FROM DROUGHT TO WET CYCLES: THE CHANGING CLIMATE OF THE CANADIAN PRAIRIES

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RATIONAL:

The purpose of this research is to improve the climatic early warning system for Canadian Prairie Agri-business essentially through development of regression models and other empirical-statistical approaches for predicting precipitation and temperature during the summer months with lead times of two-four months. The geographical areas of concern are:

1) The Prairies as a whole

2) The Peace River zone

3) Palliser North zone

4) Palliser Brown Soil zone and

5) Eastern Prairie zone

Gross annual sales of prairie grain amount to $10 billion dollars per year.
Saskatchewan example

STUDY AREA

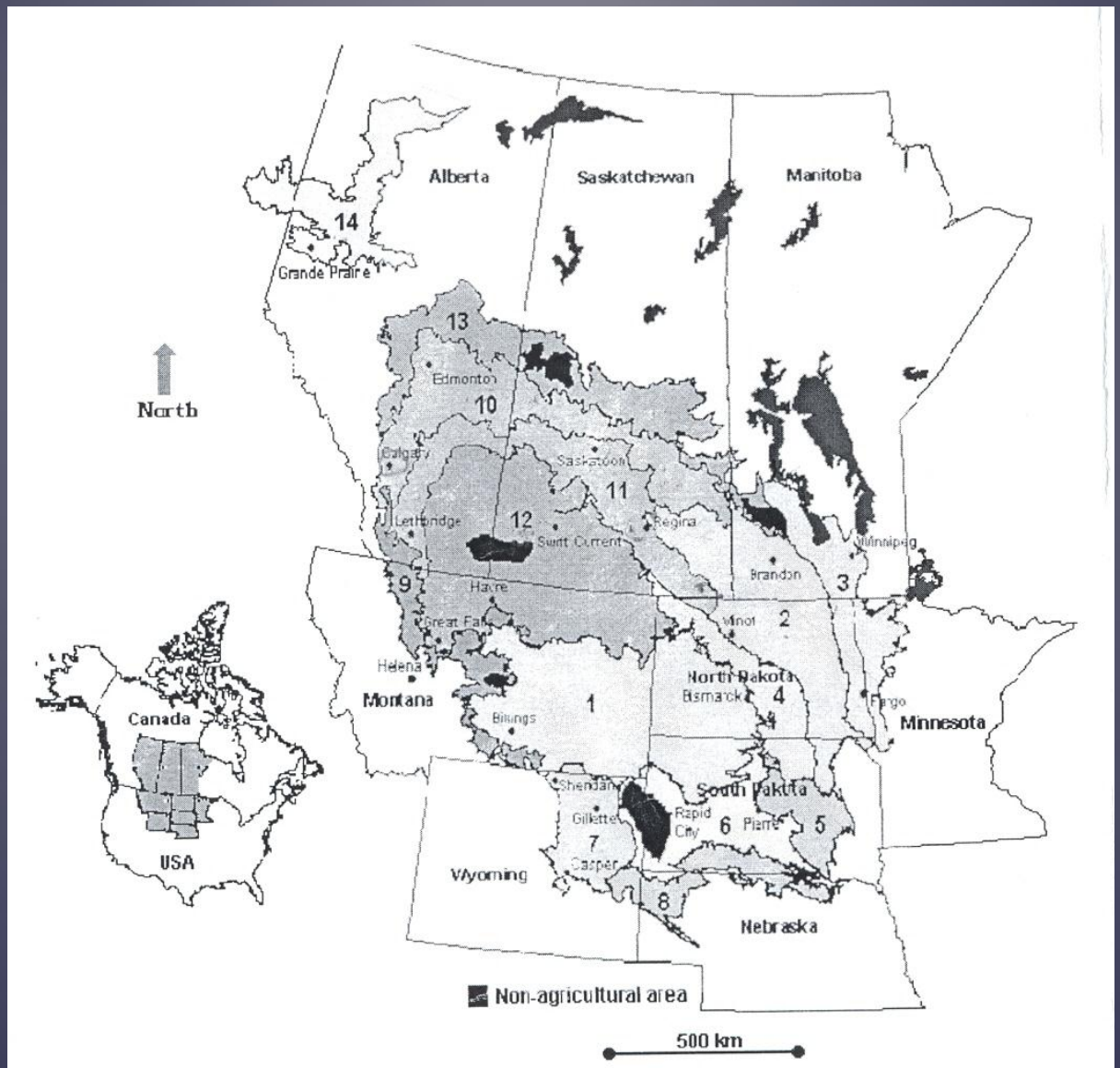


Figure 1. Agro-ecoregions of the northern Great Plains (Padbury et al. 2002, reprinted with permission).

