P1.12 A Climatology of Hourly THI Values for Livestock Producers

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1. INTRODUCTION

The Temperature Humidity Index (THI) has been used for over 30 years to alert livestock producers and haulers about heat stress conditions that threaten animal well being (LCI 1970). Livestock are subject to stress when high temperatures and high humidity combine to limit the ability of cattle to dissipate excess heat (Hahn et al., 2001; Mader et al., 2001; Mader 2003). Thom (1959) originally developed the THI to characterize heat stress for humans. Three THI categories are used by livestock producers and haulers as an operational environmental management tool: alert (THI from 75 - 78), danger (THI from 79-83), and emergency (THI greater than 84). In addition, declines in rates of animal production, feedlot cattle deaths, and livestock heat wave categories have been identified based on accumulated THI magnitude and/or the length of high THI periods. Analyses based on the use of daily data suggest that economic losses from heat stress are significant (St-Pierre et al., 2003). A goal of this research effort is to improve our understanding of heat and humidity as an environmental hazard for livestock through the climatological analysis of available hourly data for weather stations in the central United States.

Hazards research has been informed by a variety of contributors (Bryant, 1991; Burton et al., 1978; Cross, 1994; Cutter, 2001, Mitchell, 1989; Tobin and Montz, 1997; White, 1974) and a major subset deals with climatic hazards, such as floods, droughts, blizzards, severe thunderstorms, and heat waves, and the impact of these hazards on human well-being. As a result, there is considerable sharing of ideas, methods, and research findings among biometeorologists or applied climatologists and hazards researchers. Bioclimatology "deals with the relations of climate and life, especially the effects of climate on the health and activity of human beings ... and on animals and plants" (Glickman, 2000). Organism sensitivity to extreme conditions, for either wild or domesticated plants and animals, is a major bioclimatology component (Kalkstein,1991).

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Geographic research dealing with applied climatology and environmental hazards has tended to examine stress and risks that directly impact humans (and not necessarily other animals); the emphasis on humans follows from the human-environment or environmental-societal dynamics synthesis domain (Wilbanks et al., 1997). A few social scientists within the hazards research community have incorporated indirect effects associated with stressful conditions, such as significant economic losses associated with a hazard (Burton et al., 1978).

Stresses to non-human organisms have a major human/societal impact when the affected organisms are linked to an important economic system, such as food production (St-Pierre et al. 2003). In this research effort, the emphasis is on the development of new bioclimatic indicators to assist livestock producers based on long-term analysis of hourly data.

2. LIVESTOCK AND HEAT STRESS

This paper presents one aspect of a multi-year research project, 'Evaluating Models Predicting Livestock Output Due to Climate Change;' funded by the Great Plains Regional Center of the US DOE National Institute for Global Environmental Change (NIGEC). A mission for NIGEC is to provide regionally-conceived, academic research that can aid the United States' response to environmental change. A focus of the effort at Kansas State University is the development of a number of applied climate products designed to help test the validity of existing statistical/conceptual models that relate livestock production and health to accumulating heat stress.

In prior NIGEC funded work, Frank et al. (2001) and Frank (2001) identified a number of empirical algorithms relating daily weather/climate variables to livestock performance. Selected conceptual, statistical, and process-related models or relationships were derived from relevant, recent National Research Council publications covering the impacts of heat, humidity, and other environmental factors on the voluntary feed intake for beef cattle, dairy cattle, and swine (NRC, 1989; NRC 1996; NRC, 1998). Relationships identified by Fox and Tylutki (1998) also informed the development of statistical models. Using GCM output from the Canadian Climate Centre and the Hadley Center for Climate Prediction and Research, scenarios for current and future climate were tested using the empirical models. In general, these future warm season climate scenarios suggest marked reductions in production (increased days to reach market weight or declines in daily milk production) for animals not impacted by an adjustment in management strategies.

