INITIAL SOIL MOISTURE AS A PREDICTOR OF SUBSEQUENT SUMMER SEVERE WEATHER IN THE CROPPED GRASSLAND OF THE CANADIAN PRAIRIE PROVINCES

BY

An V. Tat

A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

in partial fulfilment of the requirements of the degree of

MASTER OF SCIENCE

Centre for Earth Observation Science

Department of Environment & Geography

University of Manitoba

Winnipeg, Manitoba

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

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INITIAL SOIL MOISTURE AS A PREDICTOR OF SUBSEQUENT SUMMER SEVERE WEATHER IN THE CROPPED GRASSLAND OF THE CANADIAN PRAIRIE PROVINCES

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ABSTRACT

Soil moisture, along with the type and stage of the vegetation, influences the thermodynamic structure of the atmosphere by regulating heat and moisture fluxes to the planetary boundary layer. This study examined whether modeled areal-average root-zone soil moisture (RzSm) in the "wet" and in the "dry" regions of the cropped grassland of the Canadian Prairie Provinces had predictive value in determining whether these areas would subsequently have above or below average number-of-occurrences and event-days of summer severe convective weather (i.e., tornadoes, large hail, heavy rains and/or damaging winds). RzSm, simulated by the Prairie Agro-climate Model, for the 1997 to 2003 growing-seasons was analyzed three times per season. Dry areas, with RzSm $\leq$ 50% of available water holding capacity (AWHC), and wet areas, with RzSm > 50% of AWHC, were delineated post-snowmelt, on June 15th, and on July 15th. The areal-average RzSm levels in the "dry" and in the "wet" areas were calculated, and plotted against the relative number-of-occurrences and number-of-event-days which were recorded during the remainder of the growing season for each type of summer severe convective weather. In each case; the best-fit linear regression line, and the variance that it explained (r^2 value) were computed. The hypothesis that the slope of each regression line was significantly different than zero was then tested. A relationship with an r^2 near or greater than 0.25, and with a regression line slope that was significantly different than zero, was selected as one

which could have potential value in the climatological forecasting of summer severe convective weather. For most of the severe weather types, the relative number-of-occurrences and the relative number-of-event-days, which were recorded subsequent to the three dates on which the areal-average RzSm was determined, were greater over the "wet" areas than over the "dry" areas.

This thesis represent an advancement in the development of our understanding of the linkage between RzSm and severe weather associated with moist deep convection in the cropped grassland of the Canadian Prairies. It demonstrated that modeling RzSm may improve climatological forecasts of severe convective weather.

ACKNOWLEDGEMENTS

I wish to thank the many people who helped bring this Masters degree to a satisfying completion. Special thanks go out to my supervisor, Dr. John M. Hanesiak, for helping me formulate the thesis topic, and for his valuable comments, criticisms and encouragement. I would like to thank Rick Raddatz, University of Winnipeg, who provided me with great conversations on our thesis topic as well as the modeled soil moisture dataset. Thanks to Dr. Tim N. Papakyriakou who first got me interested in the atmospheric sciences.

Thanks to the Prairie and Arctic Storm Prediction Centre for providing the summer severe weather database. Thank you Mike Noonan for providing the map of the eco-climatic zone. I would also like to thanks Jay Anderson for diligently reviewing the tornado database. Many thanks to David Mosscrop for all the assistance both inside and outside the lab, and especially for providing me a place to park on your driveway. Thanks John Iacozza for helping explain statistical analysis. I extend my appreciation to Jim Butler, Ryan Galley, C.J. Mundy, and Bob Hodgson for spending hours helping me learn ARCVIEW GIS.

I extend my thanks to the Department of Environment & Geography, the Centre for Earth Observation Science (CEOS) and the University of Manitoba who have leant me the support, facilities, space and time required to complete my thesis. Thank you

Trudy Baureiss, Mary Anna, Aggie Roberecki, Valeri Smith, Denise Whynot, Tracy Maconachie and Pat Gutoski for all of the much needed assistance.

I would like to thank the University of Manitoba for their support through a Graduate Fellowship and the Natural Sciences and Engineering Research Council of Canada for addition support.

As many people do, I would like to use a cliché to end this section. Last, but certainly not least, I would like to thank my family and friends for their love and support throughout my journey through life.

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CHAPTER 1 – INTRODUCTION

1.1 Introduction

The general circulation modeling by Koster et al. (2000, 2004) has shown that it is generally semihumid to semiarid climates and midlatutude, midcontinental areas where land surface feedbacks, have the greatest impact on the interannual variability of precipitation. In these regions, evapotranspiration (ET) is highly sensitive to soil moisture (i.e., predominantly under vegetation and soil control, as opposed to weather control). Because ET is a component of the energy balance in addition to the water balance, precipitation-efficiency, the fraction of the average horizontal water vapour flux over an area that falls as rain, feedbacks are expected to be highly sensitive to soil moisture in the same regions as is precipitation recycling (Koster et al. 2004; Raddatz, 2005).