DATA

Potential Monthly Predictors	September-August for the Period
Sunspot Number	1900-2009
API (geomagnetic)	1933-2009
Global Cosmic Ray (GCR)	1960-2009
Southern Oscillation (SOI)	1900-2009
El Nino (Nino 3.4)	1951-2009
Pacific North American Teleconnection Index (PNA)	1951-2009
North Atlantic Oscillation (NAO)	"
Arctic Oscillation (AO)	"
Eastern Pacific/ North Pacific (EP/NP)	"
Western Pacific (WP)	"
Quasi-Biennial Wind Oscillation 30 mb (QBO30 mb)	"
" 50 mb (QBO50 mb) "	
Pacific Decadal Oscillation (PDO)	1901-2009
North Pacific (NP)	1900-2009
Madden Julian Oscillation (MJO) 120° West	1979-2009
North American Snow Cover (NAS)	1967-2009
Precipitation	1900-2009
Temperature	1900-2009
Palmer Drought Severity Index (PDSI)	1970-2009

Predictands

July PDSI Prairies as a whole (PAW)
May-July precipitation "
June-July " " "
June-Aug " " "
June-Aug temperature "
June-July temperature "

July PDSI Peace River Agricultural Ecological Zone (Ag.Eco)
June-July precipitation Peace River
June-July temperature "
July precipitation "
July temperature "

Correlation and regression analysis was then repeated for Palliser North, Palliser Brown Soil and Eastern Prairies Ag Eco zones.
Spring wheat yields 1908-2009
Canola yields 1943-2009
Spring wheat protein content 1950-2009