High heat and humidity levels are important inhibitors of optimal livestock performance and most previous work has used daily or monthly averages of temperature and humidity in developing a THI statistic to compare with animal performance. Recently, studies on selected extreme events have used hourly THI calculations to examine how the magnitude of the temperature anomaly and/or the temporal extent of high THI periods are related to declines in rates of animal production and increases in feedlot cattle deaths (Mader et al., 2001). In addition, initial development of heat wave categories for livestock have been defined based on hourly THI statistics (Hahn et al., 2001). Given the significant number of feedlot cattle in the central United States (Figure 1), this study is using available hourly data from weather stations in the area to develop a long-term data base on THI to assist livestock producers in the region. Hart and Mayda (1998) characterize the area where confined animal feeding is concentrated as the "Denver-Omaha-Lubbock triangle" and identify a spatial correlation between confined animal feeding and the heart of the 1930s Dust Bowl. A goal for this research is to use hourly THI data to provide a better understanding of the range of climatic conditions and the associated risk or hazard for livestock production in the area.

3. DATA AND METHODS

Climate data used in this analysis are from the National Climate Data Center's Surface Airways data set because weather stations with hourly observations of temperature and humidity were needed. For each station with more than 20 years of recorded data (Table 1), hourly temperature and relative humidity data were extracted and then THI was calculated. High hourly THI values with a value of 65 or greater were retained for assessment of diurnal, month-to-month, and inter-annual variations. Values of THI between 65 and 75 are valuable for assessing the amount of overnight cooling that a animal might receive. In addition, we are able to examine the data record for multiple day runs with THI exceeding a selected threshold.

The major statistic used in bioclimatic assessment of weather severity for livestock is THI hours. THI hours are calculated in a manner similar to heating degree days or growing degree days, and a base value or threshold (e.g., 75) is used in THI hour the calculation. If the THI value at 3:00 pm on a given summer day is 81.5, then there would be 6.5 THI (base 75) hours (81.5 - 75 = 6.5) for that observation time. The number of THI hours is generally summed for a daily interval to give an indication of cumulative heat stress for that 24 hour period. Longer periods can also be used for accumulating THI hours, such as: a three day run, a week, a month, or a year.

Table 1. Stations analyzed and the year of maximum (Max 1) and second maximum (Max 2) of accumulated THI base 79 (* base 75 for Cheyenne, WY).

	Max 1	Max 2
Ft. Smith, AR	1998	**1980**
Little Rock, AR	**1980**	1954
Pueblo, CO	1973	**1980**
Moline, IL	1983	1988
Des Moines, IA	1983	1988
Mason City, IA	1983	1988
Sioux City, IA	1988	1955
Waterloo, IA	1988	1983
Concordia, KS	**1980**	1983
Dodge City, KS	**1980**	1983
Goodland, KS	1954	1966
Russell, KS	**1980**	1954
Topeka, KS	**1980**	1954
Wichita, KS	1954	**1980**
Paducah, KY	1954	1993
Minneapolis, MN	1955	1988
Columbia, MO	**1980**	1995
Kansas City, MO	**1980**	1978
Kansas City Intl., MO	**1980**	2000
St. Louis, MO	**1980**	1954
Springfield, MO	**1980**	1954
Grand Island, NE	**1980**	1983/2000
Lincoln, NE	**1980**	1983
Omaha, NE	1978	**1980**
Norfolk, NE	1988	1995
North Platte, NE	1995	1991
Scottsbluff, NE	**1980**	1981
Valentine, NE	1988	1995
Roswell, NM	1951	1977
Oklahoma City, OK	1988	**1980**
Tulsa, OK	1978	1954
Pierre, SD	1983	1966
Sioux Falls, SD	1983	1988
Memphis, TN	**1980**	1954
Abilene, TX	1998	**1980**
Amarillo, TX	1953	1969
Lubbock, TX	1994	1998
Wichita Falls, TX	**1980**	1998
Cheyenne, WY	1954*	1995*

In this study, summary statistics being generated include: THI hours (above the base values or thresholds of 75, 79, and 84) per day, a count of hours per day where THI exceeds a selected threshold, per month, and per year. Harrington and Bowles (2002) presented findings on diurnal and seasonal variations in THI which documented a mid-afternoon maxima, an asymmetrical daily cycle, and a peak in July (which extends into August in hot years).

