radio path of most terrestrial line-of-sight microwave links is relatively close to the surface, and the gradients in the lowest 100-m layer are therefore more suitable for propagation estimates than the gradients over the lowest 1 km. Microwaves may be affected by atmospheric layers of rather limited vertical extent, and 1-km layer statistics tend to smooth out many of the extreme gradients.

Information on the refractivity gradients to be expected in any part of the world is available in the "World Atlas of Atmospheric Radio Refractivity" (Bean et al., 1966). This Atlas contains maps showing the 100-m gradients exceeded for selected percentages of time. For application to the design of radio links, many engineers prefer a complete cumulative time probability distribution of the gradients at specific locations. The Atlas contains such distributions of the 50-m gradients at 22 stations worldwide; the present report supplements the Atlas by providing distributions of 100-m gradients at 87 stations in the Northern Hemisphere (see map, figure 1, and station index, Appendix C). Data for four months of the year are shown on the same graph to facilitate seasonal comparisons. Accompanying each graph is information on the length of record analyzed, the hours at which observations were taken, and general climatic and topographic details in the vicinity of the station.

2. SOURCE OF DATA

Refractivity gradients can be calculated from the radiosonde observations (RAOBs) made by national meteorological services in the various countries (see Appendix A). Although these observations of the vertical changes in temperature, pressure, and humidity do not provide as much detail and accuracy as is desirable for studies of radio refractivity, they are the only available source of worldwide, long-term, upper-air data.

Climatological RAOB data for the U.S. and many foreign locations are on file at the National Climatic Center in Asheville, N.C. The analysis of these data to obtain refractivity statistics requires that the refractive index be calculated for the individual data points on