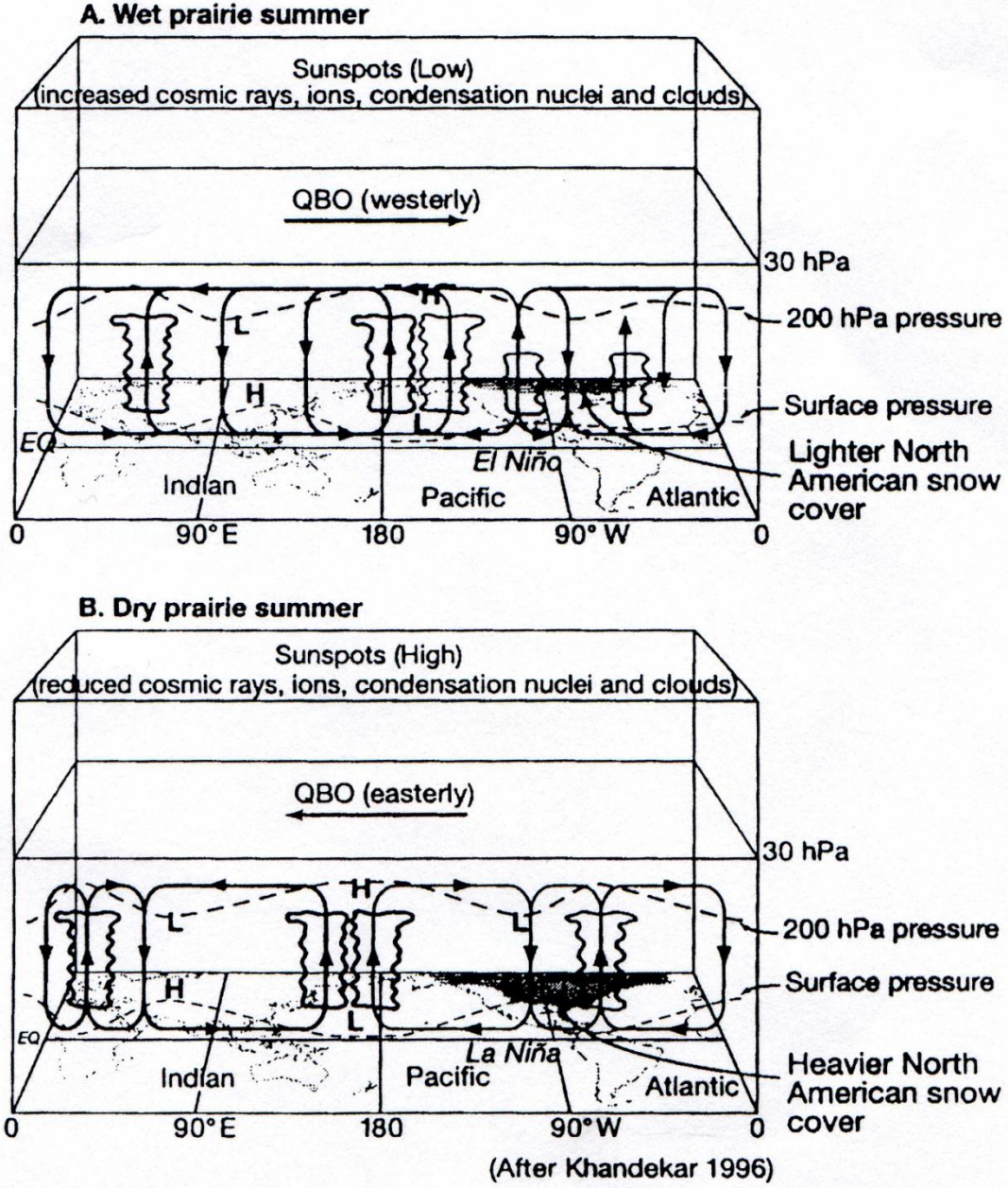
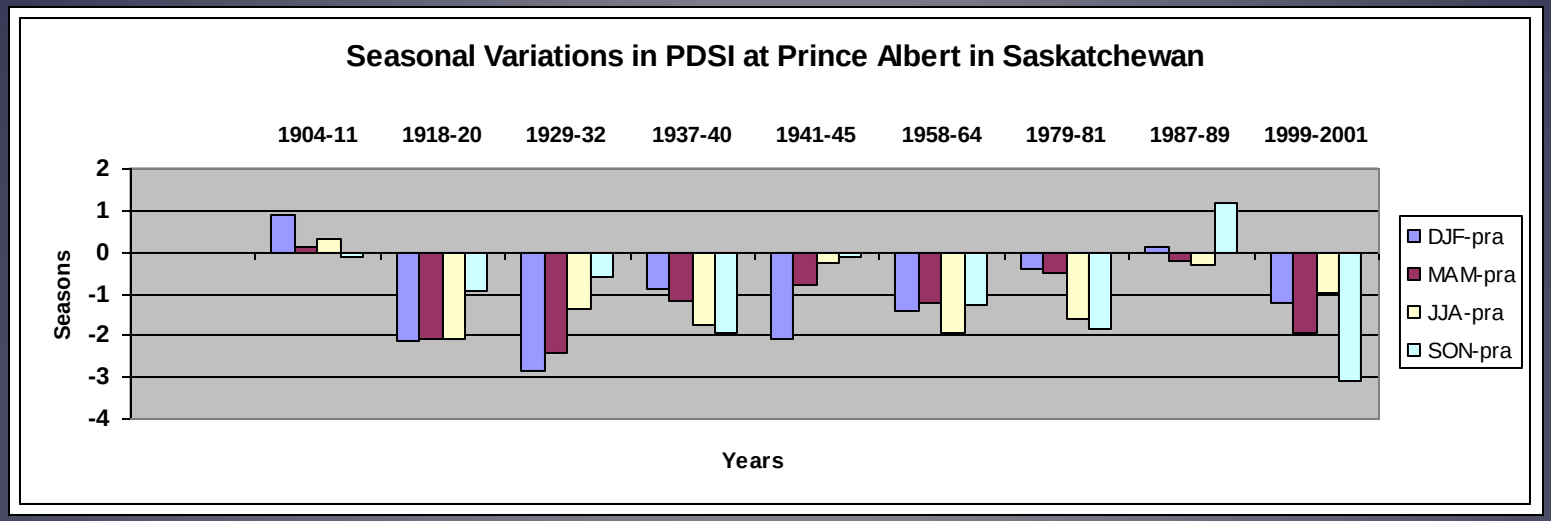