To investigate the possible roles of various surface characteristics or land-use parameters in Hong Kong, Lam et al. (2006) used the fifth generation PSU/NCAR Mesoscale model (MM5) (Anthes and Warner, 1978; Dudhia, 1993; Grell 1993). MM5 has a grid resolution of 4.5 km by 1.5 km. They focused specifically on the relative importance of six land-use parameters. MM5 incorporates a land-surface model that makes use of vegetation and soil type. These were roughness length, thermal inertia (the resistance of a material to temperature change), soil moisture availability, albedo, surface heat capacity and surface emissivity. They found that the simulated atmospheric flow

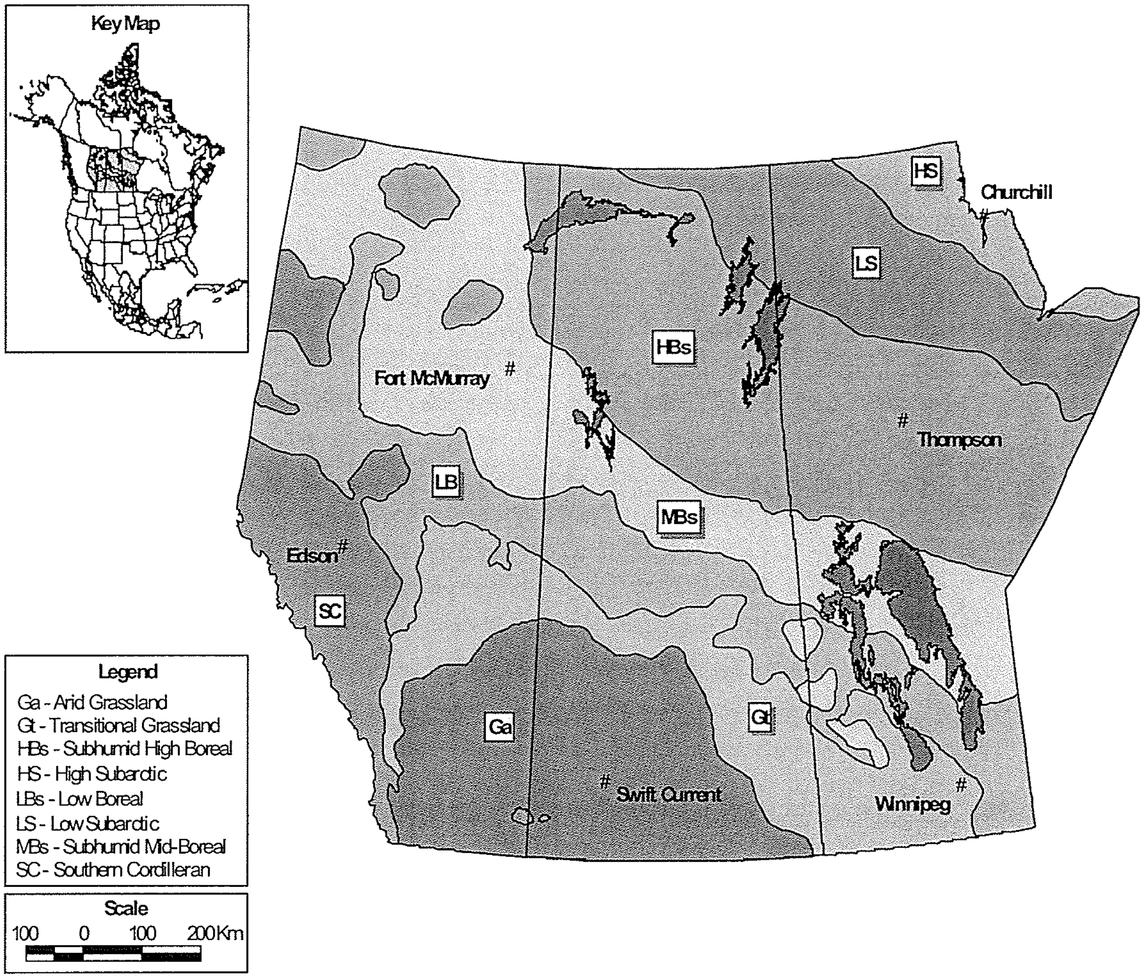

Figure 1. Map of the Canadian Prairie Provinces with the eco-climatic regions.

pattern at 100 m above sea level was most impacted and surface fluxes were mainly controlled by the soil moisture availability. The other five land-use parameters did not influence the general flow pattern during sensitivity tests.

There are three necessary "ingredients" required for the development of moist deep convection. These are instability, lift, and moisture (Aguado and Burt, 2001). Instability is an indication of an air parcel's tendency to rise freely into the atmosphere on its own (free convection) or not. Free convection (vertical acceleration) takes place when the parcel's density is less than the environmental air's density (air surrounding the parcel). Atmospheric instability (and vertical acceleration of the parcel) increases as the parcel's density becomes much less dense than the surrounding air. There are several indices used to measure instability. A common measure used to indicate instability is the convective available potential energy (CAPE), in J / kg. The larger the CAPE, the larger the instability and the greater the potential for large vertical accelerations/velocities within the cloud. Large vertical velocities (25-50 m/s) are typically associated with severe thunderstorms. Lift can be caused or aided by upper level or surface features. Upper features include short wave trough and jet streak/jet stream. Surface features include cold/warm/occluded front, dryline, outflow boundary, sea breeze and orographic lift. Moisture is the amount of water vapour in the atmosphere, typically indicated by the mixing ratio. The mixing ratio is the amount of water vapor (in g) over the amount of dry air (in kg) in a sample of air. The larger the mixing ratio, the greater the amount of water vapor in the atmosphere. A severe storm environment typically has large moisture quantities (can be as low as 10 g/kg but usually >15 g/kg) in the planetary boundary layer (PBL). There are two main sources of moisture, advection and ET. In this thesis, the low level moisture "ingredient" in the form of ET is focused on. Violent thunderstorms (tornado and large hail producers) may require another "ingredient", wind shear. Wind shear is the change in wind direction and or speed in the atmosphere. Essentially, wind shear tilts the cloud so that the downdraft does not "choke" off the moisture/energy supply from the updraft and can also cause rotation in the storm. Hence, the life span of these violent thunderstorms is prolonged.