4. RESULTS AND DISCUSSION

Temporal shifts in annual THI are profound and the heat stress hazard for livestock, while low in most years, becomes a major issue some years (Table 1 and

Figures 2 and 3). For example, 1980 was either the year or second highest year of great livestock heat stress for over half the stations analyzed. Other years where excessive heat was a problem for a number of the stations include: 1954 (especially for southern stations), 1988 (for northern stations), and 1983 (for eastern stations). Time series for Wichita, Kansas, and Norfolk, Nebraska, (Figures 2 and 3) help illustrate these temporal variations. Analysis of the skewness for the annual data for Wichita and Norfolk provides an indication that the data for Wichita are positively skewed.

There is considerable geographic variation in mean annual accumulated THI among the weather stations analyzed (Figure 4). Values decline as elevation increases westward toward the Great Plains. And, values also decline as one moves northward. The pattern of highest mean annual accumulated THI suggests a correlation with the northward advection of moisture associated with the low-level jet.

5. ACKNOWLEDGMENT

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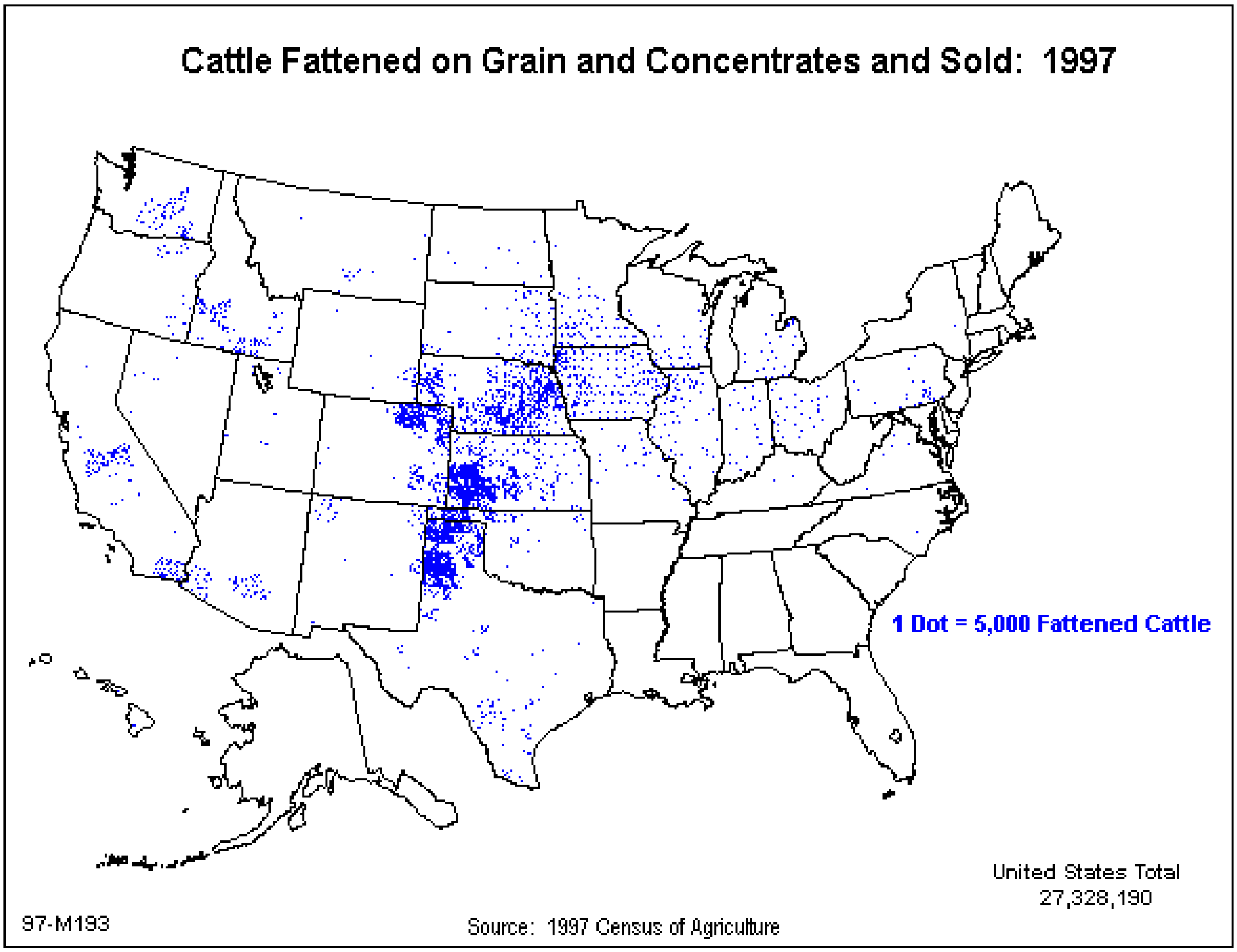

