Temperature	-	the average daily maximum and minimum for January and July.*
Mean Dewpoint	-	the mean dewpoint temperature at the surface for January and July.
Precipitation	-	the average annual total, and the average monthly total of the wettest and driest months.

At the ship stations, the "average" temperature is listed, i.e., the average of daily maximum and minimum readings. The dewpoint entry has been omitted at a number of locations where the data were not available. A brief description of the station location is given, and also a general climatic classification. These climatic data are intended only for preliminary comparisons of stations in different climatic regions; reference should be made to more complete climatic analyses when applying the refractivity data to performance estimates or link design.

4. DISCUSSION

The graphs show the percentage of the observations in which various refractivity gradients were found in the lowest 100 meters; they do not indicate the percentage of time in a year that such gradients can be expected. Although the latter statistics are desired for propagation and system performance estimates, the available data are insufficient to make such a determination. The radiosonde package rises through the lowest 100-m layer in less than 30 seconds, and this only twice a day at most stations. Thus, we have available two very brief samplings of atmsopheric structure daily, rather than frequent or continuous measurements. It seems unlikely that the extremes of the diurnal gradient variation would always occur at 0000Z and 1200Z (or 0300Z and 1500Z), therefore the refractivity gradient statistics based on RAOBs can be assumed to show a lower probability of occurrence of the extreme gradients than would be the case if observations were made hourly.

*Note that these are not the extremes for the period of record; for example, at Denver the average daily maximum and minimum temperatures in January are 42° and 15°F, but the extreme (or record) values for the month are 69° and -25°F.

The graphs are especially useful for station-to-station comparisons, such as estimating the probability of subrefraction in two areas with differing climates where performance data are available for only one of the areas. Thus, the relative probability of a certain k-value being exceeded can be estimated by reference to the graphs, as can strong superrefraction or ducting. In making such estimates, however, one should check both the length of record and the number of observations per day at a particular station. Also, the <u>local</u> time of the observations should be considered; for example, a distribution based primarily on nighttime (or only daytime) observations may give a distorted indication of the overall probability of occurrence of various gradients.

Variations in refractivity gradients tend to be closely related to the local or sun-referenced time, because of the influence of heating and cooling of the earth's surface on the stratification of air layers near the ground. For example, extreme gradients of refractivity often occur near sunrise, when nocturnal temperature inversions tend to be most pronounced, and near sunset, when there is a rapid shift from gain to loss of heat in the air layer near the ground. RAOBs, however, are taken at standard times which do not always coincide with the local time when extreme gradients are most likely to occur.

The variation of sunrise/sunset times during the year should also be considered, particularly at high-latitude stations. As an example, figure 3 shows the approximate time of sunrise and sunset at Fort Smith, N.W.T. (latitude 60°N), as compared to the normal release time of the standard 0000Z and 1200Z RAOB (i.e., about 30 minutes prior to the "standard" time of observation). In December both observations would effectively be night observations, while in mid-summer both observations are between sunrise and sunset. (This is also true of the 0300Z and 1500Z observations that were used in preparing the refractivity distributions for Fort Smith).

The atmospheric layers near the surface are greatly influenced by terrain features, ground moisture sources, and vegetation; thus, on most long overland paths, low-level refractivity gradients can be