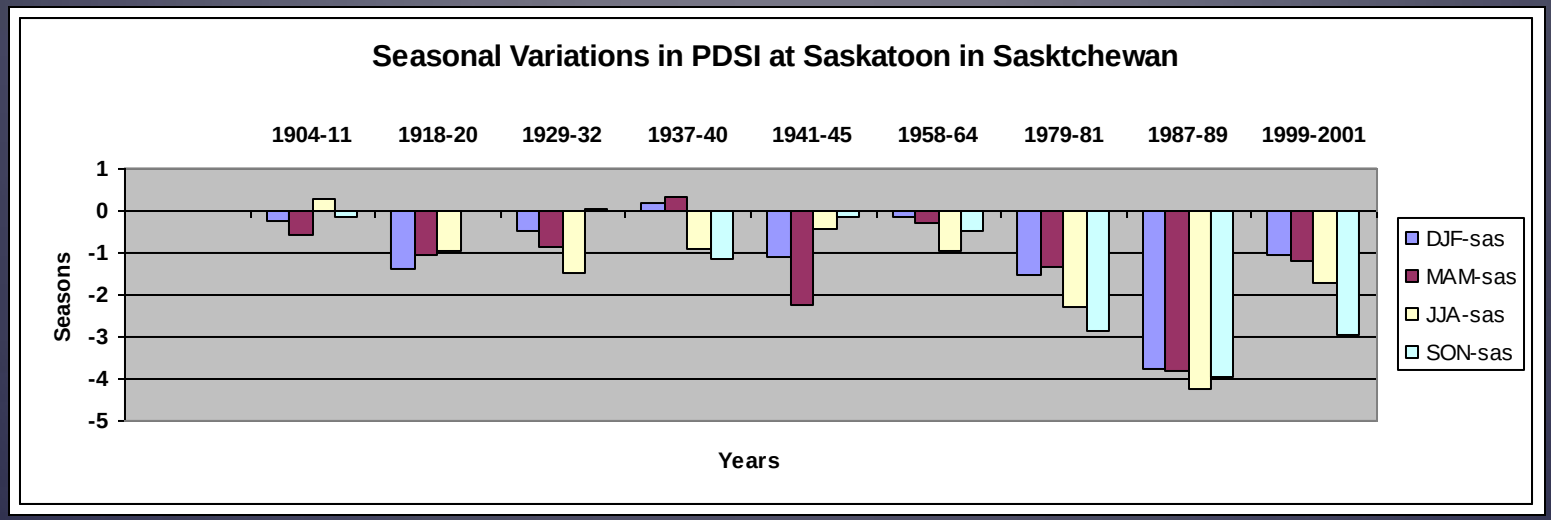
