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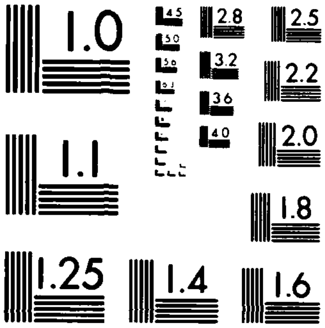

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TECHNICAL NOTE
7WW/TN-82/003

ABILITY OF THE AFGWC BOUNDARY LAYER MODEL TO DETECT AND PREDICT ANOMALOUS PROPAGATION

JAMES W. GOLDEY, MAJOR, USAF
MAY 1982

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7th WEATHER WING (MAC)
SCOTT AFB, ILLINOIS 62225

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents results of a study to 1) determine the ability of a computer-generated analysis of atmospheric refraction to detect and predict anomalies in the performance of tropospheric scatter communications links; and 2) verify the skill with which the vertical profile of atmospheric refraction is forecast after 12 hours. The need for a capability to remotely analyse and forecastrefractivity, and the advantages and disadvantages of the technique used to attempt to satisfy this need are discussed. The study was conducted over a 6-month period using data from 11 tropos

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PREFACE

An examination of actual and potential atmospheric effects on communications systems is significant to radio engineers, operators, communications systems analysts, planners, and frequency managers. Insufficient meteorological data are available at or near the various communications paths to define adequately or forecast the propagation conditions. This study was undertaken to determine, on a limited basis, the capability of a macroscale computer model to provide the desired information. The ability of the Air Force Global Weather Central (AFGWC) Boundary Layer Model (BLM) to analyze anomalous propagation (AP) conditions was examined and an attempt made to correlate with tropospheric scatter communications performance data. No meaningful correlation was established. Forecast skill was determined to be severely limited. Several recommendations are made for possible improvement to the BLM and to the overall AP analysis package.

I wish to thank several people who contributed greatly to this effort. Capt Alan Zimmerman, AFCC/FFOT, developed the program to analyze and correlate refractivity data with performance data. 1LT Bob Hall, AFCC/DOYS, collected and analyzed performance data from the European sites. Capt Dave Norman, AFCC/DOOT, collected and analyzed signal data from the SOLID SHIELD sites. Maj Dennis Moreno and Capt Jim Kester, AFGWC/WPDL, provided all BLM data. They also arranged to transmit it via the automatic digital network (AUTODIN) with receipt on punch cards, thus greatly facilitating the analysis.

This technical note documents work performed in 1977.

A-1

ABILITY OF THE AFGWC BOUNDARY LAYER MODEL TO DETECT AND PREDICT ANOMALOUS PROPAGATION

Introduction

This report presents the results of a study to:

- determine the ability of a computer-generated analysis of atmospheric refraction to detect and predict anomalies in the performance of tropospheric scatter communications links; and
- verify the skill with which vertical profiles of refraction have been provided by the Air Force Global Weather Central (AFGWC), Offutt AFB, Nebraska.

Tropospheric scatter system performance analyses were provided by the Directorate of Systems Evaluation and the Directorate of Tactical Operations, HQ Air Force Communications Command (AFCC).

The need for a capability to analyze and forecast the weather as it affects tropospheric scatter, and the advantages and disadvantages of the computer technique used to satisfy this need are discussed. An attempt was made to correlate the vertical gradient of atmospheric refraction with communications system parameters of received signal level and idle channel noise. In addition, the 12-hour forecasts of refraction were compared to the analyzed values 12 hours later.

This study was conducted using data for a 7-month period from 11 troposcatter sites throughout Europe; and for a 3-week period from 13 sites in the United States. A listing of all sites considered is included as Appendix A.

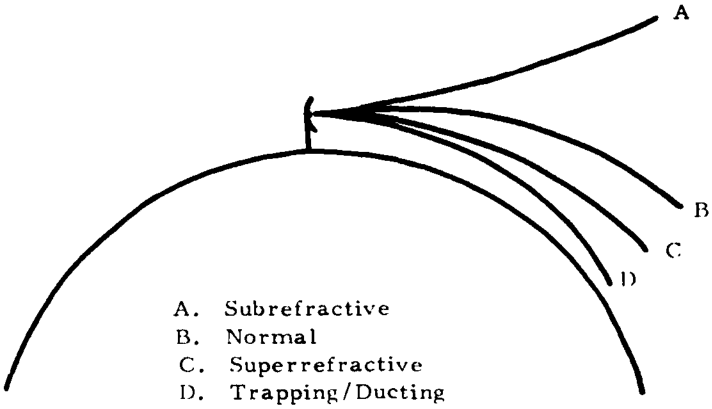
For this study atmospheric refraction was considered in terms of refractivity, N (Hadeen, 1970). The affect of the atmosphere on the propagation of electromagnetic energy can be described in terms of the change (gradient) of refractivity with height. Atmospheric refraction of electromagnetic energy can be divided into four classes (assume propagation represented as a single ray):

a. Subrefraction. Ray curvature is upward (see Figure 1). Radio/radar ranges are significantly reduced. Occurrence is rare. Refractivity increases with height. Gradient of refractivity is equal to or greater than zero N/1000 feet.