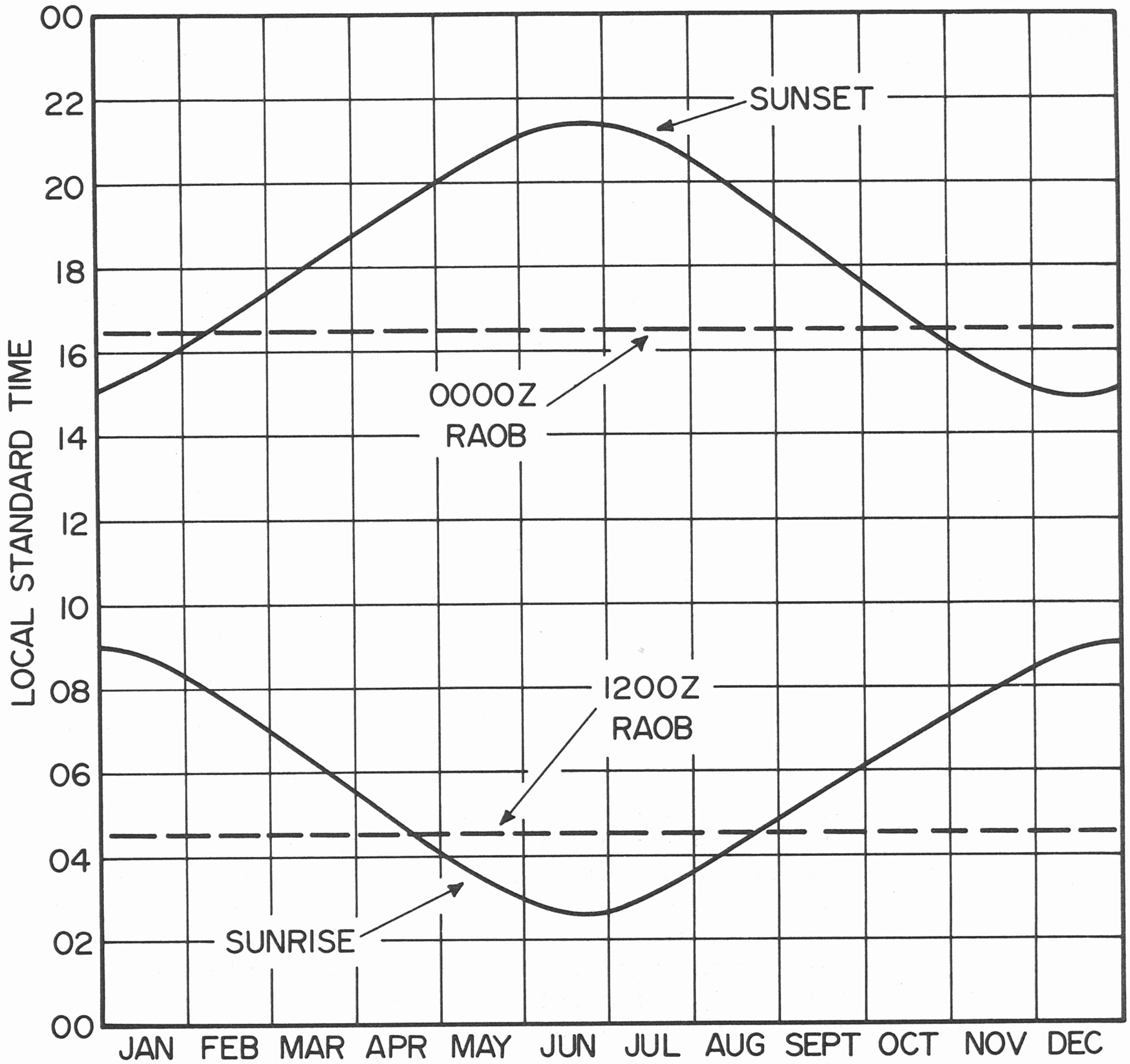

Figure 3. Relationship between sunrise/sunset times and the standard RAOB release time at Fort Smith, N.W.T.

expected to vary by appreciable amounts over distances on the order of a few kilometers. The net result of this variation in space should be to produce less extreme effective path gradients than might be assumed from consideration of radiosonde data at one point on the path. On the other hand, the RAOB data are likely to yield conservative indications of gradient intensity because of the very limited sampling period per day. This poses a dilemma that is not easily resolved. The relationship between point and path refractivity is not known, and the total time per year in which certain gradients will affect a given path must be estimated from the statistics of occurrence during two very brief observations each day at some weather station possibly hundreds of kilometers from the radio path.

Relative to the relationship between point and effective path refractivity gradients, Boithias and Battesti (1967) suggest that the minimum effective value of k varies considerably with the path length, as shown in figure 4. The general relationship is consistent with the idea that the more extreme positive refractivity gradients near the surface are greatly influenced by local conditions of terrain, moisture sources, etc., and are not likely to extend over wide areas. A further comment from a microwave design handbook (Lenkurt, 1970) is as follows:

> Experience has indicated that, for actual microwave paths, the effective k over the entire path reaches a very high or very low value for a much smaller percentage of time than would be indicated by the distribution of k values as found by meteorological measurements at single points. The most probable explanation is that the unusual conditions causing these extreme values are unlikely to occur over more than a small part of the path at any given instant.

The CCIR (1970) reports that a study of 300,000 hours of chart recordings from 21 radio relay stations in the United Kingdom, on links designed more or less for 0.6 of the first Fresnel zone clearance with k = 0.7, showed no instances of diffraction or "earth bulge" fading. This appears to indicate that the design criteria may be too conservative, and that smaller clearance might be adequate. There is at present, however, insufficient evidence to suggest by how much the clearance can be reduced with safety.

