Climate Indices for Use in Social and Behavioral Research

by William H. Walters

Overview

While climate influences many social and behavioral phenomena, it is often poorly or incompletely represented in social science research. Studies of elderly migration, for example, often rely on a single variable to represent the full set of climatic conditions found across the United States (Walters 1994b). Moreover, there is no reliable guide to the selection of the most appropriate climate variables. Any single construct such as winter temperature can be represented by a variety of indicators — minimum daily temperature, average daily temperature, number of freezing days, number of below-zero days, number of heating degree-days, etc. Although observed variables are essential in climatological research, statistically constructed indices may be more useful for many social and behavioral applications.

This report describes the use of factor analysis to create five climate indices from a set of 37 original (observed) variables. These indices represent all the major components of near-surface climate variation within the United States. In addition, they offer at least three advantages over the original variables:

1) While any individual observed variable may be affected by measurement error, each index incorporates the variance common to more than one of the original variables. For instance, the difficulty of obtaining accurate snowfall measurements will produce more error in the observed variable (snowfall depth) than in an index that incorporates both snowfall and a number of related measures.

2) The five indices are uncorrelated and represent nearly 90 percent of the variance within the original set of 37 variables. There is no need to select a subset of the variables for use in multivariate studies since all five can be used together without danger of multicollinearity.

3) The data set is readily accessible to scholars whose primary interests lie outside climatology. (Appendix A presents the complete set of indices for almost every first-order weather station within the coterminous United States.) In contrast, many of the data files distributed by NOAA require expertise in the use of complex and sometimes discipline-specific data formats.[1]

Along with the climate indices (factor scores), factor analysis produces a set of factor loadings that reveal the relationships among the original variables. The results of this analysis confirm that American climates are dominated by strong seasonal influences. In particular, summer air moisture and temperature are not closely linked to the corresponding winter conditions.

Previous Research

Factor analysis, developed for use in psychometric research, has since achieved widespread application in the field of climatology — most often in the construction of climate classification schemes. R-mode factor analysis, a variant of the usual technique, can be used to reveal the relationships among a set of observed climate variables and to represent those variables through a smaller number of factors.[2] The resulting indices (factor scores) are useful whenever it is necessary to represent the full range of climate variation through a limited number of variables, or whenever the underlying components of climate are more important than the observed values themselves. As a predictor of retirement migration, for example, an index of winter climate severity is probably more meaningful than the number of snow days or the average January temperature (Walters 1994a).

Richman (1986) reviews the use of factor analysis in climate research. He describes six modes of analysis, which can be used to (1) classify geographic locations according to climate, (2) identify time periods in which climatic conditions remained stable, and (3) represent a large number of climate variables through a smaller number of factors. While many authors have focused on the first two goals, only a few have conducted the R-mode analyses that meet the third objective. Micklin and Dickason (1981), for example, found that 16 climate indicators for the Soviet Union could be adequately represented by just four factors. These factors — aridity, continentality, atmospheric turbidity, and thermality — captured 85% of the variance within the original set of variables. Similar analyses have been undertaken for Australia (Puvaneswaran 1990), Canada (Powell 1977), Greece

(Bartzokas and Metaxas 1995), Nigeria (Olaniran 1986), and Pakistan (Oliver et al. 1978). Using data for the state of Maine, Briggs and Lemin (1992) found that 37 climate indicators could be represented by just three constructed indices. The climate of Midland, Texas, is apparently more complex, involving up to ten distinct factors (Ladd and Driscoll 1980).

Only two studies have presented R-mode factor analysis results for the entire United States. Davis and Kalkstein (1990) focus on weather rather than climate, however, while Walters (1994a) uses pre-1970 data and evaluates only those sites near metropolitan areas. The R-mode analysis presented here is based upon more recent data and represents the full range of climate variation within the coterminous United States.

Data And Methods

Data for 216 first-order weather stations were taken from the *Local Climatological Data* series of the National Oceanic and Atmospheric Administration (Wood 1996). Eighteen stations were excluded due to insufficient data. The temperature and precipitation data are site-adjusted averages, 1961 to 1990. All other variables are based on measurements made prior to 1994. The length of record varies by site and phenomenon but is typically 30 to 50 years.

Principal components analysis (PCA) with varimax rotation[3] was applied to the 37 variables shown in Table 1. These variables include all the meaningful components of climate: annual, summer, and winter values of temperature, precipitation, humidity, cloud cover, wind speed, storm days, fog days and precipitation days; as well as related indicators such as snowfall, wind chill, and heat stress.

PCA, like other types of factor analysis, is an objective, empirical procedure that reapportions the variance within the original set of variables. The results reflect the pattern of correlations among these variables so that each factor usually represents a cluster of related measures. In this instance, 87.8% of the total variance can be represented by just five factors (five indices). These factors were rotated and interpreted according to the criteria suggested by Cattell (1958), Rummel (1970) and Thurstone (1947).

Results

Varimax rotation always produces independent (uncorrelated) factors. In this case, each factor is conceptually distinct as well. That is, each has a unique and readily identifiable meaning. (*See Table 1*.)

