PACIFIC REGION TECHNICAL NOTES

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A Vector Verification Scheme

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INTRODUCTION

The development and implementation of a forecast verification and quality control system has in recent years increased in importance because of the escalating costs in providing forecast services. Until recently most thorough verification schemes have been impractical due to the large requirement for "labour-intensive" tasks such as assembling data, encoding data, and calculating numerous comparative statistics and scores. With the present availability of minicomputers and their increased disc storage capacities the "labour-intensive" tasks can now be borne by the regional electronic data processing units. Full exploitation of machine processing requires the adequate encoding of observations and worded forecasts into a comparable code which will result in the most flexible data base for which the most useful verification statistics and displays can be generated.

The purpose of this note is to introduce a "Vector Verification Scheme" which may achieve these results.

ENCODING OF FORECASTS AND OBSERVATIONS

It is proposed that the forecasts and observations be conceptually encoded in an "n-dimensional" space and represented as individual vectors as shown below:

Vector Form $V(\text{Qualifier, Time, Element}_1\text{, Element}_2\text{,....., Element}_n)$

The qualifier term is used to describe the nature of the encoded data. Examples of qualifiers for forecasts are: "MC" for main criteria during the forecast period, "VR" for variable, and "OC" for occasional. Examples of qualifiers for observations are: "SA" for regular aviation observations, "RS" for regular special observations and "SP" for special aviation observations. It is envisioned that most observations and worded forecasts could be encoded in this manner. Figure 1 illustrates the operational procedures required to maintain the reliable encoding of forecasts and observations and the eventual production of verification material.

Because of the impending Pacific Region pilot project to produce terminal forecasts at WO4's and for the sake of brevity, the examples of encoded forecasts and observations in this note will deal with only two elements of the aviation forecast; these will be visibility and ceilings. Figure 2 shows the encoded form of the terminal forecast for YYJ and the encoded observations occurring during the forecast period. Descriptive indexing information such as type of encoded message

....../2

(terminal forecast, aviation observation, etc.), year, month, day, are not shown but would be included in header form before groups of similar types of vector information.

A rough estimate of the amount of computer disc storage required (considering 20 forecast terminals and on the average of 6 extra special observations per day per station, and 4 forecasts per day) would be approximately 124,000 words; this would be roughly .5% of the capacity of the largest disc unit available to the Pacific Weather Centre. Considering 10 elements in each vector and including the public forecasts, the increased amount would be approximately 744,000 words which would be roughly 3% of the disc capacity. With data packing methods these estimates could be almost halved.

VERIFICATION STATISTICS AND DISPLAYS

Basically two types of verification outputs are required. The first type is summation verification statistics which would primarily serve managers of forecast programs. The second type is simple comparative verification displays for detailed analysis of forecast accuracy. The lack of this type of verification has been a recurring complaint of forecasters each time a new summation type verification statistic is introduced. The summation type statistic is difficult to interpret and impossible to use for close re-examination and study of forecasts.

Summation verification statistics can be generated directly from the vector formulation of the comparative-data sets of forecasts and observations. Verification statistics can be produced from the summation of the vector differences between forecasts and observations over time in any of the "sub-spaces" of the "n-dimensional space". Also, use of the angle between forecast and observation vectors may serve as a measure of accuracy. The importance of elements or certain values of the elements can be emphasized by transforming the linear scale of the vector elements to any required continuous or step function; and also by normalizing the vector lengths. An example of this is the use of a logarithmic scale, for ceilings to emphasize the importance of forecasting low ceilings and de-emphasize the difference in forecasted and observed higher ceilings. Use of a step function would provide data input for verification techniques such as the Ranked Probability Verification method and the current national aviation terminal forecast verification scheme.

Forecast terms such as variable, occasional, and risk can be scored by comparing the vector differences of these qualified forecasts with the observations, both regular and special. This can be done by defining in a table the percentage of time each qualifier is to represent over the forecast period, then take the required percentage sum of the "best" comparisons between forecasts and observations of each qualifier.