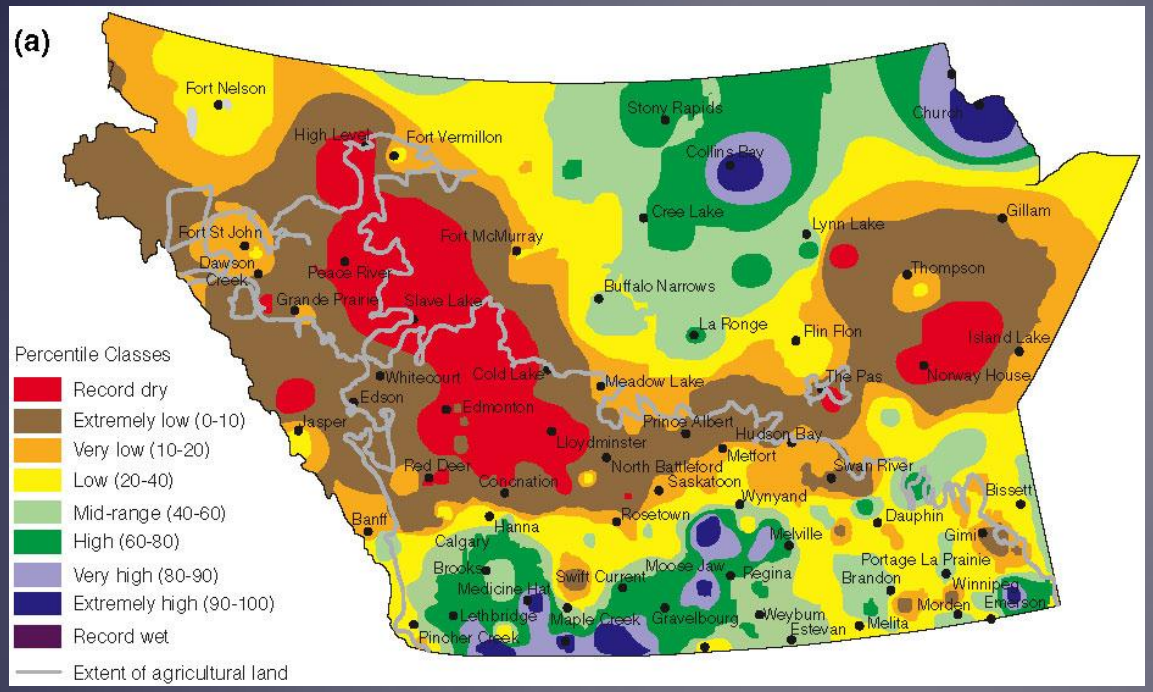
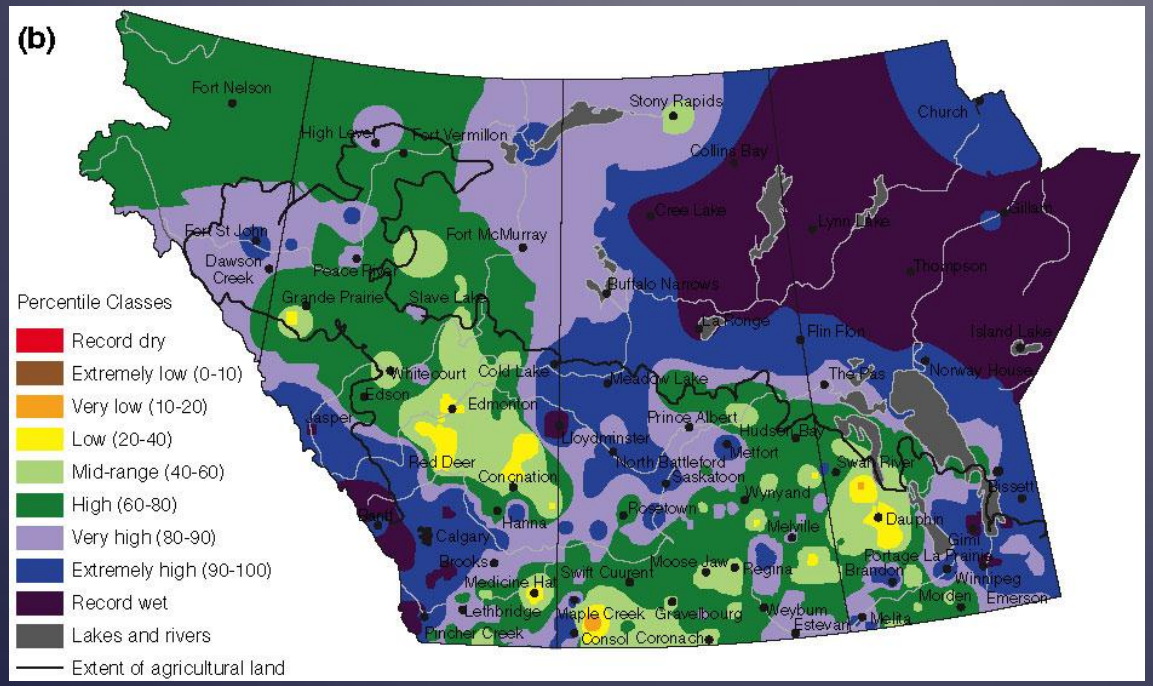