The first factor, F1, represents winter temperature and snowfall. Locations with high values of F1 tend to have mild winters, relatively few freezing days, little snowfall, and only modest seasonal temperature variation. In contrast, sites with low values of F1 can expect severe winter temperatures and heavy snowfall. To a lesser extent, F1 represents annual and summer temperatures. (High values of F1 correspond to high temperatures throughout the year.) Factor 1 is not a straightforward indicator of summer temperature, however, since (1) another factor, F4, represents maximum daily temperature throughout the summer months and (2) the summer temperature variables most closely associated with F1 are strongly related to F4 as well. While winter temperature is fully represented by F1, summer temperature fails to emerge as a single, independent component of the climate system.

The second factor, F2, is a summer air-moisture indicator representing summer precipitation, cloud cover, humidity, and storms. While summer temperature and humidity are often thought to occur in tandem, these results show that the two phenomena are not necessarily related. In particular, only one of the variables most closely associated with F2 (heat stress — humiture) is strongly related to both F1 and F2.

The third factor, F3, is much like F2 but represents winter rather than summer conditions. Locations with high values of F3 tend to have many rainy days, heavy cloud cover and high humidity throughout the cooler months. In contrast, places with low values of F3 are distinguished by relatively clear, dry winters. While the annual air moisture variables have high loadings on both F2 and F3, Factor 3 is the best single indicator of year-round precipitation, cloud cover, and humidity.

The fourth factor, F4, represents those aspects of summer temperature not included in Factor 1. In particular, summer maximum daily temperature is most closely related to F4. (High values of F4 correspond to cool summers.) Table 1 shows that the other summer temperature variables are also closely linked to F4 even though their primary association is with F1.

The fifth factor, F5, is primarily a wind-speed indicator. It incorporates all three wind-speed variables (annual, summer, and winter) as well as the number of days with dense fog.

Taken together, the factor loadings confirm that American climates are dominated by strong seasonal influences. Rather than forming a single precipitation factor, for instance, the various precipitation variables combine with other air-moisture indicators (cloud cover and humidity) to create two distinct seasonal factors, F2 and F3. Likewise, summer temperature is at least partly independent of winter temperature. Of the several components of climate, only wind speed and fog (Factor 5) fail to display strong seasonal independence.

