# MIXING RATIO AND TEMPERATURE VARIATION IN THE WINNIPEG AREA

by

Charles G. Ponce

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A thesis submitted to the Faculty of Graduate Studies of
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MASTER OF ARTS

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ABSTRACT

Over a two year period, 1976 - 1977, 253 itineraries of 86.3 km. were randomly conducted under all weather conditions along a well defined urban - rural traverse, encompassing all major land usage, upwind and downwind of Winnipeg's core area. The automobile mounted, dew point hygrometer provided dew point and temperature data which were then standardized to the initial traverse commencement time. Climatological parameters, such as mixing ratio, saturation deficits, and absolute humidities were then calculated.

Ward's error sum of squares hierarchic fusion algorithm was utilized to achieve cluster traverse organization. Linearly interpolated surface to 500 mb. radiosonde data aided in detecting air mass groupings. To facilitate urban - rural climatological comparisons with the established literature, the primary air masses chosen for investigated were the bench mark air masses, continental Arctic and continental maritime Arctic.

The general postulation throughout the thesis was that no hypothesis would be formulated regarding the traverse data sample distributions, the spatial distributions of the climatological parameters under investigation, or the

temporal variability of these climatic parameters without statistical supporting evidence. As background information regarding the bench air mass data was absent, non - parametric statistical techniques were used. The equivalent parametric statistics were also utilized on the same data inorder to measure outcome variability.

The procedure generated unique conclusions which often were contrary to those found in the literature field dealing with urban - rural humidity and temperature islands.

In the case of Winnipeg, it was statistically proven that a mixing ratio island does exist under cA - cmA air mass conditions and that the spatial zones are significant even if the climatological differences were less than 1.0g/kg. The spatial forms do not necessarily parallel that of temperature. Furthermore, under specific combinations of pressure, wind speed, wind direction and cloud cover, the mixing ratio humidity island can exist separately.

Statistically it was found that alteration of the analysis from the parametric to the non - parametric drastically modified the resulting conclusions, especially when air mass surface layer complexity increased. Previously undetected and insignificant mixing ratio and temperature regimes become exposed with non - parametric statistics.

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To all the above,

Bóg zapłać

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# CHAPTER 1

## Introduction

### 1.1 Background

This thesis is an analysis of the spatial and temporal horizontal distribution of humidity and temperature within an urban-rural context. The analysis,however,has been based upon the results and comparison of the results of nonparametrical and parametrical computations. Not a single assumption,climatological nor statistical, has been made without prior justification.

Emphasis has been placed upon mixing ratio variations and its relationship with temperature.

The role of humidity and temperature in meteorological-climatological studies can no longer be considered as only a prime tool for synoptic analysis (Ruskin, 1963). Although the understanding of the dynamics of the atmosphere-humidity systems is still in an embryonic stage, horizontal and vertical humidity variations, in time and space, are now major considerations in cloud physics and mechanics, weather modification[1], upper atmospheric

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[1] The processes of evaporation and condensation of water vapor provide a means of transporting energy from one locale to another. A change in the mean temperature of the lower atmosphere shifts the location in which these processes take place and thus alters the distribution of atmospheric temperature over a greater portion of the area.

circulation[2], refraction of radio waves, aircraft condensation formation and in fog forecasting. For certain purposes, such as studies of radiative fluxes and the role humidity plays in air pollution reactions and urban heat island development, mixing ratios and absolute humidities are now an absolute requirement (Hage, 1975).

Distributional aspects of humidity are also of vital concern in fields such as agriculture, food science, medicine, air-conditioning and military. For example,the precise knowledge of seasonal and diurnal variations of humidity and temperature are critical to the specification of ventilation requirements for civil defense shelters (Ludwig,1967).

Unfortunately, accurate representation of areal, spatial, and temporal distribution of water vapor in the atmosphere, at all levels and at all meteorological-climatological scale ranges, has lagged considerably behind representation of other climatic elements. Temperature variations have dominated and still dominate most discussions (Dodd, 1964; Oke, 1974; Yoshino, 1976). As early as the late 18th-early 19th century when Louis Cotte and Luke Howard, pioneers of urban-climatic studies, published explicit accounts on urban climate

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[2] During the 'International Quite Sun Year' (IQSY), humidity was used as a tracer in the study of world-wide stratospheric circulation.

variations of Paris and London respectively, the humidity research gap was present. Kremser's paper entitled "Der Einfluss der Grosstadte auf die Luftfeuchtigkeit" (The Influence of Large Towns on Air Humidity) was the first article since Cotte's publication that treated humidity variations not as strict dependents of temperature but as the results of urbanization (Greiger, 1961). Anthropogenic sources of water vapor were now recognized as important contributing factors.