Fig. 2. Conceptual model of factor producing wet and dry prairie summers. H: high, L: low pressure system

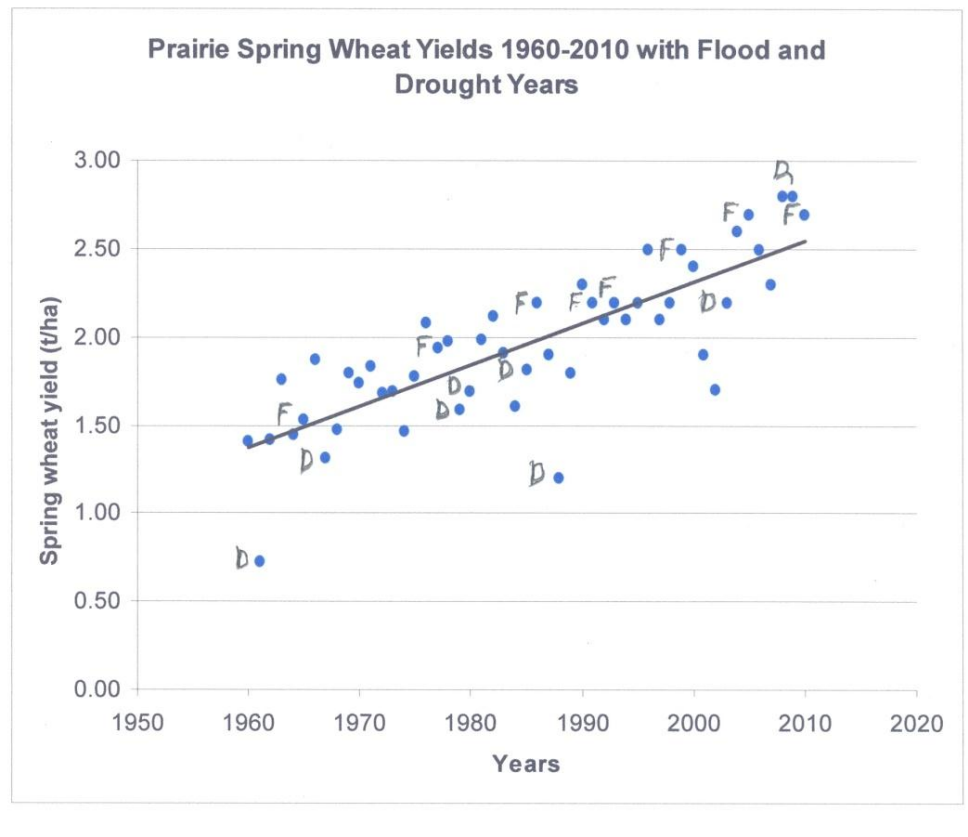

Seasonal Variations in PDSI at Prince Albert in Saskatchewan
1904-11
1918-20
1929-32
1937-40
1941-45
1958-64
1979-81
1987-89
1999-2001
2
1
0
-1
-2
-3
-4
Seasons
Years
DJF-pra
MAM-pra
JJA-pra
SON-pra


Seasonal Variations in PDSI at Saskatoon in Sasktchewan
1904-11
1918-20
1929-32
1937-40
1941-45
1958-64
1979-81
1987-89
1999-2001
1
0
-1
-2
-3
-4
-5
Seasons
Years
DJF-sas
MAM-sas
JJA-sas
SON-sas





Meteorological drought conditions for September 2001- August 2002 (a). Areas in red are record dry conditions. Contrast with conditions observed September 2005 – August 2006 (b).



FLOOD YEARS

May-July	Rainfall (mm/mo)
1991	89
2010	88
1999	86
1993	83
2005	83
1965	79
1977	78
1986	77

DROUGHT YEARS

May-July	Rainfall (mm/mo)
1967	31
1961	38
2009	47
1985	47
2003	49
1980	51
1979	51
1988	53

Note: 2001 65 mm (Heat related)
2002 57 mm (Heat related)

A) MODEL 1. (Stepwise)

Predictand: June-August precipitation for prairies **Adj r-sq .63**

	Unstandardized Coefficients	t	Significance level
Constant	71.67	45.55	.00
WPNOV	4.76	4.00	.00
PNAJAN	-5.57	-3.10	.01
MJOAPR	-7.54	-2.56	.02
PNAMAY	2.97	2.44	.02

B) CORRELATION COEFFICIENTS BETWEEN INDICES AND JUNE-AUGUST RAINFALL

N	**Predictors**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**
	Type				Months								
59	WP	.05	.18	.37***	.03	-.16	.00	.11	-.24*	.21*	-.12	-.14	.02
59	PNA	-.16	.07	.07	-.14	-.27*	.10	.08	.09	.23*	.06	.09	.07
31	MJO	.13	-.07	.13	-.18	.10	-.47***	.03	-.32*	-.01	-.13	.07	.07
59	PNA	-.16	.07	.07	-.14	-.27*	.10	.08	.09	.23*	.06	.09	.07