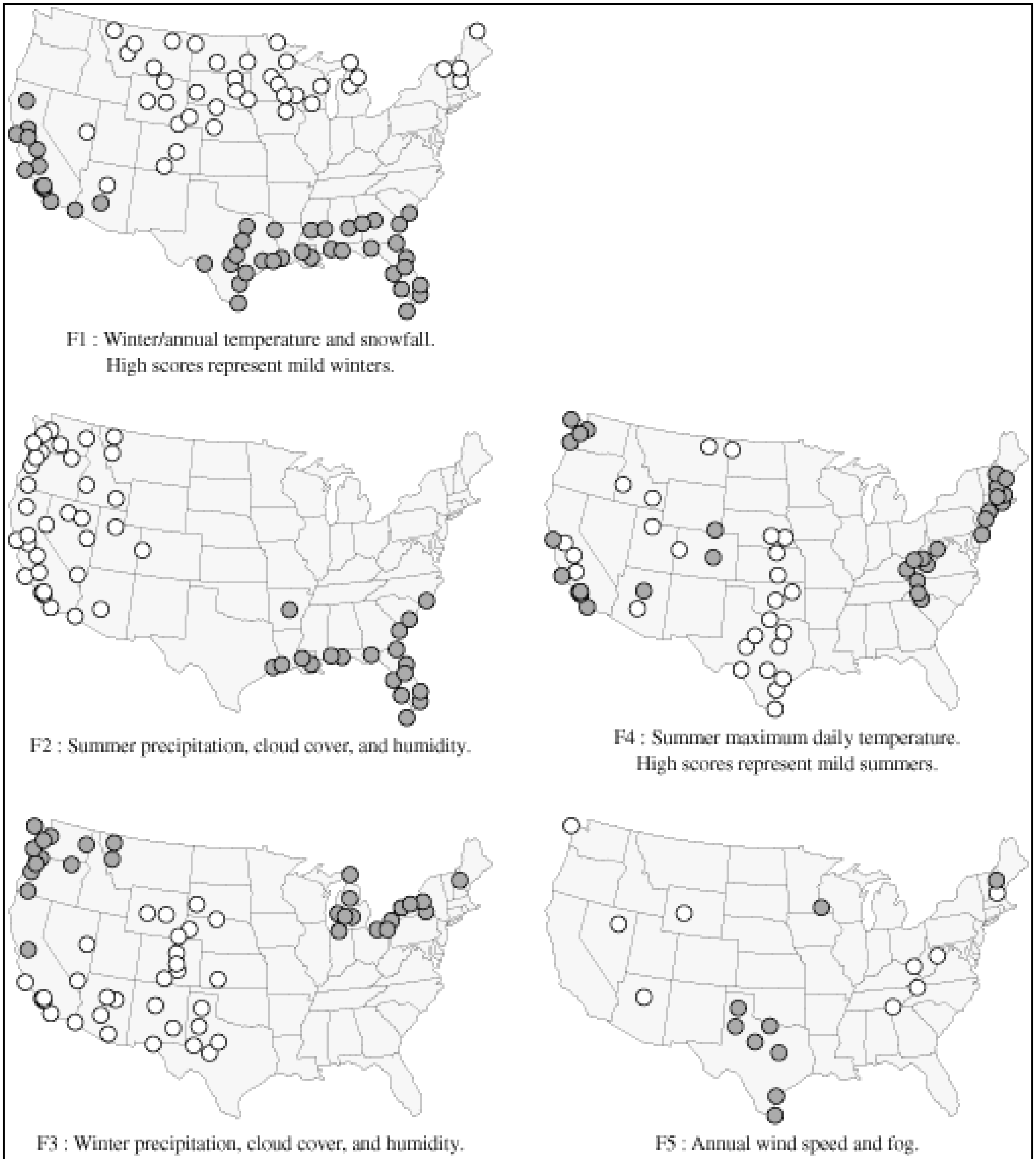

Figure 1. Spatial patterns of the factor scores. Values more than one standard deviation higher (lower) than the mean are represented by dark (light) circles.

The climate indices (factor scores) for each weather station are presented in Appendix A.[4] By mapping the highest and lowest scores, we can identify the spatial pattern associated with each factor. Figure 1 reveals that each factor is spatially coherent — nearby locations have similar values — and that each has a distinctive geographical pattern. Winter/annual temperature and snowfall (F1) vary with latitude, for instance, while summer air moisture (F2) is highest in the Southeast and lowest in the West. Figure 1 also helps illustrate why the summer temperature variables are associated with both F1 and F4. Factor 1 shows the influence of latitude, primarily, while F4 best represents the distinction between continental and marine climates. Summer temperature is therefore a function of both latitude and continentality. In contrast, winter temperature and snowfall can be adequately represented by a single factor (F1) that varies chiefly by latitude.

Conclusions

The American climate system can be represented by just five indices — five sets of factor scores. Because these scores are uncorrelated, all five can be used together — as explanatory variables, for instance — without danger of multicollinearity.

The results of this analysis are consistent with previous research on the factor structure of American climates. In particular, five of the six factors identified in an earlier study (Walters 1994a) can be seen here as well. This suggests that the factor structure has not changed over time and that it does not vary when new locations are added to the analysis. The relationships observed here are not necessarily valid for other countries or for particular regions of the U.S., however. The climate of Queensland, Australia, for example, does not display strong seasonality (Puvaneswaran 1990). Likewise, the climates of Nigeria (Olaniran 1986), Pakistan (Oliver et al 1978) and Maine (Briggs and Lemin 1992) are dominated by regional and local factors not present in the United States at the national level.

Notes

1. See, for example, the *First Order Summary of the Day* (http://www.ncdc.noaa.gov/onlineprod/tfsod/climvis/ftppage.html).

