				Jun 26				Jun 27				Jun 28				Jun 29				Jun 30				Jul 1				Jul 2				Jul 3				Jul 4				Jul 5				Jul 6				Jul 7				Jul 8				Jul 9				Jul 10				Jul 11				Jul 12				Jul 13				Jul 14				Jul 15				Jul 16				Jul 17				Jul 18				Jul 19				Jul 20				Jul 21				Jul 22				Jul 23				Jul 24				Jul 25				Jul 26				Jul 27				Jul 28				Jul 29				Jul 30				Jul 31				Aug 1				Aug 2				Aug 3				Aug 4				Aug 5				Aug 6				Aug 7				Aug 8				Aug 9				Aug 10				Aug 11				Aug 12				Aug 13				Aug 14				Aug 15				Aug 16				Aug 17				Aug 18				Aug 19				Aug 20				Aug 21				Aug 22				Aug 23				Aug 24				Aug 25				Aug 26				Aug 27				Aug 28				Aug 29				Aug 30				Aug 31				Sep 1				Sep 2				Sep 3				Sep 4				Sep 5				Sep 6				Sep 7				Sep 8				Sep 9				Sep 10				Sep 11				Sep 12				Sep 13				Sep 14				Sep 15				Sep 16				Sep 17				Sep 18				Sep 19				Sep 20				Sep 21				Sep 22				Sep 23				Sep 24				Sep 25				Sep 26				Sep 27				Sep 28				Sep 29				Sep 30				Oct 1				Oct 2				Oct 3				Oct 4				Oct 5				Oct 6				Oct 7				Oct 8				Oct 9				Oct 10				Oct 11				Oct 12				Oct 13				Oct 14				Oct 15				Oct 16				Oct 17				Oct 18				Oct 19				Oct 20				Oct 21				Oct 22				Oct 23				Oct 24				Oct 25				Oct 26				Oct 27				Oct 28				Oct 29				Oct 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