b. Normal Refraction. Ray curvature is downward, but not as much as the curvature of the Earth (see Figure 1). Radio/radar performance is generally undisturbed. Occurrence is common. Refractivity decreases with height. Gradient of refractivity ranges from 0 to -24N/1000 feet. Normal refractive gradient in a "standard" atmosphere at 60-percent relative humidity is -12N/1000 feet.

c. Superrefraction. Ray curvature is downward, more sharply than normal, but still not as much as the curvature of the Earth (see Figure 1). Radio/radar ranges may be significantly extended. Occurrence is frequent. Refractivity decreases with height. Gradient of refractivity ranges from -24 to -48N/1000 feet.

d. Trapping (extreme superrefraction). Ray curvature is downward, equal to or greater than the curvature of the Earth's surface (see Figure 1). Radio/radar performance is greatly disturbed, ranges are greatly extended. Areas of signal loss or "holes" may appear. Occurrence is infrequent. Refractivity decreases sharply with height. Gradient of refractivity is less than or equal to -48N/1000 feet. This condition is also know as ducting.



Class	Curvature	Range	Occurrence	Refractivity	Gradient/feet
A	up	reduced	rare	increases	>zero/1000
B	down	undisturbed	common	decreases	0 to -24 N/1000
C	down	extended	frequent	decreases	-24 to -48 N/1000
D	down	extended	infrequent	sharp decrease	< -48 N/1000

(Propagation of electromagnetic energy along a path that is different from the usual or expected path, i.e. normal refractivity, is known as "anomalous propagation" or AP.)

Figure 1. Ray Paths through Various Atmospheric Refractive Conditions.

Problem Discussion

The fundamental assumption in this investigation was that atmospheric refraction would have some noticeable affect on the performance of tropospheric scatter communications. Further, knowing that a degradation in system performance was weather-induced would provide some useful information--either to the operators on a real-time basis or for post analysis in assessing the quality of link performance. Finally, if a correlation between link performance and weather events as analyzed by some centralized synoptic analysis technique could be established, then forecasting such occurrences would be simplified and would be helpful to the operators. According to the USAF Scientific Advisory Board Geophysics Panel Task Group on Meteorological Effects on Microwave Propagation (1975), if degradation were expected, tropo-circuit operations could "reduce operating bandwidth (at the expense of information rate) which restores the loss in signal-to-noise ratio."

There are many methods or techniques for determining the existence of the various degrees of atmospheric refraction, but all have some deficiencies. Most disadvantages are related to either the expense of specially instrumenting communications sites or paths, or the accuracy of the data obtained. A technique or product which could utilize the wealth of meteorological data already routinely available, and which would allow computer analysis and processing at a central location for any desired point would essentially eliminate cost consideration. However, this technique must still be sufficiently accurate to detect anomolies that are crucial to system performance. Further, if a forecast product is desirable and useful (as assumed), there must be demonstrated forecast skill.

The product tested in this project was the Anomalous Propagation (AP) Analysis and Forecast from the Air Force Global Weather Central (AFGWC) Fine Mesh Boundary Layer Model (BLM).

The Boundary Layer Model

General information on the Boundary Layer Model (BLM) used by the Air Force Global Weather Central (AFGWC) is provided in this section. More detailed information is available in AFGWC Technical Memorandum 70-5 (Hadeen, 1970).

The BLM is a numerical model for analyzing and forecasting important meteorological parameters within the lower portion of the troposphere (surface to 1600 meters). The model provides data at eight levels (surface, 50m, 150m, 300m, 600m, 900m, 1200m, and 1600m) over a fixed distribution of grid points with an interval of 100 nautical miles. Input data are obtained from the worldwide network of radiosonde stations. The data obtained from radiosonde observations (raobs) are translated to the fixed, multilevel grid by a weighted interpolation scheme to provide an initial analysis field of each of the meteorological parameters at each point. Hourly forecast values for up to 24 hours are obtained by solving the appropriate tendency equations. This ensures the forecast fields are physically and dynamically consistent.

The BLM is run for specified geographic areas called "windows." Forecast parameters can be linearly interpolated to any point within the window. From these parameters values of refractive index are calculated at each of the eight fixed levels, and gradients between levels, i.e., in the "layer", are determined.

A significant feature of the BLM is the "smoothed" ground surface that is used. Actual terrain height values at each of the grid points have been adjusted to keep the model from becoming computationally unstable.

The BLM has several advantages in providing initial analyses and 6-, 12-, and 18-hour forecasts of vertical refractive index structure:

- Refractive index forecasts are relatively inexpensive to make since the BLM is run for other purposes--refractive index information is a derivative product and can be provided with little additional computer time.

- The BLM provides access to otherwise remote areas, as long as the specified points are within the operational "window."

- Additionally, and perhaps most important, it provides an objective interpolation of "nearby" radiosonde data to the point specified by applying physically and dynamically consistent weighting techniques to the basic radiosonde data.

There are also several shortfalls in the BLM method of obtaining refractivity data:

- The BLM is limited to the operational "windows," which generally speaking include the United States, Europe, and the Far East. Thus, it does not have worldwide applicability.