2. Richman (1986) provides a good overview of this technique.

3. Several oblique and orthogonal rotation methods were evaluated empirically. While each method generated a similar set of factors, varimax gave the most robust results — the results that changed the least when random variation (representing error) was added to the original climate variables.

4. A machine-readable version of Appendix A is available from the author.

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Table 1 . Rotated Factor Loadings [a]

Variable		F1	F2	F3	F4	F5	h^2
freezing days (annual)		-0.97	—	—	—	—	0.95
min daily temp (winter)		0.97	—	—	—	—	0.95
avg daily temp (winter)		0.97	—	—	—	—	0.96
heating degree days (annual)		-0.96	—	—	—	—	0.98
zero-degree days (annual)	*	-0.95	—	—	—	—	0.92
avg daily temp (annual)		0.94	—	—	—	—	0.99
snow days (annual)	*	-0.94	—	—	—	—	0.92
snowfall (annual)	*	-0.94	—	—	—	—	0.92
wind chill (winter)		0.93	—	—	—	—	0.96
seasonal temp variation		-0.80	—	—	-0.41	—	0.85
cooling degree days (annual)		0.79	—	—	-0.40	—	0.92
storm days (winter)	*	0.72	0.44	—	—	—	0.75
avg daily temp (summer)		0.70	—	-0.30	-0.51	—	0.92
heat stress — THI (summer)		0.68	0.58	—	-0.33	—	0.92
ninety-degree days (annual)		0.66	—	-0.33	-0.53	—	0.84
precipitation (summer)		—	0.91	—	—	—	0.91
precipitation days (summer)		—	0.88	—	—	—	0.88
storm days (annual)		—	0.84	—	-0.30	—	0.87
storm days (summer)		—	0.81	—	—	—	0.78
cloud cover (summer)		—	0.75	0.37	0.38	—	0.87
heat stress — humiture (summer)		0.48	0.74	—	—	—	0.86
humidity (summer)		—	0.67	0.45	0.41	—	0.86
precipitation (annual)		0.32	0.63	0.47	0.34	—	0.86
humidity (winter)		—	—	0.89	—	—	0.80
cloud cover (winter)		-0.37	—	0.88	—	—	0.92
precipitation days (winter)		—	—	0.81	0.41	—	0.86
cloud cover (annual)		-0.44	0.35	0.74	—	—	0.91
humidity (annual)		—	0.49	0.71	0.30	—	0.85
precipitation days (annual)		-0.31	0.44	0.69	0.36	—	0.89
precipitation (winter)		0.42	—	0.53	0.51	—	0.74
fog days (summer)	*	—	0.42	—	0.70	—	0.79
max daily temp (summer)		0.55	—	-0.39	-0.65	—	0.91
wind speed (annual)		—	—	—	—	0.92	0.94
wind speed (summer)		—	—	—	—	0.88	0.89
wind speed (winter)		—	—	—	—	0.87	0.92
fog days (winter)		—	—	0.37	—	0.61	0.68
fog days (annual)		—	—	—	0.58	0.58	0.75
% variance explained		39.3	25.5	11.4	8.2	3.5	
cumulative %		39.3	64.8	76.2	84.3	87.8	