Out of 230 papers presented at the 1963 International Symposium on Humidity and Moisture in Washington D.C., not one paper at the conference dealt with the distributional aspects of humidity (Dodd, 1964). This was paradoxical since the symposium was convened in order to provide a perspective view of the total cross-disciplinary nature of humidity and moisture studies( Rushin, 1963). Even in 1968, at the Geneva World Meteorological Organization Conference on Urban Climates, again not a single paper dealing with humidity variation and dispersion was again presented. From 1774 to 1969 only 17 articles have dealt with humidity variations, both within and between an urban and rural complex (Chandler, 1969). During the time raw data for this thesis was acquired and analyzed, only one major paper entitled "Humidity Distributions in a Small City and Their Relationships to Surface Materials" by James A. Henry, was published (Chandler, 1976).

Of the few comparative studies undertaken, analysis has been limited to those days and nights when such climatic parameters as wind speed and opacity were advantageous to the establishment and retention of intense urban heat islands, not humidity islands. Measurements of the moisture content of urban and rural atmospheres were also limited in time duration. Thus what observational evidence there is, is not completely conclusive (Chandler, 1976).

## 1.2 Objectives

Since cities appear to initiate complex interactions between advective, diffusive and radiative processes following local changes in boundary conditions, an understanding of the relative temporal and spatial distribution of water vapor and its relationship to temperature may provide further impetus for analysis or re-analysis of the urban mesoclimate. The probability of a re-analysis increases, not only at an urban mesoclimatic scale but at all climatic levels,when one examines the underlining reasoning behind climatological-meteorological studies. That is,the statistical framework for the majority of these studies was based upon parametric data assumptions. Assumptions which either were carried over from similar research undertakings or were assumed as valid for the data in question mainly because the field of parametric statistics is far better understood and is much better represented in computer packages. Whether or not the

assumptions were valid were not to be questioned. The results of the findings are therefore distorted unless otherwise proven.

Therefore, the objectives of this study are:

(1) to deduce the possible anthropogenic and meteorological parameters which would influence the structure,duration and magnitude of the urban heat and mixing ratio islands with specific reference to the research zone and the climatic conditions that prevailed prior and during the acquisition of climatic data. By adopting such an approach,a theoretical foundation is built. The selected statistically significant analyzed data can thus be fitted against the hypothesis. This procedure,furthermore,prevents the fitting of numerous questionable ideals against the data.

(2) to present, analyze and delineate statistically-significant spatial and temporal distributions of mixing ratio from original traverse data taken over a two year span under all weather conditions within a well defined urban-rural complex. Cluster analysis will be employed to achieve some sort of traverse organization while non-parametric statistical techniques will be used on the particular fusions in order to locate which of these fusions have statistically significant temperature and/or mixing ratio distributions. The selected dendrogram groupings will then be subjected to the equivalent parametric statistics. Comparisons will be made with emphasis placed upon discovering to what degree parametric assumption violations effect or alter the computed results.

(3) to estimate and delineate the magnitude variations of the temperature and mixing ratio islands on the basis of air mass type and climatic parameter differentiation. These changes will be further investigated through the examination of case studies. However,if the selected data groupings are such that there seems to be no time unity,case studies will not be undertaken. For example,if only 5 out of 30 traverses of a particular air mass have been proven to be statistically significant on one or both of the climatic parameters under scrutiny and these 5 traverses are not within the same time

frame,it would be misleading to label this group as a general representation of temperature and/or mixing ratio variations for that particular air mass.

Fulfillment of these interrelated objectives will be achieved through an inverse hierarchical examination of the data. Scrutinization shall commence with the analysis of the most illogical climatological cluster, that is, the main cluster comprising of 253 traverses, and shall terminate with the numerous explicitly defined sub-clusters of the main air mass categories. Meteorological-temporal parameter combinations to be infused with each analysis will be introduced such that those conditions which maximize the urban mixing ratio and/or heat islands will precede those which minimize island formation.

Though scrupulous in nature, these methods ensure the dominance of statistical infered conclusions. Hence, the prior "reference" and inductive hypothetical reasoning techniques will be rendered validless. A non-significant statistical conclusion is in itself significant because it has proven the fact of insignificance.

A static methodology is thus ruled out. New test statistics chosen for objective optimization, shall be introduced whenever greater clarification of the results

are required. However, when the nonparametric and their equivalent parametric forms yield conflicting conclusions for the same data field, conclusions which would appear as "false inadequate impressions" in the literature field of this thesis' topic, the thesis shall terminate. This of course does not connote abandonment of the objectives, but on the contrary, indicates investigation and enlightenment. Clarification will be provided in later chapters. Here themes dealing with the so-called unifying framework of urban climatological systems shall be investigated.