Figure 1. Cattle on Feed, 1997 (Source: USDA)

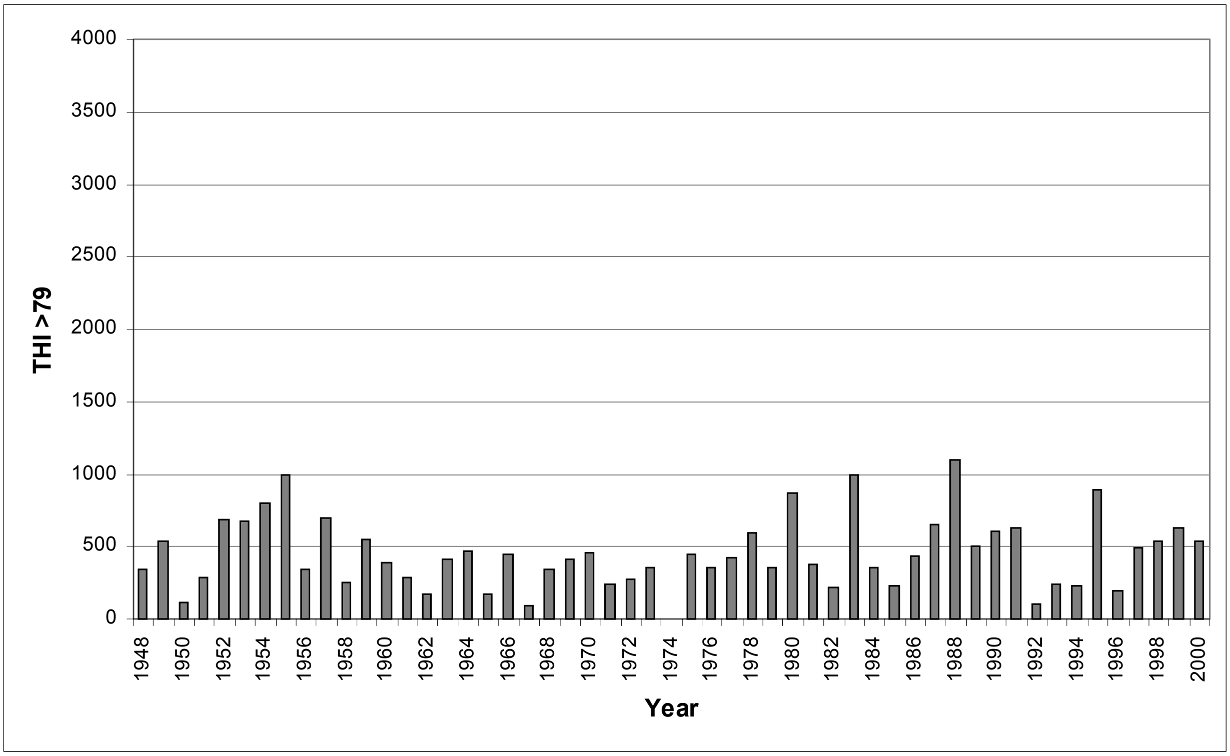

Figure 2. Annual accumulated THI (base 79) for Norfolk, Nebraska.