- It uses only radiosonde data as input, and therefore suffers from the same inherent deficiencies as the basic radiosonde data.

- The "smoothed" surface introduces a discrepancy between the surface elevation of the site being investigated and the lower boundary of the first layer considered in the model. As will be shown later, differences between site elevation and the model's surface elevation at that point may exceed 1000 meters. Thus, the computational "noise" factor introduced may be of the same order as the thickness of the boundary layer itself.

- Finally, the upper limit of 1600 meters on BLM data and the assumption of uniform layering are also detriments. The major technical problem is the use of a macroscale model and data coverage to address a mesoscale problem.

Correlation of Refractivity with European Path Performance

After the fundamental assumption that atmospheric refraction would have a noticeable effect on troposcatter, it was further assumed that such effects could be identified by changes in received signal level (RSL) and/or idle channel noise (ICN). Since refractivity data from the BLM is available twice daily (0000Z and 1200Z), operators at the 11 troposcatter sites in Europe (see Appendix A) were asked to provide daily observations of RSL and ICN as near as possible to 0000Z and 1200Z. Coordination could not be established with Hoek van Holland, a US Army site, in time for participation in this phase of the test. Therefore, there were effectively 10 European sites participating.

Event Correlation

The first step in the analysis was to establish the occurrences of a significant effect or event from the path performance data. As it was not totally clear whether RSL and ICN fluctuations would be correlated (or if one would dominate), and since performance in both directions on a link must be considered, several methods of analyzing the European performance data were considered. A statistical analysis scheme was used to process the RSL and ICN data and identify significant deviations ("outliers") from the normal distribution of values as the events to be correlated with refractivity data. The several methods used in this statistical analysis were:

a. Compare ICN with RSL at each site and identify as events those times when both ICN and RSL were correlated and outliers.

b. Correlate ICN with RSL at each site and identify as events those times when <u>either</u> ICN or RSL was an outlier.

c. Compare RSL at one end of path with RSL at other end and identify as events those times when RSLs from both ends were correlated and outliers.

d. Correlate RSL at one end of path with RSL at other end and identify as events those times when RSLs from either end (but not both) were outliers.

e. Same as c., with ICN.

f. Same as d., with ICN.

Since the correlation of event times with refractivity values was to be made for each individual site, events identified by the latter four methods above were ascribed to each end of the path.

In all cases, events identified by one particular method were assumed to accurately represent a time of anomalous performance due to atmospheric refraction. The question then became whether the BLM could accurately analyze the refraction at that time. Due to the surface smoothing in the BLM, it was not feasible to consider that only the lowest layer in the BLM (surface to 50m) should be considered in the correlation. Thus, the correlation was attempted for each of the seven layers of the BLM data. The refractive index gradients through the layers were categorized as to whether they were subrefractive, normal, superrefractive, or trapping conditions. A frequency distribution of the four refraction conditions was made for each layer at each site separately, and grouped according to whether there was anomalous propagation reported (an identified event) or not reported (all other times throughout the total test period).

"Smoother" Surface Bias

With all methods of analyzing the occurrence of a significant event (anomalous propagation assumed) at all sites, there was no significant increase in the occurrence of superrefractive and trapping conditions with anomalous propagation (AP) reported over the cases with no AP reported. In other words, the distribution of the four refractive categories in all layers was apparently unrelated to the occurrence of AP as determined by the above methods.

With few exceptions, the highest two or three layers had normal refractive index gradients. This is significant when considering the impact of surface smoothing in the BLM. At two sites the actual site elevation was nearly 1200 meters higher than the "smoothed" surface elevation in the BLM. For these mountain-top sites the actual site elevation corresponds closely to the lower level of the highest layer in the boundary layer, 1200 meters. Thus, the first six layers in the BLM could be disregarded for these sites. Yet, for 6 months the propagation conditions were analyzed as normal in the highest layer of the BLM at these sites.

At the five remaining sites considered in Europe, the model elevation was missing for one, and the other four had site elevations below model surface elevations--the range of differences being from 4 to 636 meters. In these cases, it was merely assumed that the layers should be translated downward until the model surface corresponded to site elevation. Nonetheless, no meaningful correlations could be made.

Correlation of Refractivity with CONUS Tactical Operations

In support of the 1976 Exercise SOLID SHIELD in the Carolinas, US Army and US Air Force communications personnel operated tactical troposcatter communications systems. During the 3-week period, recordings of received signal level (RSL) were made either on strip charts (continuous) or manually (at 2-hour intervals). These data were visually scanned to pick out periods of abnormally high or low RSL, with reference to the median signal level. Significant events included such things as 20-dB gain in both directions, and signal saturation at both ends. Records of RSL were available from only three of the 13 sites.

