5.1 ESTIMATION OF THE URBAN HEAT ISLAND EFFECT FOR THE GLOBAL HISTORICAL CLIMATOLOGICAL NETWORK

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1. INTRODUCTION

The influence of urbanization and land use/land cover (LULC) on several meteorological variables, primarily temperature, has been well documented (e.g., Landsberg 1981). Adjustment of temperatures for the U.S. Historical Climatology Network (HCN; NCDC, 2002a) is based on the population of cities associated with weather observation stations. In development of these adjustments, Karl et al., (1988) detected the influence of urbanization on long-term temperature records (the urban heat-island bias) for cities with populations less than 10 000.

No routine operational adjustments are currently made to the Global Historical Climatological Network data set (GHCN; NCDC 2002b). Urban influences on global data sets are typically removed through identification of urban stations and adjustment of temperature records for the urban station based on surrounding stations (e.g., Hanson et al., 2001).

Gallo and Owen (1999) observed that the satellite-derived normalized difference vegetation index (NDVI) sampled over urban and rural regions composed of a variety of land surface environments, were related to the differences in observed urban and rural temperatures. The difference in the NDVI between urban and rural environments appears to be an indicator of the differences in the surface properties (i.e., evaporation and heat storage capacity) between the two environments.

A satellite-based methodology for estimation of the urban heat-island (UHI) bias on a global basis was developed by Gallo and Owen (2002). The objectives of this study included assessment of the use of remotely sensed data to provide recommendations related to urban heat-island related temperature adjustments for stations included in global climatological data networks.

2. METHODOLOGY

This analysis relied primarily on globally available, satellite derived, data sets. These data sets included a global 1-km AVHRR-derived NDVI 10-day composite data set (Eidenshink and Faundeen, 1994) developed on requirements of the International Geosphere-Biosphere Programme (IGBP), a global DMSP-OLS city lights data (Elvidge et al., 1997) and the IGBP global 1-km land cover data set (Belward et al.,1999) that includes a water data layer, and an urban data layer derived from Digital Chart of the World data. This urban layer, while out of date for some regions of the world, was found to supplement the DMSP-OLS city lights data for those regions of the world with low energy utilization for city (or other) lights at night.

The global 1-km NDVI 10-day composite data sets were composited on a monthly basis for July through October 1992, January through April 1993 and July through September 1993. As the NDVI was used to assess the urban influence on the stations, the analysis was confined to July through October for the Northern Hemisphere and January through April for the Southern Hemisphere.

Two monthly NDVI data sets were produced that included the water mask (ND1) and the water and urban masks (ND2). The "local" climate station NDVI data was extracted from the ND1 data for each station at a three by three grid cell region (1 km grid cells) centered on the station location. Individual grid cells defined as water were excluded from the sample and further analysis.

A 41 by 41 grid cell area centered on the station location was then sampled, from the ND2 data, for NDVI values from those grid cells identified as rural and not water. The local sample, the three by three grid cell area centered on the station and computed as described above, was not included in this sample. This 41 by 41 km sample was considered the "regional" NDVI sample. Mean NDVI values were computed for both the local and regional samples. The difference between the local and regional samples of NDVI was then computed as

$$NDVI_{LR} = NDVI_L - NDVI_R \quad . \qquad [1]$$

Elevation at the local sample station location was compared to that of every 1 km grid cell within a 41 by 41 km area centered on the station location through the use of the GTOPO30 data set available from the USGS EROS Data Center (USGS, 2002). Stations were excluded from further analysis if the difference between any grid cell in the 41 by 41 km area that surrounds a station and that at the station was greater than 500 m. Nearly 2900 of the more than 7200 perspective GHCN stations were excluded due to variation in elevation.

The $NDVI_{LR}$ values were used to define a station as urban or rural based on results of Gallo and Owen (1999). Differences in local and regional average air temperatures were estimated based on the observed differences in NDVI ($NDVI_{LR}$) and the results of Gallo

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and Owen (1999).

3. RESULTS

Due to the change in seasons and the developed relationships between air temperature and NDVI, a separate analysis was made for the stations located in the Northern and Southern Hemispheres.

Northern Hemisphere

More than 3500 stations within the Northern Hemisphere were analyzed (Table 1). The number defined as urban varied, as expected, with the monthly variations in local and regional vegetation characteristics as observed with the NDVI. The proportion of those stations analyzed that were considered urban ranged from 9% (Oct. 1992) to 28% (July 1993).

The mean estimated temperature difference between the stations identified as urban based on local and regional differences in observed NDVI, and their surrounding rural environment, ranged from 0.69 ^{o}C for October of 1992 to 0.98 ^{o}C for August of 1993. The maximum estimated temperature difference between a station and its surrounding rural environment ranged from 2.03 ^{o}C (October 1992) to 3.2 ^{o}C (August 1993).

A paired t-test of the differences in the observed NDVI, between the local (normally the lower NDVI value) and regional samples (larger NDVI value), revealed significant (α = .01) differences in NDVI for those stations identified as urban, for each month examined. Significant differences were also observed for those stations identified as rural for each of the months examined. Differences in estimated temperature were also significant for all months for both the urban and rural designated subsets of stations.

Southern Hemisphere

Less than 900 stations were analyzed for the Southern Hemisphere. Similar to the Northern Hemisphere analysis the number of stations defined as urban varied, from 94 (April, 1993) to 172 (March, 1993). The proportion of the stations analyzed that were identified as urban ranged from 11% (April 1993) to 20% (March 1993).

The NDVI-based estimated temperature difference between the urban stations and their surrounding rural environment ranged from a mean of 0.8 (March 1993) to 0.97 ^{o}C (February 1993). Maximum differences ranged from 1.82 to 2.53 ^{o}C.

4. CONCLUSIONS

The observed differences in NDVI and estimated temperature between local and regional samples of stations classified as urban were not unexpected. The observed differences for those GHCN stations that were classified as rural suggest that a more detailed analysis of the rural stations and their surrounding environment may be necessary to assure that temperature trends derived from rural environments are truly not influenced by any urbanization.

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Table 1. Number of stations in N. Hemisphere analysis, percent of stations urban, mean estimated temperature difference (^{o}C) between station and surrounding environment, and maximum estimated temperature difference.

month	n	urban %	mean temp.	max temp.
July 1992	3537	23.0	0.94	2.70
Aug. 1992	3538	22.9	0.96	2.73
Sept. 1992	3569	18.7	0.69	2.07
Oct. 1992	3531	9.3	0.89	2.03
July 1993	3510	27.7	0.97	3.03
Aug.1993	3510	26.2	0.98	3.22
Sept. 1993	3511	25.0	0.78	2.89