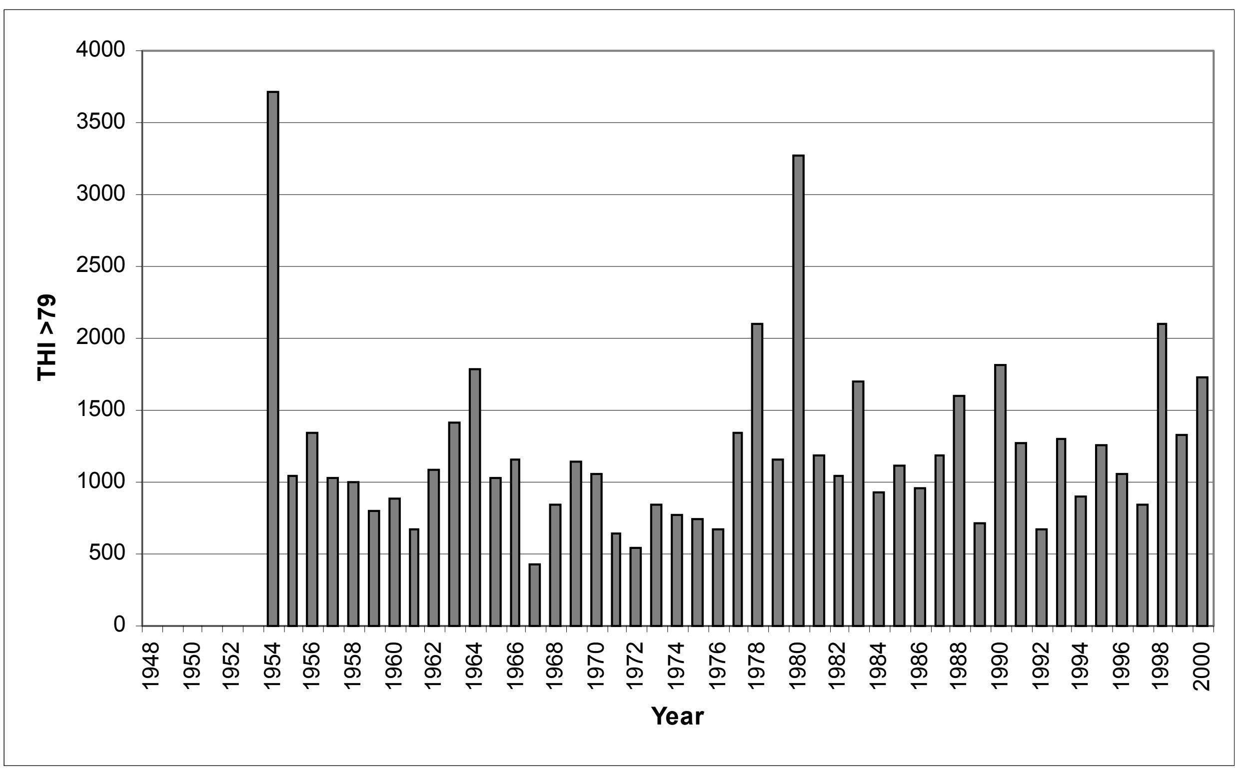

Figure 3. Annual accumulated THI (base 79) for Wichita, Kansas.