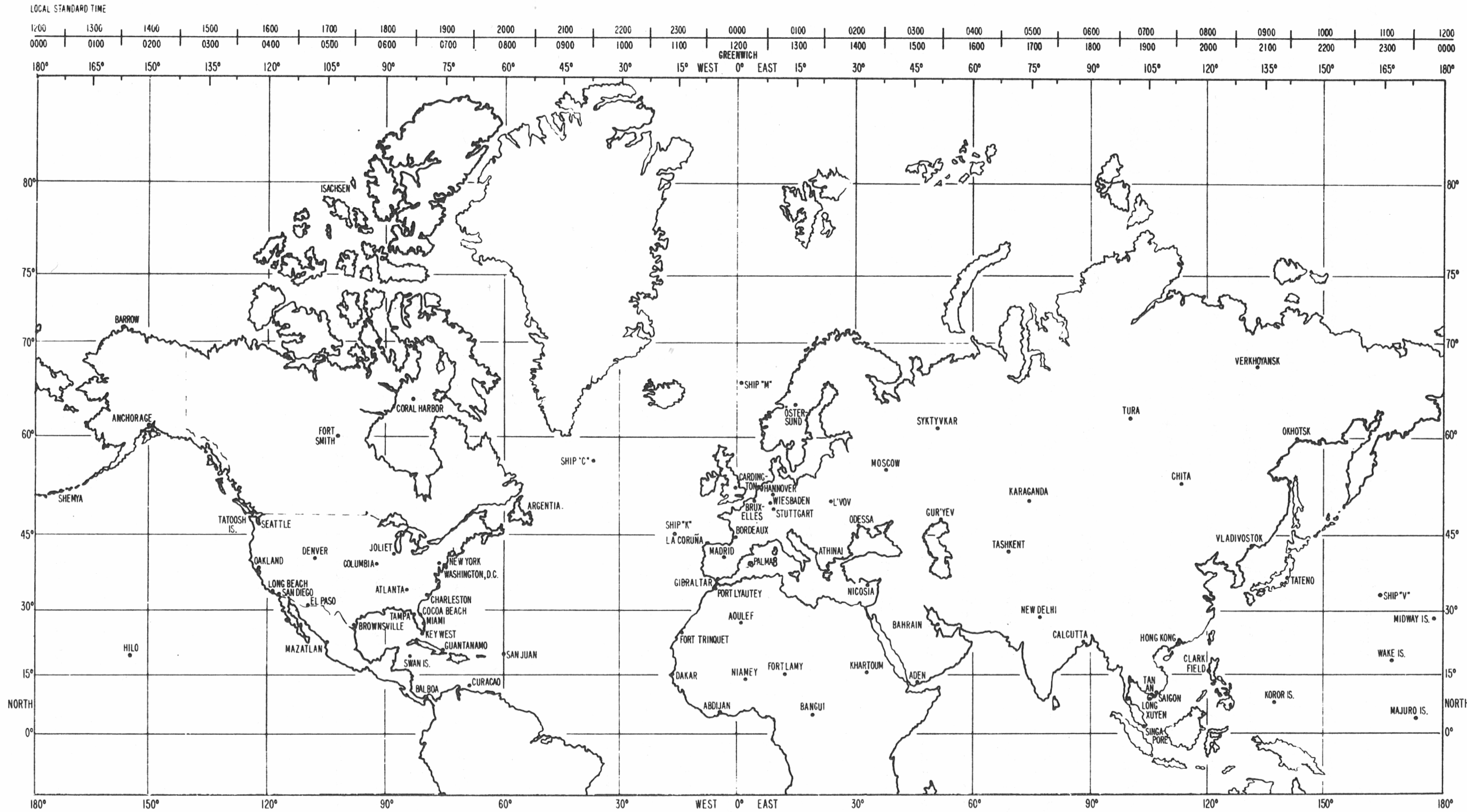

Figure 1. Location of stations for which refractivity gradient data are given in Appendix C.

each sounding; an interpolation must be made to obtain the refractivity value at the desired height (for example, 100 meters above ground); and the gradient over the interval (ground surface to 100 m) can then be calculated. To avoid possible misleading indications related to the year-to-year variations in weather conditions, data for a number of years must be considered if a good climatological average is to be obtained.

Most of the gradient distributions in this report were calculated at the Institute for Telecommunication Sciences (ITS) in Boulder as a part of a project sponsored by the U.S. Navy Weather Research Facility to prepare worldwide refractivity information in map format (Bean et al., 1966). To the extent possible at the time, climatic data for a 5-year period, including two observations per day, were used in this analysis. Only one month in each season was processed, and the observations at different times of day were not treated separately, with the exceptions of Aden and Nicosia. Stations were selected to provide wide geographical coverage, rather than to give a dense coverage in a few areas (i.e., funding limitations prevented any attempt to analyze all available RAOB data). In the U.S., for example, figure 1 shows that data from only 22 stations have been analyzed; figure 2 indicates a total of 85 stations in the domestic RAOB network of the National Weather Service as of October 1973 (NOAA, 1973). Thus, greatly increased density of coverage of refractivity information is possible in the U.S., but it should be noted that figure 2 indicates only locations where the basic data (temperature, pressure, humidity) would be available; refractivity is not routinely calculated at most RAOB stations.

This report includes additional refractivity data based upon work done in other projects or by institutes in other countries. Not all analyses cover periods of several years--a few are based on data for only one month. While these shorter periods do not provide good climatological statistics, the analyses have been included to illustrate the type of diurnal variations to be expected, to indicate a later verification of an earlier analysis, or to provide information on areas where no other refractivity data were available. Errata and supplementary