[a] Principal components analysis with varimax rotation. Annual = average for all months. Summer = average for June, July, and August. Winter = average for December, January, and February. Values in bold type are the highest loadings for each variable. Loadings between -0.30 and 0.30 are not shown. Variables marked with an asterisk (*) were entered in cube root form to maintain linearity. Communality (h^2) indicates the proportion of the variance within each variable that is shared with the other variables in the set.

Appendix A

Climate indices (factor scores — regression method) for 216 first-order weather stations in the coterminous United States. Sixteen stations were excluded due to insufficient data. Each factor has a mean of 0.00 and a standard deviation of 1.00.

Weather Station	*State*	*F1*	*F2*	*F3*	*F4*	*F5*
Birmingham	*AL*	*0.74*	*0.88*	*0.28*	*-0.07*	*-0.95*
Huntsville	*AL*	*0.66*	*0.78*	*0.38*	*0.06*	*-0.50*
Mobile	*AL*	*1.36*	*1.67*	*0.22*	*-0.14*	*0.30*
Montgomery	*AL*	*1.18*	*0.81*	*0.22*	*0.02*	*-0.74*
Fort Smith	*AR*	*0.51*	*0.43*	*-0.02*	*-0.66*	*-0.52*
Little Rock	*AR*	*0.79*	*1.02*	*0.23*	*-0.49*	*-0.28*
Flagstaff	*AZ*	*-1.10*	*-0.32*	*-1.93*	*1.17*	*-1.32*
Phoenix	*AZ*	*1.49*	*-1.43*	*-2.25*	*-1.17*	*-0.56*
Tucson	*AZ*	*0.95*	*-0.56*	*-2.57*	*-0.60*	*-0.20*
Winslow	*AZ*	*-0.29*	*-0.94*	*-1.85*	*-0.67*	*-0.20*
Yuma	*AZ*	*1.69*	*-1.83*	*-2.78*	*-0.90*	*0.18*
Bakersfield	*CA*	*1.49*	*-2.86*	*0.01*	*-1.36*	*0.03*
Fresno	*CA*	*1.58*	*-2.92*	*0.87*	*-1.58*	*0.46*
Long Beach	*CA*	*1.65*	*-1.97*	*-1.25*	*2.39*	*-0.53*
Los Angeles (Airport)	*CA*	*1.63*	*-1.90*	*-1.36*	*3.03*	*-0.31*
Los Angeles (Civic Center)	*CA*	*1.70*	*-1.79*	*-1.76*	*2.41*	*-0.99*
Redding	*CA*	*1.16*	*-2.17*	*0.23*	*-0.82*	*-0.18*
Sacramento	*CA*	*1.55*	*-2.77*	*0.95*	*-0.85*	*0.69*
San Diego	*CA*	*1.59*	*-1.85*	*-1.23*	*2.66*	*-0.67*
San Francisco (Airport)	*CA*	*1.33*	*-2.46*	*0.07*	*1.68*	*0.72*
Santa Maria	*CA*	*1.33*	*-2.14*	*-1.46*	*3.96*	*-0.22*
Stockton	*CA*	*1.55*	*-2.98*	*1.03*	*-1.14*	*0.75*
Alamosa	*CO*	*-1.59*	*-0.43*	*-1.54*	*0.37*	*-0.56*
Colorado Springs	*CO*	*-1.07*	*0.40*	*-2.86*	*1.49*	*-0.19*
Denver	*CO*	*-0.92*	*-0.14*	*-1.87*	*0.46*	*-0.55*
Grand Junction	*CO*	*-0.48*	*-1.22*	*-0.72*	*-1.34*	*-0.30*
Pueblo	*CO*	*-0.74*	*-0.23*	*-2.32*	*-0.03*	*-0.04*
Bridgeport	*CT*	*-0.13*	*0.06*	*-0.38*	*1.19*	*0.74*
Hartford	*CT*	*-0.53*	*0.14*	*-0.15*	*0.97*	*-0.46*
Washington (Dulles)	*DC*	*-0.11*	*0.29*	*-0.02*	*0.70*	*-0.72*
Washington (National)	*DC*	*0.20*	*0.19*	*-0.18*	*-0.02*	*-0.15*
Wilmington	*DE*	*0.02*	*0.17*	*-0.06*	*0.70*	*-0.06*
Daytona Beach	*FL*	*1.56*	*1.58*	*-0.09*	*0.01*	*0.06*
Fort Myers	*FL*	*1.71*	*2.44*	*-0.60*	*-0.57*	*0.01*
Jacksonville	*FL*	*1.40*	*1.43*	*0.06*	*-0.03*	*0.01*
Key West	*FL*	*2.01*	*1.18*	*-0.32*	*-0.55*	*0.61*
Miami	*FL*	*1.77*	*1.91*	*-0.45*	*-0.12*	*-0.02*
Orlando	*FL*	*1.61*	*1.98*	*-0.30*	*-0.40*	*0.18*
Pensacola	*FL*	*1.46*	*1.38*	*0.26*	*-0.15*	*0.24*
Tallahassee	*FL*	*1.44*	*1.91*	*0.06*	*0.18*	*-0.39*
Tampa	*FL*	*1.62*	*1.85*	*-0.32*	*-0.46*	*0.03*
West Palm Beach	*FL*	*1.72*	*1.87*	*-0.17*	*-0.29*	*0.06*
Athens	*GA*	*0.86*	*0.67*	*-0.18*	*0.71*	*-0.37*
Atlanta	*GA*	*0.80*	*0.65*	*-0.13*	*0.59*	*0.06*
Augusta	*GA*	*0.91*	*0.85*	*-0.11*	*0.24*	*-0.79*
Columbus	*GA*	*1.11*	*0.86*	*0.26*	*-0.19*	*-0.76*
Macon	*GA*	*1.05*	*0.80*	*0.04*	*0.00*	*-0.41*
Savannah	*GA*	*1.16*	*1.35*	*-0.28*	*0.30*	*-0.12*
Des Moines	*IA*	*-0.75*	*0.59*	*-0.09*	*-0.70*	*0.38*
Sioux City	*IA*	*-0.89*	*0.41*	*-0.15*	*-0.75*	*0.46*
Waterloo	*IA*	*-1.02*	*0.51*	*0.09*	*-0.53*	*0.33*