The first link considered was designated AF-1, and was from Seymour-Johnson AFB to Shaw AFB. There were 14 occasions identified as having significantly high or low RSLs (Table 1). These times were classed as "events" with anomalous propagation (AP) experienced on the path. During the AP event periods at Seymour-Johnson, the first layer had normal propagation conditions 14 percent of the time; superrefraction, 71 percent, and trapping, 14 percent of the time. However, during the remaining times at Seymour-Johnson (no AP experienced), only 22 percent had normal conditions analyzed, while 65 percent had superrefraction, and 13 percent had trapping conditions. At the other end of the path (there was two-way transmission), from the sample of events with AP conditions reported, 7 percent had normal propagation analyzed, 64 percent had superrefraction, and 29 percent had trapping conditions. During the remaining times at Shaw, 30 percent had normal conditions, 48 percent had superrefraction, and 17 percent had trapping conditions.

Table 1. AF-1 Outlier Return Signal Level (RSL).

Propagation Class	Seymour-Johnson AP events (percent)	Seymour-Johnson Non-events (percent)	Shaw AP events (percent)	Shaw Non-events (percent)
Subrefraction	--	--	--	--
Normal Refraction	14	22	7	30
Superrefraction	71	65	64	48
Trapping	14	13	29	17

Thus, subjective analysis shows that event occurrence did not positively correlate with superrefraction or trapping conditions.

Considering the results of the previous analyses, another approach was taken to correlate the tactical troposcatter RSL with weather data. This was essentially an event correlation, whereby the refractivity analysis was accomplished for each time period, and the listing was printed out. The previously identified

AP events were then individually matched against the refractivity analyses to see if we could correlate only decreases or only increases in RSL with anomalous layers. Those times for which no AP had been identified were also checked against the corresponding refractivity data. Increases in RSL occurred with all analyzed propagation conditions, and decreases in RSL occurred with only superrefraction or trapping (not with normal propagation). However, many times when superrefraction or trapping were analyzed, the RSL values were stable.

Correlation of Forecast versus Observed BLM Refractivity Data

The 12-hour forecast of refractivity was compared to the analyzed value 12 hours later (the valid time of the forecast), at each level for all 11 European sites and 13 SOLID SHIELD sites. Additionally, the gradients through the layers were compared, since the refractive gradient rather than the value of refractivity at any one level affects propagation. Finally, the category of refraction (subrefraction, supperrefraction, etc.) was computed for the 12-hour forecast and the analyzed values. These catagories were compared.

Even though atmospheric refractivity is a derived quantity in the BLM (the refractivity field itself is not forecast), it is used at each level to determine gradient and category. It would not be sufficient to compare only gradient values through a particular layer, since the values of refractivity at the top and bottom of the layer could have an equal error in forecast value. Thus, there would be no difference between forecast and analyzed gradient values. Similarly, a comparison of only the refractivity values at each level would not suffice, as there could be small positive difference between forecast and observed values at one level and a small negative difference at the next level. Thus, the gradient difference through the layer could be significant. Finally, considering a difference between forecast and analyzed gradients of only 48 N-units per 1000 feet, spread over the range from zero N per 1000 feet to -48N per 1000 feet, highlights the significance of some relatively small differences between forecast and analyzed refractivity values at the individual levels. (It should be noted that the product available from AFGWC presents all refractivity values in B-units; however, those were converted to N-units before analysis by the equation:

$$N = B - 0.012h$$

where h is the height in feet. Acceptable route mean square error (RMSE) for the layers was assumed to be half the normal refraction and superrefraction ranges, i.e., 12 N-gradient/1000 feet.

a. European sites, level analysis. RMSE values (Table 2) for the difference between forecast and observed N-values at each level range from 2.9 to 11.7 over the 7-month period. Extreme individual refractivity differences ranged from 36 to -31 N-units. RMSE values for these levels do not seem excessive. However, consider the first layer, surface to 50m. If we assume perfect correlation at the upper boundary and a difference between surface forecast and observed N-values of 5, then the layer will have about 30 N-gradient/1000 feet. To attain an acceptable error of approximately 12 N/1000 feet in the first layer, there cannot be errors in N-values at the upper and lower boundaries that total more than 2 N-units in combined absolute value, e.g., forecast-observed at the surface of +1 N-unit and -1 N-unit at 50m. Thus, RMSEs for the difference between forecast and observed N-values at each level indicate a general poor ability of the BLM to forecast refractivity accurately.

b. European sites, layer analysis. (Figures 2 and 3) The plot of RMSE of forecast versus observed gradients through the first layer show that sites 1-4 and 9-11 had statistically acceptable values (near 12 N-gradients/1000 feet). Possible exceptions are site 1 during April and site 9 during the spring. However, at specific times, gradient differences of -60 to -70 N/1000 feet were found. At one time (24 April 1976, 1200Z) there was a -97 N/1000 feet difference at site 1. The remaining sites, 5-8, generally showed RMSEs higher than the desired standard (Figure 3). The maximum layer RMSE error was 41.6 N/1000 feet.

Table 2. RMSE of Forecast versus Observed N-Value at 11 European Sites by Month.