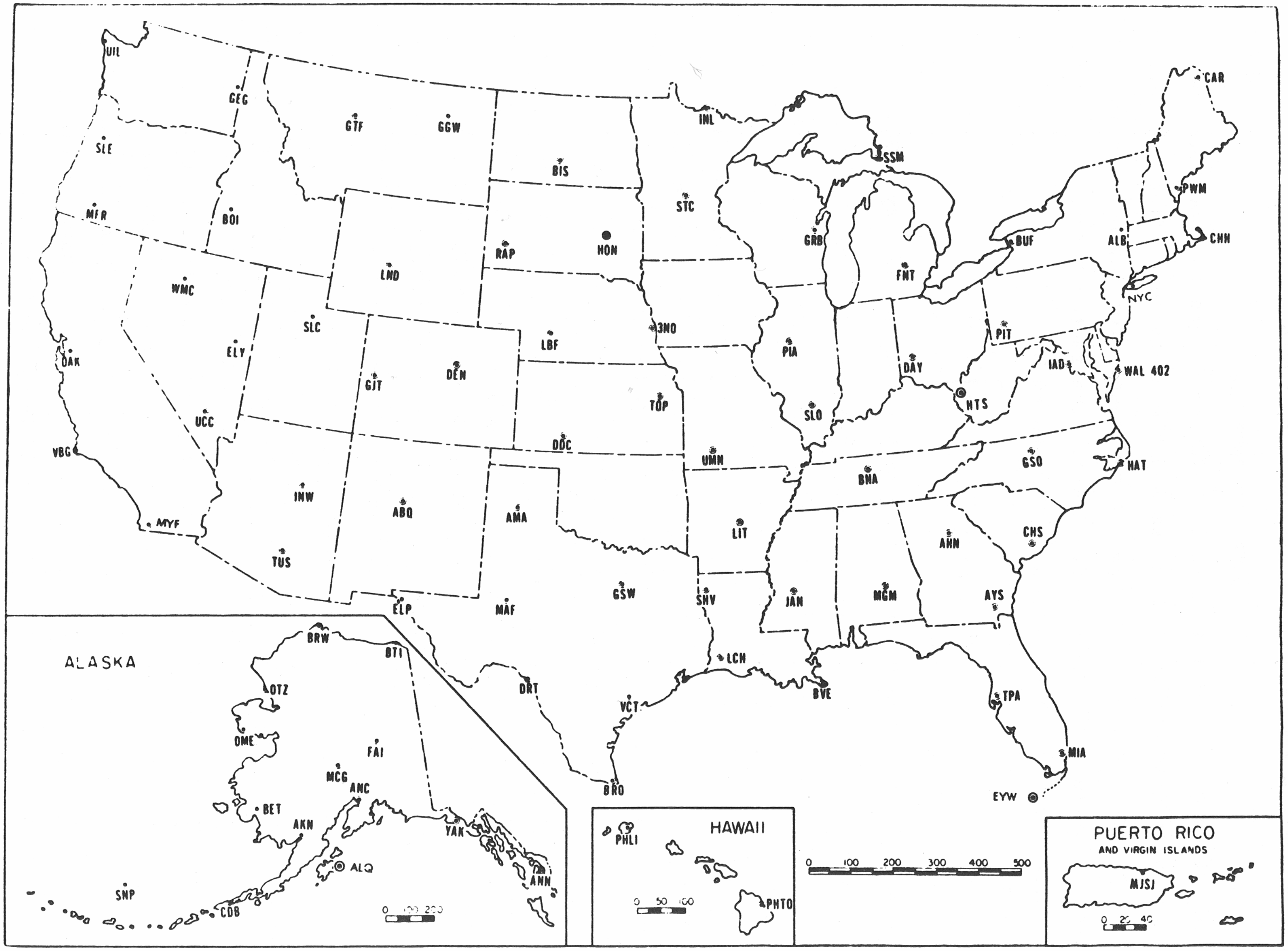

Figure 2. Domestic radiosonde network of the U.S. National Weather Service, October 1973.

information for "A World Atlas of Atmospheric Radio Refractivity" (Bean et al., 1966) are also included as Appendix D.

3. DATA PRESENTATION

Scale. Each graph has a dual scale on the ordinate to show both the refractivity gradient in N-units/km and the equivalent effective earth radius factor, "k", which is used to compensate for ray bending in terrain profile analysis of radio links. The factor "k" is related to the refractivity gradient $\Delta N/\Delta h$ in N-units/km by

$$k \simeq \left[1 + 6370 \frac{\Delta N}{\Delta h} \times 10^{-6}\right]^{-1}$$

where 6370 km represents the actual earth radius (Dougherty, 1968).

Time. Prior to 1957 the standard time of RAOBs was 0300Z and 1500Z; since then it has been 0000Z and 1200Z. In this report, all times of observation have been converted to an arbitrary "Local Standard Time" (LST) based on the assumption of zones exactly 15 degrees wide and centered on longitudes of 0°, 15°, 45°, etc. Figure 1 has a scale for comparing the local time of observation with the standard 0000Z and 1200Z observations based on the local time on the Greenwich meridian.

Refractivity Distributions. Unless otherwise indicated, the graphs show the cumulative distribution of the radio refractivity gradients in the ground-based 100-m layer, as calculated from radiosonde observations during the period specified under "Data". The analyses are by ITS, except where other agencies or individuals are referenced below the graph.

Each curve shown is based on all observations in a particular month for the period indicated, and includes data obtained from observations at more than one time of day, if available. For Aden and Nicosia, however, the data were analyzed separately for the different times of observation, and additional graphs are presented which indicate the characteristic differences between observations at different times of day at these stations. For shorter periods, diurnal characteristics are also shown for Calcutta, Clark Field, Tampa, and Tan An.