For example, if the forecast was C5V2, then the 500-foot ceiling is assumed to occur 50% of the time with the 200-foot ceiling the remaining 50%. If the forecast was C5V2 OCNL 1, the ceiling of 500 feet is expected 50% of the time, while the 2 and 1 hundred foot ceilings comprise the remaining 50% of the time. If OCNL were defined as 25% then the 200-foot ceiling would be expected 37.5% and the 100-foot ceiling 12.5% of the time over the total forecast period. Formulation of the score is shown below:

$$\text{SCORE} = \frac{1}{n}\left[\sum_{i=1}^{n_a}\left|\vec{F}-\vec{O}\right|_{MC_i} + \sum_{i=1}^{n_b}\left|\vec{F}-\vec{O}\right|_{VR_i} + \sum_{i=1}^{n_c}\left|\vec{F}-\vec{O}\right|_{OC_i} + \sum_{i=1}^{n_d}\left|\vec{F}-\vec{O}\right|_{RK_i}\right]$$

$\vec{F}$ = Forecast Vector
$\vec{O}$ = Observation Vector
$n = n_a + n_b + n_c + n_d$
= total number of Intervals (operationally: intervals = 1 minute)
n_a, n_b, n_c, n_d = number of "best" forecast intervals based on designated percentage for Main Criteria (MC), Variable (VR), Occasional (OC), and Risk (RK): respectively for combined qualifiers

"zero = Perfect Forecast"

Figure 3 provides examples of the computed scores for various combinations of qualifiers using a simple linear ceiling scale.

The comparative verification displays can be generated by choosing various "2-dimensional" spaces from the "n-dimensional" space of the data set of forecasts and observations. The qualifier forecast, such as variable, occasional and risk can also be represented along with the aviation "special" type observation. The scale of the displays can be altered by choosing various functions to emphasize particular ranges of the meteorological information. Figures 4, 5 and 6, which are formulated from the encoded data in Figure 2, demonstrate some of the possible verification displays which may be of use to the forecaster.

SUMMARY

Presented in this note is a "Vector Verification Scheme" which may be amenable to verifying all weather forecasts emanating from the Pacific Weather Centre. The design of this scheme utilizes the existing available computer technology. The scheme considers the acquisition and storage of observations and forecasts in easily comparable vector formats which include qualified forecasts and special intermediate observations. The main advantage of this scheme is its flexibility to easily generate user-defined verification statistics. Thus it is able to produce summation statistics and scores applicable to managers and also a useful real-time display for forecast analysis and study by the forecaster. A possible additional product could be an automated forecast watch.