Revision, where required, will follow.

## 1.3 Methodology

The research objectives are attained through the acquisition of a large quantity of dew point and temperature data, measured by automobile mounted instrumentation, driven along a well defined traverse, encompassing all major land usage, upwind and downwind of Winnipeg's core area, over a two year sampling period. Traverse data was reduced to a constant time after conversion from millivolts to degrees Celsius was completed. Regular synoptic observations at the Winnipeg International Airport Meteorological Station were then merged to form the data base. Analysis of daily surface and upper air charts plus examination of

prognostic aviation forecasts provided the broader meteorological picture with respect to air mass type. The data base was subdivided according to season, air mass and wind quadrant direction. Fixed point estimaters were grouped accordingly and subjected to para- and nonpara-metric tests of significance. Interpretation, conclusion, and assumptions were based upon those results which showed strong statistical significance.

## 1.4 History of the Study

The foundation of this study and interest of the author stemmed from similar research previously undertaken along a parallel traverse in Winnipeg by Bell of the University of Winnipeg. The lack of humidity research in urban-rural mesoclimatic studies intensified by the desire to examine the effect of urbanization on certain climatic parameters, provided the stimulus to undertake a few night time traverses in November 1975. Results indicated that even under cloudy, windy conditions, the heat and humidity islands exist climatologically, even though statistical significance between the average fixed point observations was less than the 95% level. Plans were therefore made with Bell to undertake further study.

Over a two year period, 253 traverses were randomly conducted, yielding 32, 131 cases of point data. There

were 127 fixed point measurements per traverse (see Map 5.2.1). From the basic data acquired, air vapor pressure also known as the saturated vapor pressure at dew point, was calculated. Formulae for the above conversions and for further conversions to mixing ratios, etc. were obtained from the Smithsonian Meteorological Tables.

The data was accordingly edited and an attempt was made to perform a comprehensive analysis of this data.

## 1.5 Definitions and Units of Measurements

The two climatic parameters under investigation in this study are mixing ratio and temperature. As the former climatic parameter can not be directly measured from the environment,the dew (frost)-point temperature of the air will be logged. All units in this thesis are metric.

The thermodynamic dew point temperature, Td, of moist air at temperature, T, and at pressure, p, and mixing ratio, r, is the temperature to which the air must be cooled in order that it shall be saturated with respect to liquid water at the initial pressure, p, and mixing ratio, r. Temperature is the major climatic control determining the maximum dew point value. Other influencing factors are:

(1) air mass type
(2) wind direction and speed

(3) moisture conditions on the ground

(4) turbulent mass exchange

(5) cloudiness as affecting the insolation of an area

(6) water surface temperature and water body area upwind of an area

(7) evapotranspiration and anthropogenic sources of water vapor

The thermodynamic frost point temperature's definition parallels the above in all respects except that it is determined with respect to ice.

The mixing ratio, r, of moist air is the ratio of the mass, mv, of water vapor in grams to the mass of dry air in kilograms with which the water vapor is associated with. Together with absolute humidities, mixing ratios are the best indicators of air mass type for only condensation and evaporation can alter the values.

All definitions of the above parameters correspond to those formulated and adopted by the World Meteorological Organization. These definitions are in affect at present.

The boundaries of Winnipeg are defined as all areas located within and bounded by Manitoba Provincial Highways 100 and 101. The latter highways are locally referred to as the Perimeter.

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# CHAPTER 2

## Urban Heat Island:Formation and Retention

### 2.1 Introduction

The following discussion on urban heat island formation and retention shall be very selective since voluminous literature has been directed towards this topic. Detailed examination of such contributing parameters to heat island formation, as:

(1) the effect varying concentrations of gaseous pollutants have on the radiative balance.
(2) wind velocity
(3) cloud cover and opacity
(4) anthropogenic heat sources
(5) city density structure
(6) time

have been adequately documented by Oke(1944), Yoshino(1975), Bach(1976) and Chandler(1976). These aspects, therefore, need not be mentioned here. Consequently, the discussion shall be limited to those contributing factors most prominent within the research area. Typical urban albedoes[1] and the thermodynamic properties of urban surfaces shall be compared with their rural counterparts. The possible effect aerosols might have upon the research area's radiative balance shall then be discussed. The latter control is of considerable

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[1] Albedo is defined here as the decimal fraction of reflected or scattered to incident global radiation, and is used to denote the characteristic reflectivity of radiation within the range 0.36 to 4.00 microns.