Boise	*ID*	*-0.21*	*-2.00*	*0.71*	*-1.04*	*0.07*
Pocatello	*ID*	*-0.84*	*-1.56*	*0.74*	*-1.39*	*0.35*
Chicago	*IL*	*-0.72*	*0.29*	*0.44*	*-0.41*	*0.08*
Moline	*IL*	*-0.70*	*0.64*	*0.00*	*-0.39*	*-0.02*
Peoria	*IL*	*-0.52*	*0.48*	*0.41*	*-0.56*	*0.14*
Rockford	*IL*	*-0.83*	*0.47*	*0.27*	*-0.31*	*0.06*
Springfield	*IL*	*-0.37*	*0.45*	*0.37*	*-0.75*	*0.45*
Evansville	*IN*	*0.05*	*0.37*	*0.52*	*-0.54*	*-0.56*
Fort Wayne	*IN*	*-0.58*	*0.25*	*0.86*	*-0.48*	*0.01*
Indianapolis	*IN*	*-0.33*	*0.42*	*0.75*	*-0.39*	*-0.06*
South Bend	*IN*	*-0.67*	*0.31*	*1.16*	*-0.42*	*0.06*
Concordia	*KS*	*-0.49*	*0.63*	*-0.33*	*-1.07*	*0.42*
Dodge City	*KS*	*-0.21*	*0.26*	*-1.67*	*-0.29*	*0.74*
Topeka	*KS*	*-0.42*	*0.86*	*0.07*	*-0.87*	*-0.06*
Wichita	*KS*	*-0.07*	*0.13*	*-0.19*	*-1.33*	*0.23*
Jackson	*KY*	*0.10*	*0.80*	*0.32*	*1.31*	*-0.66*
Lexington	*KY*	*-0.05*	*0.54*	*0.54*	*-0.03*	*-0.24*
Louisville	*KY*	*0.02*	*0.47*	*0.42*	*-0.25*	*-0.65*
Paducah	*KY*	*0.28*	*0.69*	*0.42*	*-0.33*	*-0.44*
Baton Rouge	*LA*	*1.42*	*1.36*	*0.36*	*-0.18*	*-0.22*
Lake Charles	*LA*	*1.59*	*1.09*	*0.83*	*-0.58*	*0.47*
New Orleans	*LA*	*1.56*	*1.27*	*0.71*	*-0.45*	*0.01*
Shreveport	*LA*	*1.17*	*0.41*	*0.46*	*-0.78*	*-0.09*
Boston	*MA*	*-0.26*	*0.02*	*-0.50*	*1.21*	*0.80*
Worcester	*MA*	*-0.56*	*0.04*	*-0.48*	*2.21*	*0.61*
Baltimore	*MD*	*0.07*	*0.11*	*-0.27*	*0.55*	*-0.06*
Caribou	*ME*	*-1.79*	*0.39*	*0.35*	*0.69*	*0.23*
Portland	*ME*	*-0.83*	*0.12*	*-0.39*	*1.94*	*-0.37*
Alpena	*MI*	*-1.30*	*0.06*	*0.83*	*0.26*	*-0.81*
Detroit	*MI*	*-0.66*	*0.04*	*0.85*	*-0.32*	*0.14*
Flint	*MI*	*-0.85*	*0.05*	*0.83*	*-0.16*	*-0.08*
Grand Rapids	*MI*	*-0.83*	*0.09*	*1.32*	*-0.40*	*-0.07*
Houghton Lake	*MI*	*-1.24*	*-0.05*	*1.07*	*0.03*	*-0.46*
Lansing	*MI*	*-0.88*	*0.10*	*1.15*	*-0.41*	*-0.10*
Muskegon	*MI*	*-0.82*	*-0.11*	*1.34*	*-0.25*	*0.07*
Sault Ste. Marie	*MI*	*-1.49*	*0.09*	*1.17*	*0.68*	*-0.38*
Duluth	*MN*	*-1.69*	*0.48*	*-0.21*	*0.90*	*0.42*
International Falls	*MN*	*-2.07*	*0.47*	*-0.04*	*0.09*	*-0.64*
Minneapolis-St. Paul	*MN*	*-1.28*	*0.38*	*-0.13*	*-0.58*	*0.12*
Rochester	*MN*	*-1.26*	*0.47*	*0.23*	*-0.47*	*1.27*
St. Cloud	*MN*	*-1.53*	*0.28*	*-0.21*	*0.03*	*-0.68*
Columbia	*MO*	*-0.21*	*0.52*	*0.13*	*-0.43*	*0.19*
Kansas City	*MO*	*-0.29*	*0.61*	*-0.35*	*-0.51*	*0.54*
Springfield	*MO*	*0.01*	*0.63*	*-0.08*	*-0.44*	*0.44*
St. Louis	*MO*	*-0.05*	*0.40*	*0.38*	*-0.90*	*0.02*
Jackson	*MS*	*1.11*	*0.92*	*0.61*	*-0.52*	*-0.48*
Meridian	*MS*	*1.12*	*0.78*	*0.39*	*0.03*	*-0.93*
Tupelo	*MS*	*0.83*	*0.58*	*0.37*	*-0.16*	*-0.74*
Billings	*MT*	*-1.11*	*-0.64*	*-0.89*	*-0.11*	*0.39*
Glasgow	*MT*	*-1.45*	*-0.61*	*0.01*	*-1.12*	*0.41*
Great Falls	*MT*	*-1.29*	*-0.54*	*-0.64*	*-0.13*	*0.76*
Helena	*MT*	*-1.28*	*-0.66*	*-0.23*	*-0.47*	*-0.85*
Kalispell	*MT*	*-1.14*	*-1.12*	*1.31*	*0.02*	*-0.95*
Missoula	*MT*	*-0.95*	*-1.22*	*1.29*	*-0.49*	*-0.96*
Asheville	*NC*	*0.20*	*0.86*	*-0.52*	*2.18*	*-0.42*
Cape Hatteras	*NC*	*0.98*	*0.69*	*0.40*	*0.37*	*0.57*