Site	Level	Nov	Dec	Jan(1)	Jan(2)	Feb	Mar	Apr	May
1	1	5.7	4.6	4.6	5.0	5.3	5.5	7.5	10.6
	2	5.9	4.0	4.3	4.9	5.6	5.5	7.3	10.1
	3	6.7	4.0	4.9	5.0	5.7	5.7	8.8	9.8
	4	5.8	4.0	4.2	3.8	5.0	6.2	7.8	8.7
	5	7.2	4.5	4.5	4.2	4.3	6.8	7.2	10.4
	6	7.5	5.8	4.9	5.5	4.6	7.6	7.8	11.1
	7	7.6	5.8	5.3	4.4	4.6	7.2	7.9	10.8
	8	7.4	6.0	5.4	4.4	4.4	6.8	7.7	10.9
2	1	5.6	4.3	5.6	6.5	4.5	5.1	6.7	10.1
	2	6.0	4.4	5.1	6.8	4.9	5.5	6.7	9.6
	3	6.2	4.6	5.0	6.0	5.3	5.5	7.1	9.7
	4	6.2	4.2	5.6	7.0	4.8	5.4	6.8	8.6
	5	5.4	4.2	5.2	3.8	4.2	6.1	6.6	7.5
	6	6.1	5.1	5.1	3.2	4.0	6.2	6.8	7.8
	7	6.6	5.2	5.2	3.6	3.8	5.4	6.5	8.2
	8	6.0	5.3	4.6	3.9	3.7	5.4	6.5	9.0
3	1	6.1	3.8	4.1	6.0	3.7	6.1	8.2	9.1
	2	6.1	3.6	4.0	5.6	3.7	6.2	8.1	8.8
	3	6.5	4.0	4.3	5.9	4.4	6.8	9.2	9.0
	4	6.8	3.9	4.3	6.4	4.0	6.4	9.6	8.3
	5	8.4	4.5	4.4	7.0	4.4	7.0	9.6	10.3
	6	8.8	5.0	4.9	7.2	4.8	7.9	9.9	11.0
	7	8.7	5.5	5.4	5.6	4.4	7.1	9.6	10.4
	8	8.4	5.6	5.9	5.9	4.2	7.4	9.8	10.8
4	1	8.2	5.3	3.7	5.8	5.2	6.6	6.9	9.9
	2	8.2	5.2	3.7	6.0	5.1	6.3	6.7	9.6
	3	9.3	6.0	4.0	6.2	5.3	6.3	7.6	9.3
	4	7.0	5.3	4.6	6.3	5.5	5.5	7.4	8.7
	5	7.2	5.6	5.2	6.5	4.9	5.8	7.8	8.6
	6	8.1	5.7	5.9	6.8	4.6	6.9	8.4	9.6
	7	8.6	5.8	5.7	5.4	4.2	7.0	8.4	9.1
	8	8.7	5.7	5.6	5.5	4.3	7.3	8.6	9.2
5	1	11.1	9.4	6.5	6.1	8.6	6.8	9.0	10.7
	2	11.4	9.2	6.6	4.9	8.3	6.5	9.8	8.9
	3	10.7	9.2	6.4	5.1	7.8	6.5	10.7	9.1
	4	8.3	6.7	5.4	6.1	6.1	6.2	9.8	8.7
	5	6.7	5.6	5.7	5.6	4.9	5.5	8.4	7.8
	6	6.6	5.5	5.2	5.3	4.6	5.8	7.4	7.9
	7	7.8	6.0	5.1	5.2	4.5	6.0	7.0	8.6
	8	9.0	5.4	5.4	6.3	5.4	6.4	7.3	8.8
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	2	7.1	6.0	5.5	6.5	6.8	7.3	8.0	8.6
	3	6.7	6.7	6.4	6.7	6.7	7.8	8.9	10.9
	4	6.7	6.7	5.3	5.7	6.9	7.7	7.8	9.8
	5	6.4	6.0	5.0	6.2	6.4	6.9	7.4	10.0
	6	6.8	6.6	6.5	6.7	7.6	7.8	8.2	10.[illegible]
	7	7.9	7.0	6.9	6.9	7.7	8.4	8.5	10.7
	8	8.1	7.4	8.3	6.4	8.6	9.1	8.2	11.[illegible]

Table 2 (cont'd). RMSE of Forecast versus Observed N-Value at 11 European Sites by Month.