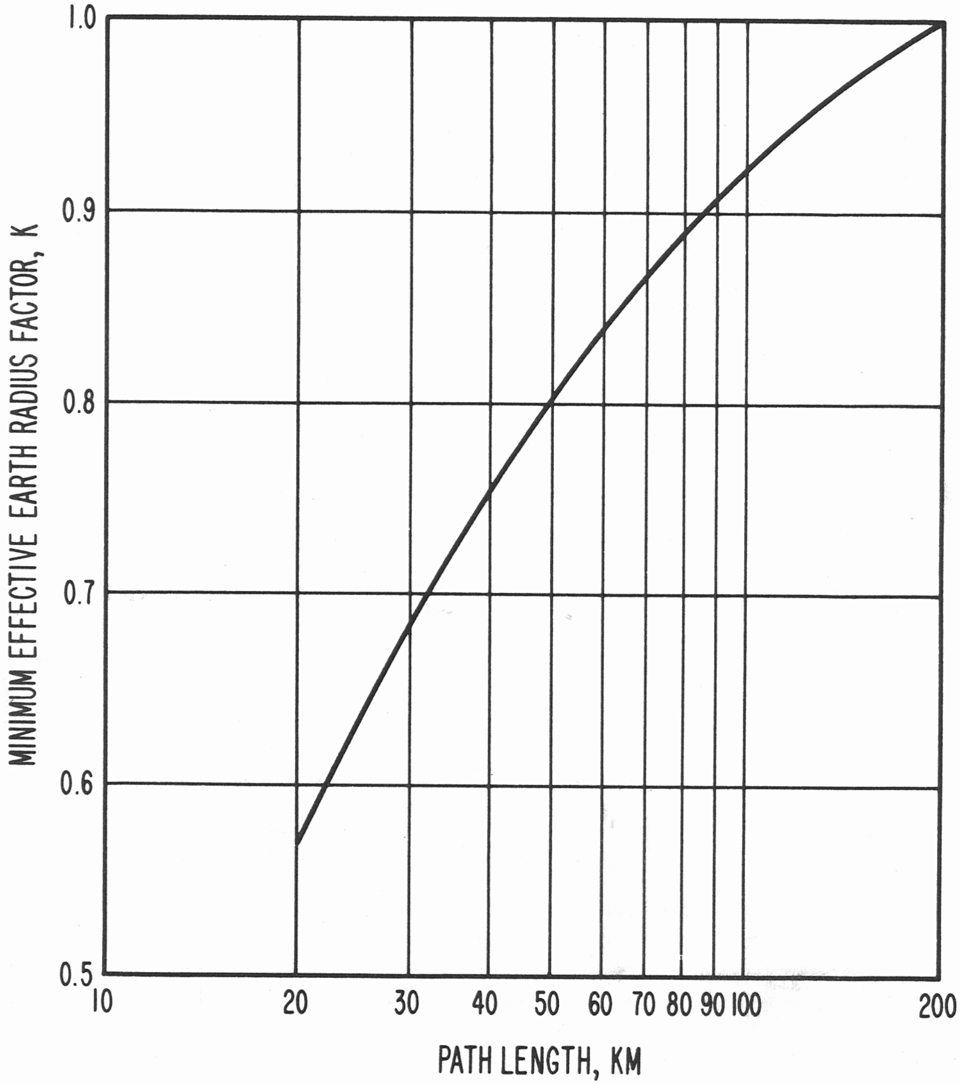

Figure 4. Minimum effective value of "k" exceeded for approximately 99.9% of the time in a continental temperate climate (CCIR, 1970).

Coastal areas and river valleys are especially likely to have anomalous propagation related to air stratification, and extreme refractivity values are most likely to occur in layers of rather limited vertical extent. The decrease in probability of extreme gradients that occurs as the averaging interval is increased is illustrated by the distribution for Cardington (see Appendix C).

Tropical and sub-tropical regions generally have larger diurnal and interdiurnal variations in refractivity gradients than do temperate regions (Hart et al., 1971). Extreme gradients are also much more common in the tropics, and over layers of limited thickness (up to a few tens of meters) may at times exceed ±1000 N-units/km. Use of the data from the nearest RAOB station is not always a satisfactory approach to radio-climatological estimates in the tropics, unless local modifications of the indicated refractivity are considered. A radio-meteorological investigation in the Mekong Delta of Viet Nam (Samson and Maloney, 1971) showed that significant long-term differences existed even over distances on the order of 100 km.

The refractivity is highly sensitive to humidity, which can change rapidly over comparatively limited horizontal or vertical distances in the tropics. Such changes often occur in land/sea breeze circulations, trade-wind subsidence regions, and monsoonal flows. At higher latitudes, however, the movement of air masses involved in large-scale weather systems may effectively produce a temporary "tropical" environment in a normally "temperate" region, as when warm, moist air masses move over the central U.S. from the Gulf of Mexico. Thus the extreme gradients common to many tropical regions can also be expected to occur at times in more temperate regions.

5. CONCLUSIONS

Refractivity data from RAOBs can be of value in link design and performance estimates, but its applicability is subject to the limitations discussed in the preceding section. The data in Appendix C must therefore be applied with considerable engineering judgment.