Charlotte	*NC*	*0.58*	*0.46*	*-0.31*	*0.63*	*-0.59*
Greensboro	*NC*	*0.37*	*0.62*	*-0.36*	*0.89*	*-0.55*
Raleigh	*NC*	*0.49*	*0.64*	*-0.41*	*0.91*	*-0.51*
Wilmington	*NC*	*0.90*	*1.09*	*-0.13*	*0.49*	*-0.17*
Bismarck	*ND*	*-1.62*	*-0.03*	*-0.27*	*-0.71*	*-0.01*
Fargo	*ND*	*-1.66*	*0.14*	*-0.09*	*-0.83*	*0.70*
Williston	*ND*	*-1.61*	*-0.31*	*-0.08*	*-1.00*	*0.02*
Grand Island	*NE*	*-0.86*	*0.45*	*-0.03*	*-1.06*	*0.43*
Lincoln	*NE*	*-0.77*	*0.46*	*0.19*	*-1.35*	*0.17*
Norfolk	*NE*	*-0.95*	*0.45*	*-0.63*	*-0.69*	*0.58*
North Platte	*NE*	*-1.02*	*0.24*	*-0.92*	*-0.36*	*0.13*
Omaha (Eppley)	*NE*	*-0.71*	*0.55*	*-0.35*	*-0.69*	*0.29*
Omaha (North)	*NE*	*-0.73*	*0.55*	*-0.45*	*-0.41*	*-0.17*
Scottsbluff	*NE*	*-1.07*	*-0.01*	*-1.22*	*-0.36*	*0.11*
Valentine	*NE*	*-1.22*	*0.19*	*-1.06*	*-0.72*	*-0.18*
Concord	*NH*	*-1.02*	*0.13*	*-0.40*	*1.55*	*-1.01*
Mount Washington	*NH*	*-1.10*	*0.34*	*1.00*	*4.13*	*11.90*
Atlantic City (NAFEC)	*NJ*	*-0.01*	*0.21*	*-0.18*	*1.10*	*0.20*
Newark	*NJ*	*-0.05*	*0.17*	*-0.16*	*0.34*	*0.13*
Albuquerque	*NM*	*-0.18*	*-0.63*	*-2.34*	*-0.04*	*-0.22*
Roswell	*NM*	*0.22*	*-0.46*	*-2.18*	*-0.05*	*-0.05*
Elko	*NV*	*-0.87*	*-1.61*	*-0.24*	*-0.64*	*-1.28*
Ely	*NV*	*-1.26*	*-1.20*	*-1.11*	*-0.59*	*0.06*
Las Vegas	*NV*	*0.86*	*-1.90*	*-2.77*	*-0.95*	*0.31*
Reno	*NV*	*-0.44*	*-2.10*	*-0.97*	*-0.20*	*-0.93*
Winnemucca	*NV*	*-0.67*	*-1.92*	*-0.46*	*-0.89*	*-0.51*
Albany	*NY*	*-0.92*	*0.27*	*0.34*	*0.34*	*-0.52*
Binghamton	*NY*	*-0.89*	*0.15*	*1.01*	*0.77*	*0.17*
Buffalo	*NY*	*-0.81*	*0.05*	*1.56*	*-0.34*	*0.47*
New York (Central Park)	*NY*	*-0.02*	*-0.02*	*-0.30*	*0.35*	*-0.38*
New York (JFK)	*NY*	*0.04*	*0.10*	*-0.46*	*1.17*	*0.75*
New York (La Guardia)	*NY*	*-0.02*	*0.07*	*-0.51*	*0.70*	*0.69*
Rochester	*NY*	*-0.88*	*-0.06*	*1.29*	*-0.17*	*-0.38*
Syracuse	*NY*	*-0.99*	*0.15*	*1.41*	*-0.28*	*-0.52*
Akron-Canton	*OH*	*-0.61*	*0.25*	*1.00*	*0.03*	*-0.14*
Cincinnati	*OH*	*-0.26*	*0.46*	*0.60*	*-0.06*	*-0.29*
Cleveland	*OH*	*-0.67*	*0.14*	*1.23*	*-0.42*	*-0.03*
Columbus	*OH*	*-0.46*	*0.39*	*0.72*	*-0.07*	*-0.67*
Dayton	*OH*	*-0.40*	*0.26*	*0.74*	*-0.27*	*0.03*
Mansfield	*OH*	*-0.58*	*0.23*	*0.95*	*-0.08*	*0.42*
Toledo	*OH*	*-0.70*	*0.20*	*0.85*	*-0.27*	*-0.29*
Youngstown	*OH*	*-0.72*	*0.22*	*1.25*	*0.09*	*-0.17*
Oklahoma City	*OK*	*0.42*	*-0.01*	*-0.37*	*-1.11*	*0.94*
Tulsa	*OK*	*0.37*	*0.30*	*0.00*	*-1.25*	*0.30*
Astoria	*OR*	*0.77*	*-1.09*	*2.33*	*2.61*	*-0.35*
Eugene	*OR*	*0.87*	*-2.00*	*2.58*	*0.79*	*0.11*
Medford	*OR*	*0.65*	*-2.52*	*1.85*	*-0.60*	*-0.49*
Pendleton	*OR*	*0.00*	*-2.29*	*1.18*	*-0.82*	*0.26*
Portland	*OR*	*0.57*	*-1.65*	*2.16*	*0.52*	*-0.34*
Salem	*OR*	*0.56*	*-1.91*	*2.32*	*0.51*	*-0.49*
Allentown	*PA*	*-0.34*	*0.28*	*0.02*	*0.59*	*-0.21*
Erie	*PA*	*-0.72*	*0.18*	*1.50*	*-0.42*	*0.16*
Middletown/Harrisburg	*PA*	*-0.22*	*0.18*	*-0.02*	*0.49*	*-0.79*
Philadelphia	*PA*	*-0.02*	*0.17*	*-0.13*	*0.49*	*-0.04*
Pittsburgh	*PA*	*-0.61*	*0.23*	*0.87*	*0.15*	*-0.54*
Wilkes-Barre/Scranton	*PA*	*-0.64*	*0.19*	*0.42*	*0.52*	*-0.64*