Site	Level	Nov	Dec	Jan(1)	Jan(2)	Feb	Mar	Apr	May
7	1	11.4	7.5	7.5	6.6	8.5	8.6	8.1	10.0
	2	10.6	7.5	6.2	7.2	8.6	9.0	7.9	9.7
	3	10.7	7.2	6.1	8.0	8.2	9.9	9.9	11.0
	4	10.4	7.9	7.3	5.9	8.5	9.8	10.[illegible]	10.8
	5	7.9	5.7	5.6	5.0	6.6	7.2	8.9	10.7
	6	6.6	5.6	5.7	5.4	6.9	7.5	8.4	11.0
	7	8.8	6.7	5.2	5.0	7.3	7.4	8.4	10.7
	8	8.1	6.8	5.2	4.8	8.2	8.4	7.4	11.4
8	1	6.2	6.6	7.8	5.7	7.1	7.2	9.3	8.3
	2	5.6	5.9	5.6	5.0	7.7	6.4	9.2	7.6
	3	5.9	6.1	6.4	6.4	9.7	8.1	10.7	10.4
	4	5.6	6.0	5.1	4.8	6.7	6.7	7.9	10.6
	5	5.4	6.0	5.5	4.4	5.3	6.7	6.1	8.1
	6	5.9	7.0	7.7	4.7	5.9	7.9	6.1	8.1
	7	6.2	7.0	8.7	5.8	6.4	8.5	6.0	7.8
	8	6.7	7.1	10.4	6.6	6.4	9.1	6.3	8.2
9	1	6.8	5.8	6.9	6.4	7.8	6.4	7.8	9.1
	2	6.7	6.4	6.8	5.7	7.4	6.6	7.4	8.5
	3	7.2	6.8	7.7	5.3	8.1	8.6	7.6	11.0
	4	8.0	7.8	6.8	6.2	8.2	9.1	6.6	11.7
	5	6.7	7.1	7.4	4.6	6.4	8.6	7.3	9.0
	6	6.7	8.1	8.1	4.1	6.2	8.4	7.8	8.5
	7	7.7	8.6	8.3	3.7	6.2	7.8	7.9	7.7
	8	8.9	8.5	9.2	4.6	6.8	7.5	7.9	7.9
10	1	5.3	2.9	4.6	5.0	3.4	4.4	5.6	7.3
	2	5.6	3.5	4.7	5.6	3.6	4.5	6.3	7.4
	3	6.0	4.4	5.3	5.0	4.3	6.2	8.1	8.0
	4	5.1	4.6	5.3	5.6	6.0	7.8	8.0	8.0
	5	5.4	5.5	7.2	3.5	8.0	8.7	7.6	7.1
	6	7.1	6.6	8.2	4.9	7.3	10.9	7.8	7.0
	7	6.6	5.9	6.4	5.3	6.6	10.4	7.2	6.8
	8	6.2	6.1	7.6	4.9	6.7	9.	8.3	7.6
11	1	3.9	3.4	4.5	2.8	3.1	4.0	6.0	7.3
	2	4.4	4.0	5.2	4.1	3.2	4.4	6.1	7.4
	3	4.9	4.1	5.1	4.2	3.6	5.1	6.7	8.0
	4	4.2	4.0	4.2	2.9	4.2	5.8	7.3	8.0
	5	5.2	4.3	4.7	4.1	6.5	6.5	6.6	7.1
	6	5.8	4.9	5.6	5.3	6.4	8.9	6.8	7.0
	7	5.0	4.8	5.8	5.0	6.0	8.2	7.2	6.8
	8	5.3	6.1	6.0	4.5	5.7	7.4	7.9	7.6

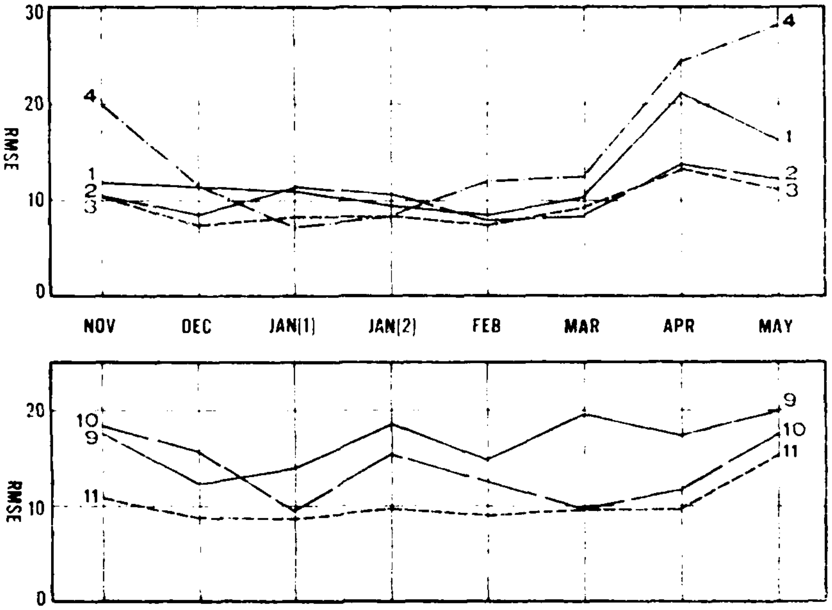

Figure 2. Monthly RMSE of Forecast versus Observed Gradient through the First Layer, by Site.

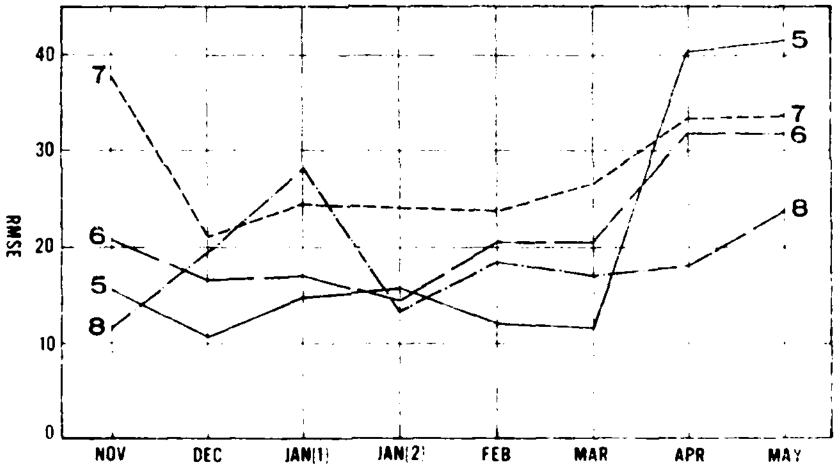

Figure 3. Monthly RMSE of Forecast versus Observed Gradient through the First Layer, for Sites 5-8.