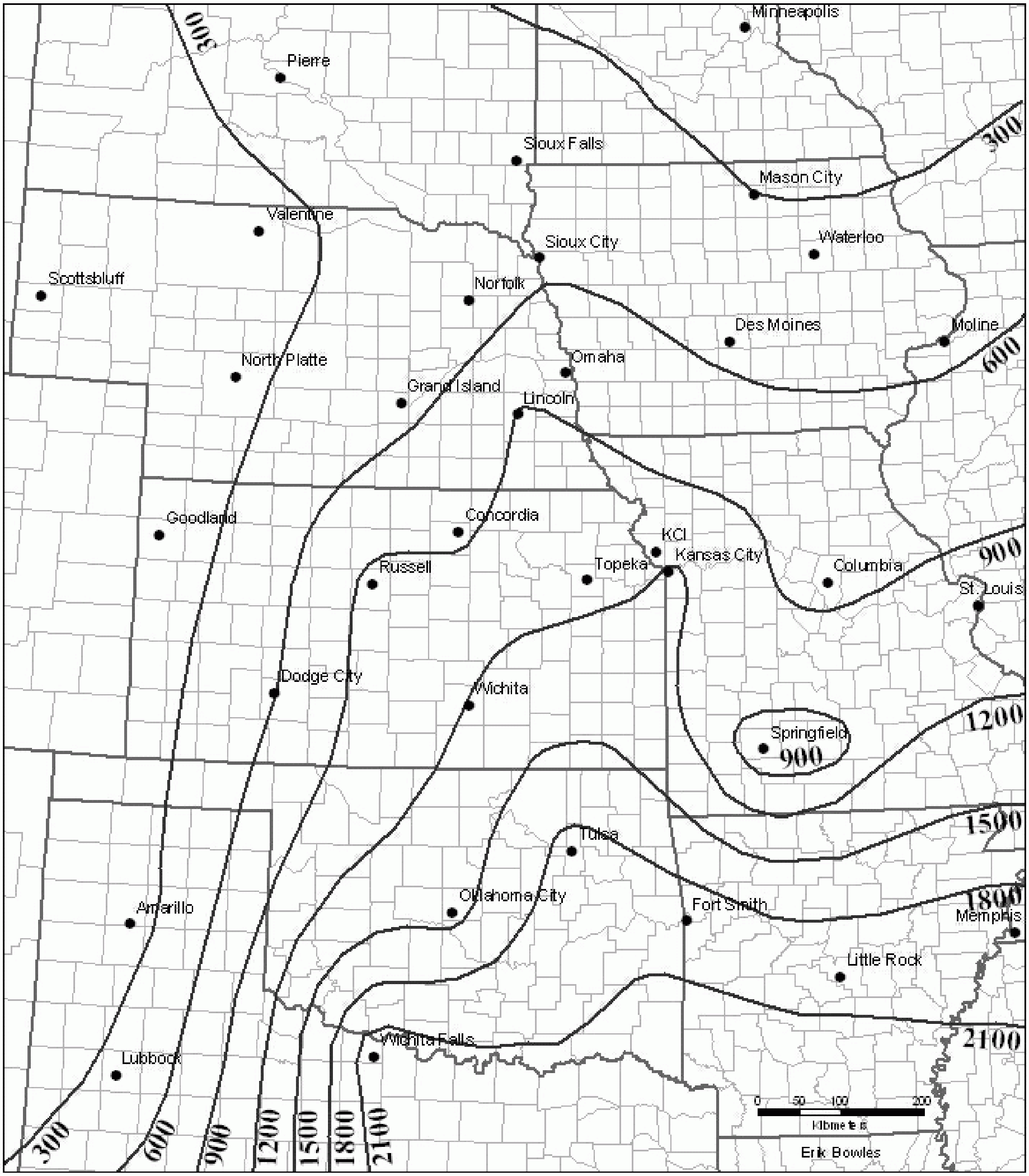

Figure 4. Average annual accumulated THI (base 79).