FIGURE 1

FLOW OF INFORMATION AND PROCESSING FOR WORDED FORECAST VERIFICATION

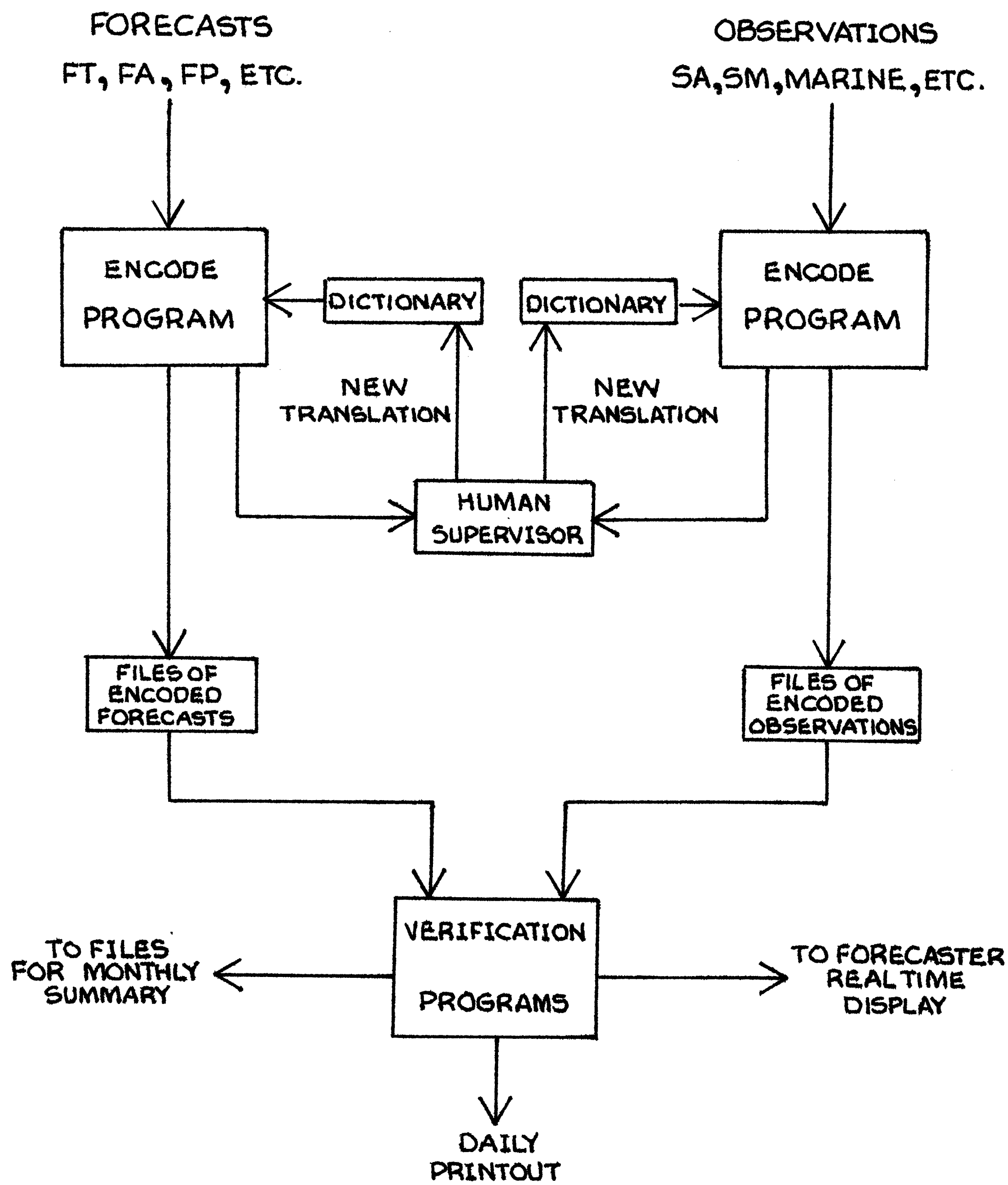


FIGURE 2.

EXAMPLE OF "A VECTOR VERIFICATION SCHEME" ENCODED FORECASTS AND OBSERVATIONS

FORECAST

YYJ 091705 C50 BKN 100 OVC. 21Z 10 SCT
C20 BKN OCNLY C10 OVC 3R-F.

ENCODED FORECAST

VF_1 (MC, 1700, 50, —)
VF_2 (MC, 2100, 20, —)
VF_3 (OC, 2100, 10, 3)

ENCODED OBSERVATIONS

VO_1 (SA, 1700, 50, 15)
VO_2 (SA, 1800, 40, 15)
VO_3 (SA, 1900, 35, 15)
VO_4 (SA, 2000, 20, 15)
VO_5 (SA, 2100, 20, 15)
VO_6 (SA, 2200, 20, 6)
VO_7 (SA, 2300, 10, 3)
VO_8 (SP, 2330, 10, 2)
VO_9 (SA, 0000, 10, 3)
VO_{10} (RS, 0100, 20, 3)
VO_{11} (SA, 0200, 20, 3)
VO_{12} (SA, 0300, 20, 3)
VO_{13} (SA, 0400, 20, 3)
VO_{14} (SA, 0500, 20, 3)

VECTOR FORM: V (Qualifier, Time, $Element_1$, $Element_2$, ... $Element_n$)

QUALIFIERS:

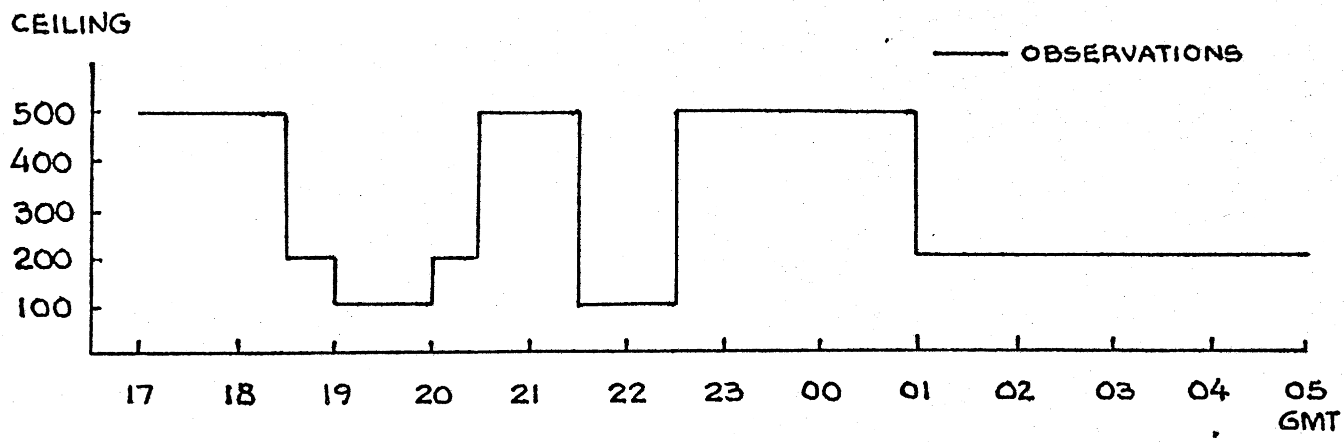
MC = Main Criteria
VR = Variable
OC = Occasional
RK = Risk

SA = Regular Aviation Observation
RS = Regular Special Aviation Observation
SP = Special Aviation Observation

FIGURE 3

EXAMPLE OF COMPUTING SCORES FOR QUALIFIED FORECASTS OF CEILINGS

(Based on half hourly observation intervals (n = 24)



IF:

(a) FORECAST IS C5V2

then $\sum_{i=1}^{n_a} |F-O|_{MC_i} = 600$ where $n_a = 12$, $n_b = 12$

$\sum_{i=1}^{n_b} |F-O|_{VR_i} = 400$

SCORE = 1/24 (600+400) = 41.67

(b) FORECAST IS C5 OCNL 2

then $\sum_{i=1}^{n_a} |F-O|_{MC_i} = 2400$ where $n_a = 18$, $n_c = 6$

$\sum_{i=1}^{n_c} |F-O|_{OC_i} = 400$

SCORE = 1/24 (2800) = 116.67

(c) FORECAST IS C5V2 OCNL 1

then $\sum_{i=1}^{n_a} |F-O|_{MC_i} = 600$ where $n_a = 12$, $n_b = 9$, $n_c = 3$