Appendix A. cont...

Williamsport	*PA*	*-0.55*	*0.49*	*0.26*	*0.86*	*-0.79*
Providence	*RI*	*-0.33*	*0.08*	*-0.33*	*1.26*	*0.16*
Charleston	*SC*	*1.08*	*1.35*	*-0.09*	*0.18*	*-0.03*
Columbia	*SC*	*0.87*	*0.96*	*-0.20*	*0.29*	*-0.68*
Greenville-Spartanburg	*SC*	*0.66*	*0.58*	*-0.38*	*1.07*	*-0.62*
Aberdeen	*SD*	*-1.43*	*0.10*	*-0.27*	*-0.82*	*0.46*
Huron	*SD*	*-1.30*	*0.21*	*-0.31*	*-0.92*	*0.57*
Rapid City	*SD*	*-1.16*	*-0.01*	*-1.14*	*-0.13*	*0.37*
Sioux Falls	*SD*	*-1.17*	*0.33*	*-0.20*	*-0.82*	*0.55*
Bristol	*TN*	*0.08*	*0.55*	*0.14*	*1.25*	*-1.42*
Chattanooga	*TN*	*0.57*	*0.79*	*0.25*	*0.43*	*-1.09*
Knoxville	*TN*	*0.34*	*0.59*	*0.30*	*0.58*	*-0.88*
Memphis	*TN*	*0.79*	*0.48*	*0.38*	*-0.73*	*-0.14*
Nashville	*TN*	*0.38*	*0.63*	*0.33*	*-0.19*	*-0.55*
Abilene	*TX*	*0.73*	*-0.23*	*-1.01*	*-1.09*	*1.03*
Amarillo	*TX*	*0.00*	*0.00*	*-2.08*	*-0.18*	*1.68*
Austin	*TX*	*1.40*	*-0.21*	*0.06*	*-0.93*	*0.45*
Brownsville	*TX*	*2.03*	*-0.52*	*0.93*	*-1.51*	*1.55*
Corpus Christi	*TX*	*1.82*	*-0.36*	*0.85*	*-1.38*	*1.69*
Dallas-Forth Worth	*TX*	*1.02*	*-0.15*	*-0.13*	*-1.41*	*0.74*
Del Rio	*TX*	*1.29*	*-0.60*	*-0.63*	*-1.28*	*0.75*
El Paso	*TX*	*0.44*	*-0.66*	*-2.64*	*-0.31*	*-0.19*
Houston	*TX*	*1.41*	*0.67*	*0.76*	*-0.91*	*-0.03*
Lubbock	*TX*	*0.25*	*-0.08*	*-1.77*	*-0.38*	*1.21*
Midland-Odessa	*TX*	*0.64*	*-0.54*	*-1.68*	*-0.61*	*0.94*
Port Arthur	*TX*	*1.59*	*1.05*	*0.96*	*-0.96*	*0.75*
San Angelo	*TX*	*0.80*	*-0.47*	*-1.02*	*-1.05*	*0.58*
San Antonio	*TX*	*1.41*	*-0.30*	*0.20*	*-1.19*	*0.53*
Victoria	*TX*	*1.63*	*0.29*	*0.81*	*-1.21*	*0.98*
Waco	*TX*	*1.18*	*-0.21*	*0.20*	*-1.73*	*1.08*
Wichita Falls	*TX*	*0.67*	*-0.06*	*-0.62*	*-1.43*	*1.07*
Salt Lake City	*UT*	*-0.36*	*-1.30*	*0.42*	*-1.68*	*0.05*
Norfolk	*VA*	*0.56*	*0.47*	*-0.18*	*0.50*	*0.34*
Richmond	*VA*	*0.26*	*0.56*	*-0.10*	*0.51*	*-0.57*
Roanoke	*VA*	*0.01*	*0.42*	*-0.58*	*0.95*	*-0.63*
Burlington	*VT*	*-1.34*	*0.25*	*0.51*	*0.23*	*-0.60*
Olympia	*WA*	*0.54*	*-1.67*	*2.56*	*1.89*	*-0.19*
Quillayute	*WA*	*0.76*	*-0.73*	*2.68*	*3.43*	*-1.17*
Seattle-Tacoma	*WA*	*0.55*	*-1.53*	*1.78*	*1.51*	*-0.07*
Spokane	*WA*	*-0.42*	*-1.99*	*1.53*	*-0.35*	*0.51*
Yakima	*WA*	*-0.34*	*-2.24*	*0.82*	*-0.84*	*-0.52*
Green Bay	*WI*	*-1.18*	*0.23*	*0.16*	*0.14*	*-0.05*
La Crosse	*WI*	*-1.10*	*0.56*	*-0.07*	*-0.15*	*-0.48*
Madison	*WI*	*-1.06*	*0.37*	*0.25*	*-0.14*	*-0.04*
Milwaukee	*WI*	*-0.85*	*0.21*	*0.20*	*0.22*	*0.51*
Beckley	*WV*	*-0.47*	*0.68*	*0.68*	*1.15*	*-0.38*
Charleston	*WV*	*-0.01*	*0.73*	*0.21*	*1.71*	*-0.86*
Elkins	*WV*	*-0.70*	*0.93*	*0.70*	*1.79*	*-1.32*
Huntington	*WV*	*-0.07*	*0.62*	*0.36*	*1.24*	*-1.00*
Casper	*WY*	*-1.38*	*-0.51*	*-1.04*	*-0.42*	*0.85*
Cheyenne	*WY*	*-1.23*	*0.19*	*-2.21*	*1.07*	*0.77*
Lander	*WY*	*-1.40*	*-0.89*	*-1.30*	*-0.11*	*-1.12*
Sheridan	*WY*	*-1.40*	*-0.51*	*-0.51*	*-0.33*	*-0.90*