Again, extreme individual layer gradient differences were noted. At site 5 on 16 April 1976, there was a difference between forecast and observed gradient of 171 N/1000 feet at 0000Z and a difference of -152 N/1000 feet at 1200Z, a range of 323 N/1000 feet in 12 hours. Again, at site 5 on 14 May 1976 at 1200Z the difference was -219 N/1000 feet. Such large individual forecast versus observed gradient differences also highlight the inability of the BLM to forecast refractive gradients accurately.

c. US sites, level and layer analysis (Table 3). The 4-26 May 1976 statistics for the 13 SOLID SHIELD sites were surprising in that they indicated poorer "skill" on the east coast of the United States than at most European sites. The RMSE values for difference between forecast and observed N-values at each level ranged from 8.8 to 16.3 for the 3-week period. Without exception, at each site

Table 3. RMSE of Forecast versus Observed N-Value at 13 SOLID SHIELD Sites.

Level	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
1	11.8	16.1	14.2	10.5	11.0	14.4	14.1
2	10.4	13.0	11.2	9.9	10.0	11.2	11.0
3	12.0	14.1	12.3	9.9	10.5	12.4	12.3
4	10.5	10.6	10.5	9.3	10.2	10.5	10.5
5	9.4	9.6	9.2	9.4	10.0	9.4	9.3
6	10.2	12.3	10.9	10.9	11.1	10.9	11.0
7	11.5	12.3	11.4	12.5	12.4	11.6	11.6
8	12.3	13.7	12.7	14.0	13.8	12.8	12.7

* * * * * * * * * * *

Level	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13
1	16.2	12.3	11.3	11.9	16.3	15.3
2	12.1	10.6	11.1	10.5	13.4	12.3
3	13.5	11.4	10.6	10.0	12.3	11.8
4	11.1	9.7	10.3	9.2	10.3	9.9
5	9.6	8.8	10.9	9.1	12.2	11.7
6	11.5	10.2	12.5	10.9	13.2	13.9
7	12.1	11.2	14.4	12.1	13.8	14.0
8	13.2	12.8	16.2	14.1	15.4	15.8

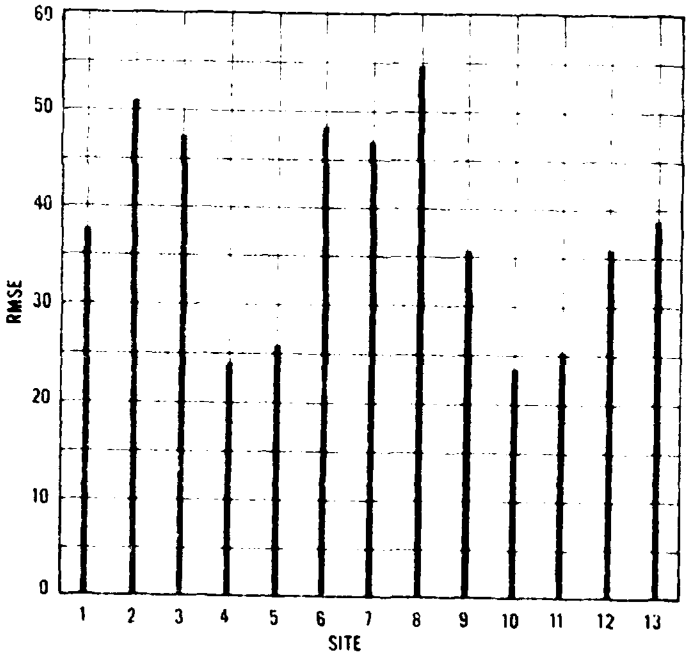

Figure 4. RMSE of Forecast versus Observed Gradient through the First Layer for the Period 4-26 May 76 for SOLID SHIELD Sites.

the surface and 1600-meter levels had the highest RMSE; and the midlevels were generally best.

The RMSE values of forecast versus observed gradients through the first layer (Figure 4) all exceeded the 12 N/1000 feet value considered as acceptable. Four sites had RMSE values near 25 and one had an RMSE near 55. As with the European sites, there were some notable extreme values of difference between forecast and observed gradient, the worst being -159 N-units/1000 feet on 7 May 1976 at 0000Z for site 2.

In support of another project, AP analyses and forecasts from the BLM were received for England AFB, Louisiana, for the period 26 August 1976 to 14 September 1976. The RMSE of differences between forecast and observed N-gradients for the first layer was 70.85 for the 3-week period. Some examples of extreme differences (in N-units per 1000 feet) were: -116, -140, -177, and -213. In the latter case the forecast value was -237, while the analyzed value was -24. At that time the forecast N-value at the surface was 412 and at 50 meters it was 373. The analyzed N-values were 354 and 350, respectively.