$\sum_{i=1}^{n_b} |F-O|_{VR_i} = 100$

$\sum_{i=1}^{n_c} |F-O|_{OC_i} = 0$

SCORE = 1/24 (700) = 29.17

FIGURE 4

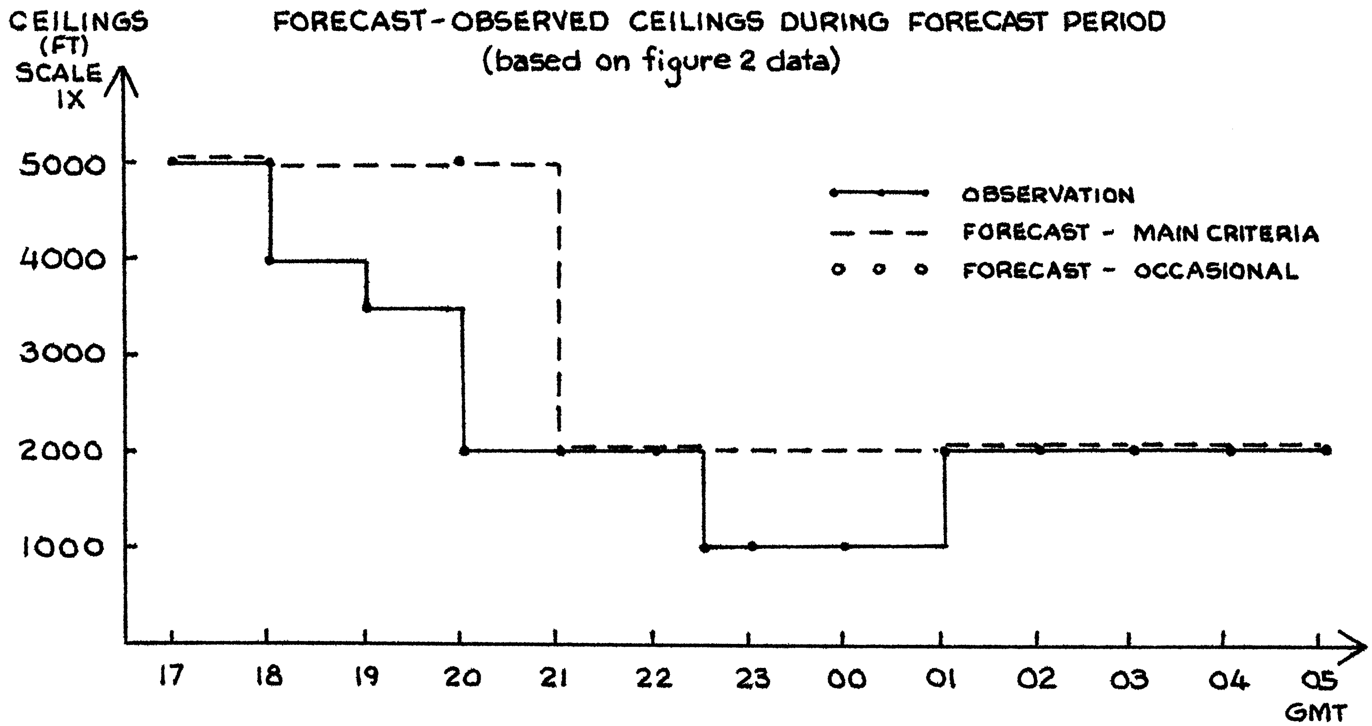


FIGURE 5

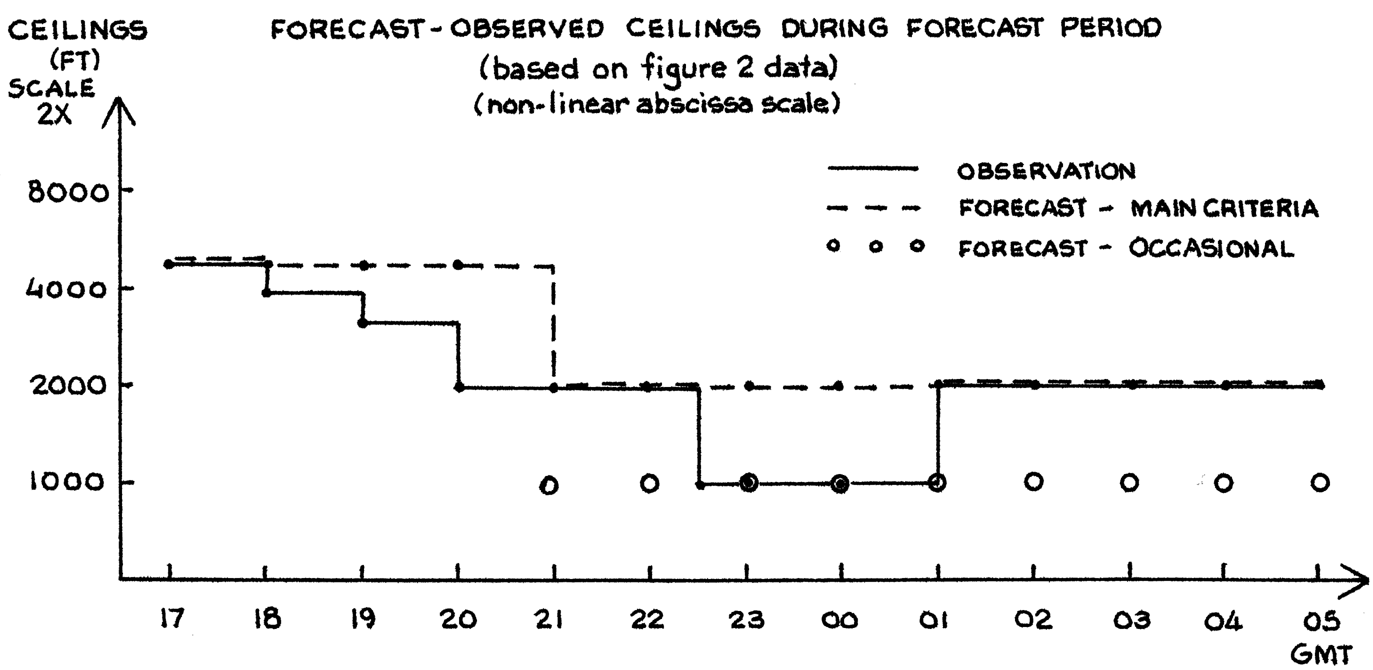
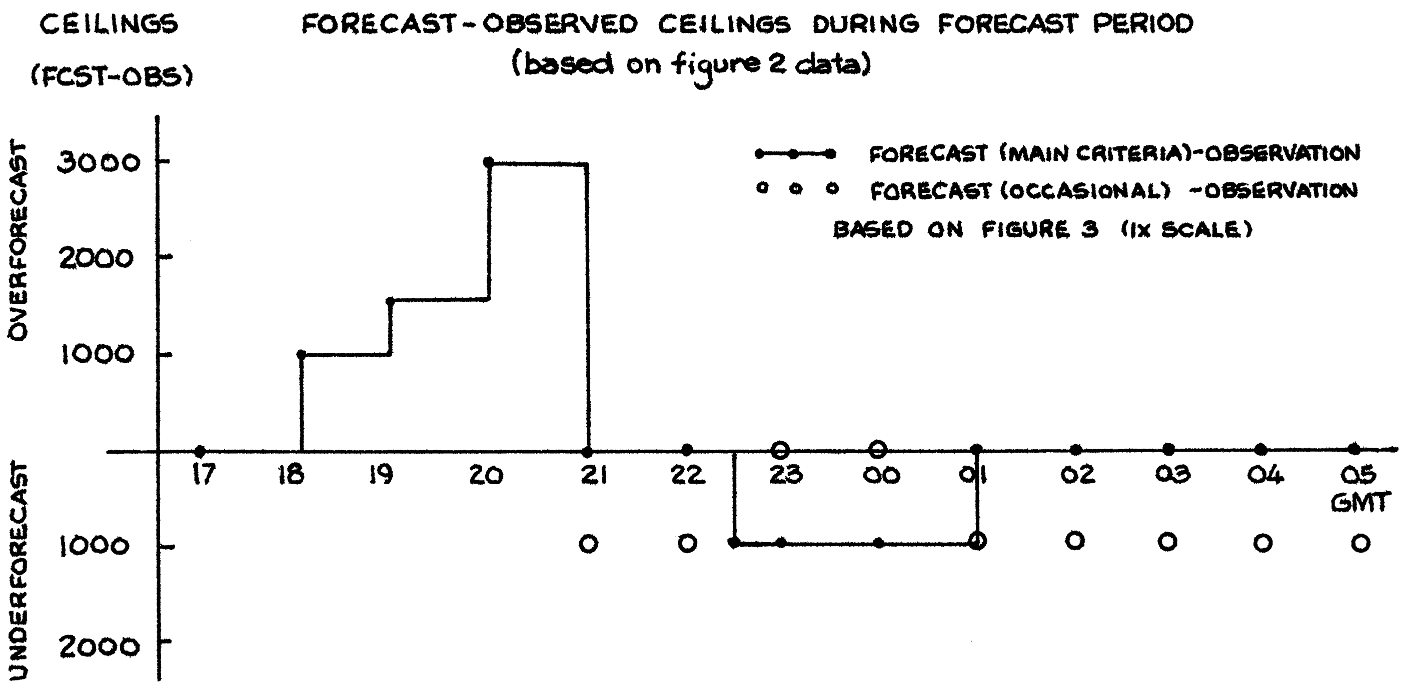


FIGURE 6


CEILINGS
(FCST-OBS)
FORECAST-OBSERVED CEILINGS DURING FORECAST PERIOD
(based on figure 2 data)
FORECAST (MAIN CRITERIA)-OBSERVATION
FORECAST (OCCASIONAL) -OBSERVATION
BASED ON FIGURE 3 (IX SCALE)
OVERFORECAST
UNDERFORECAST
3000
2000
1000
1000
2000
17
18
19
20
21
22
23
00
01
02
03
04
05
GMT