PNA, PDO and MJO COMPOSITE **Predictand Prairie July PDSI**

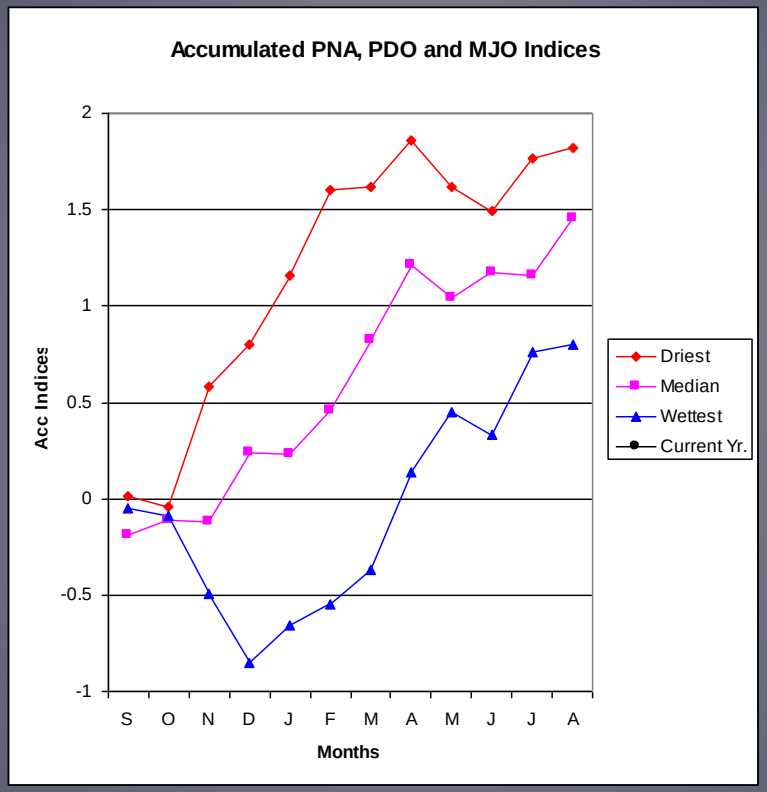


Fig. 1 Summations of PDO, PNA and MJO indices for the three driest, three median and three wettest summers as determined by the July PDSI during 1971-2010.

B) CORRELATION COEFFICIENTS BETWEEN INDICES AND PRAIRIE JULY PDSI

N	Predictors	S	O	N	D	J	F	M	A	M	J	J	A
40	PNA	.02	-.34**	-.53***	.01	-.12	-.16	.05	.21	.25	-.16	.02	.26
40	PDO	.08	-.21	-.35*	-.28*	-.26*	-.25	-.10	-.06	.05	.07	.13	.01
40	MJO	.03	.12	-.43**	.18	-.02	.05	-.05	-.11	-.32*	-.02	.04	.00

*Significant at 5% Level, ** Significant at 1% level, *** Significant at .1% level

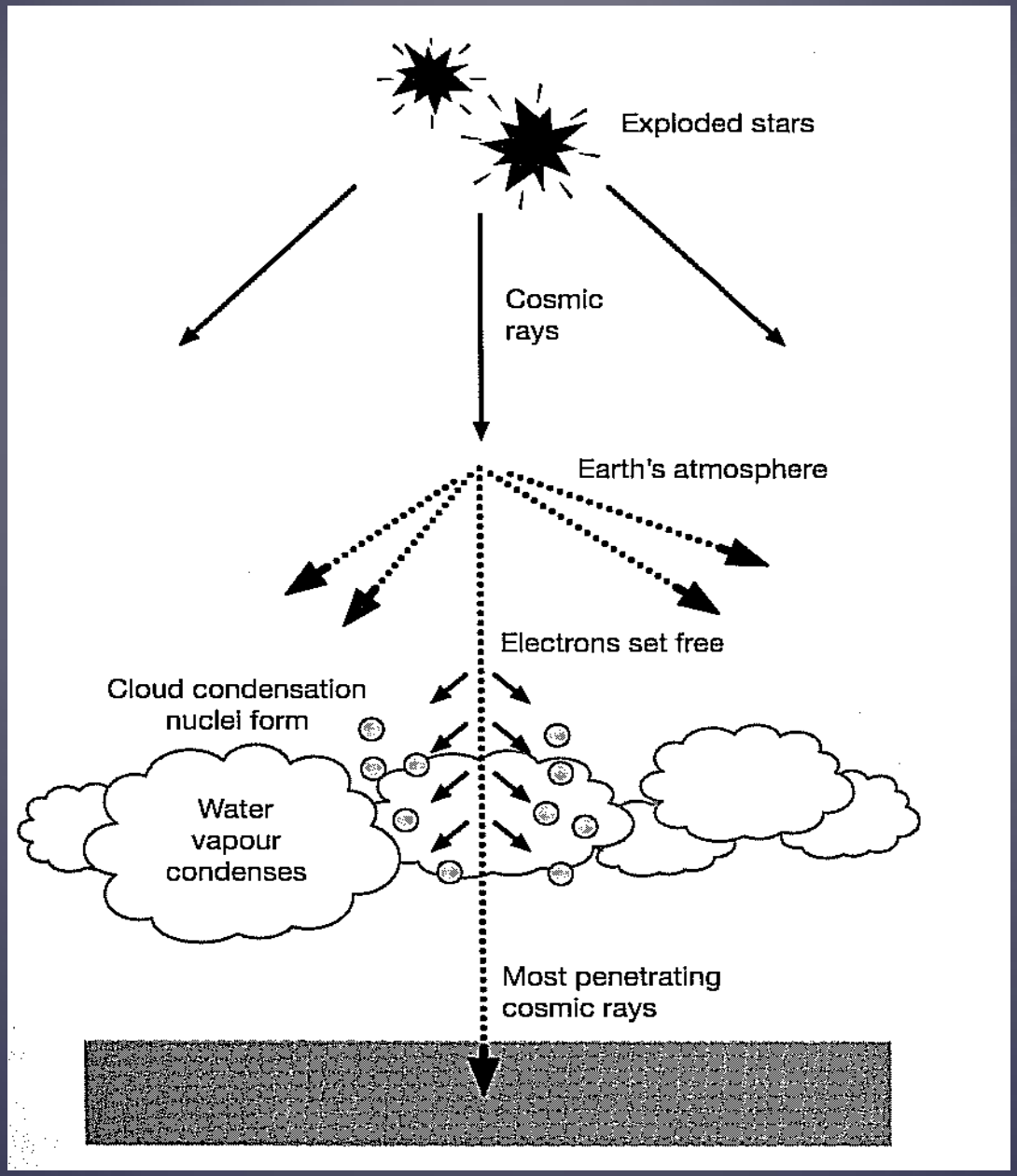
A) MODEL 3. (Backward)