Conclusions and Recommendations

As a result of this limited analysis some conclusions and recommendations may be made concerning the ability of the BLM product to detect and forecast a gradient of atmospheric refraction and thus, predict troposcatter communications systems performance.

a. Regardless of which indicator of path performance was used, no meaningful correlation was established between performances and refractivity gradient through any layer. The conclusion is that the AP analysis from the BLM cannot be used to detect or predict troposcatter path performance. Several reasons for this conclusion are possible.

(1) The gross scale of input data, limited to radiosonde reports.

(2) The spacing of grid points from which linear interpolation to the site is made.

(3) The terrain smoothing, which introduces large discrepancies between actual site elevation and model surface elevation, with differences on the order of the boundary layer itself.

(4) Meteorological values at other points on the propagation path may be, and probably are, more significant to path performance than single site refractivity gradients. Certainly some consideration should be given to turbulent or reflective layers, especially in the vicinity of the "common volume."

(5) Generally, limitations in the current AP analysis program exist through use of only the BLM. Capping the BLM with other models to extend the upper limit beyond 1600 meters, and examining the region of the "common volume" may be fruitful.

b. The 12-hour forecast capability is severely limited.

(1) This limitation is independent of the system to which results are applied, and thus holds true for troposcatter, line-of-sight, radar, etc.

(2) There appear to be seasonal trends, as noted in the RMSE values of forecast versus observed gradient of refractivity at the European sites. Generally, all sites had lower RMSE values during the period from December through March. About half of the sites had acceptable RMSE values during that 4-month period.

The following recommendations would lead to an improved BLM-AP forecast capability:

a. Additional sources of input data should be included at the surface, such as surface observations from synoptic reporting stations.

b. Less smoothing of the surface height values and/or a finer grid spacing should be employed.

c. A continuing verification program should be conducted at AFGWC by forecasting for the coordinates of some raob station, rather that just forecasting at grid point and verifying against a nearby raob.

d. Verification against some raob station whose data are not used as input, such as Eglin AFB. If soundings are made at Eglin at 0600Z and 1800Z, these off-time reports could be used to verify the 6-hour and 18-hour forecasts available from the BLM.

e. Refractivity versus RSL or event correlation studies should be attempted for other systems (line-of-sight microwave, airport surveillance radar) which are subject to detectable environmental effects.

f. AFGWC should consider production of an improved AP analysis package including not only the above suggested BLM refinements but "capping" (or model blending), ray tracing techniques employing path-integrated refractivity gradients, and more attention to the "common volume" region.

REFERENCES

Hadeen, K.D., 1970: "AFGWC Boundary Layer Model," AFGWC Technical Memorandum 70-5, April 1970, AD713058.

"Report of the USAF Scientific Advisory Board Geophysics Panel Task Group on Meteorological Effects on Microwave Propagation," May 1975.

Skolnik, M.I., 1962: Introduction to Radar Systems, McGraw-Hill Book Co.

Appendix A

LIST OF SITES

Site No.	Site Name	Latitude (deg,min)	Longitude (deg,min)	Station Elevation (meters)	Model Elevation (meters)
	European Troposcatter Sites				
1	Sahin Tepesi, Turkey	40°28'N	29°12'E	882	328
2	Ortakoy, Turkey	40°34'N	26°57'E	172	208
3	Eskisehir, Turkey	39°47'N	30°35'E	783	826
4	Malatya, Turkey	38°21'N	37°48'E	2038	1510
5	Karatas, Turkey	36°40'N	35°22'E	4	640
6	Mt Virgine, Italy	40°56'N	14°43'E	1495	302
7	Martina Franca, Italy	40°41'N	17°16'E	95	421
8	Coltano, Italy	43°39'N	10°25'E	192	*
9	Mt Limbara, Italy	40°51'N	09°10'E	33	1174
10	Martlesham Heath, United Kingdom	52°03'N	01°15'E	31	35
11	Hoek van Holland, Netherlands	51°59'N	04°07'E	32	*
	Exercise *SOLID SHIELD* Sites				
1	Seymour Johnson AFB, North Carolina	35°20'N	77°59'W	15	29
2	Shaw AFB, South Carolina	33°58'N	80°28'W	80	94
3	Ft Bragg(1), North Carolina	35°07'N	79°01'W	116	78
4	New River, North Carolina	34°43'N	77°28'W	*	11
5	Oak Grove, North Carolina	35°02'N	77°15'W	*	12
6	Pope AFB, North Carolina	35°10'N	79°02'W	70	81
7	Ft Bragg(2), North Carolina	35°11'N	78°55'W	87	75
8	Camp Mackall, North Carolina	35°02'N	79°31'W	125	105
9	Bladen Lakes, North Carolina	34°43'N	78°31'W	20	34
10	Radio Island, North Carolina	34°43'N	76°41'W	7	2
11	Ft Fisher, North Carolina	33°59'N	77°55'W	3	7
12	Camp Oliver, South Carolina	32°01'N	81°50'W	61	52
13	Hunter AAF, South Carolina	32°01'N	81°09'W	13	32

*Not Available

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