Predictand: Peace River July PDSI Agricultural Ecological Zone Adj. r. sq .54

	Unstandardized Coefficients	t	Significance level.
Constant	-0.79	-2.64	.01
PRNOVPPT	.03	2.46	.02
PNAAPR	.35	2.43	.02
PNAMAY	.33	2.55	.02
PRPDSIJAN	.55	3.49	.00

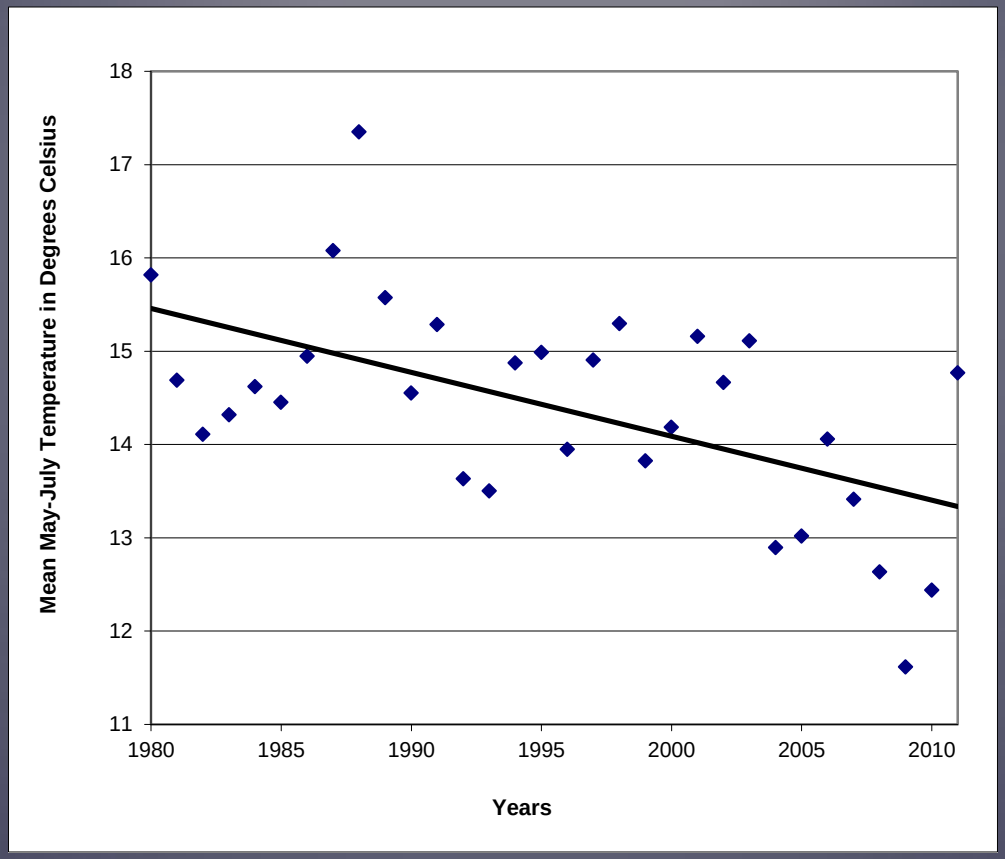
B) CORRELATION COEFFICIENTS BETWEEN INDICES AND JULY PDSI, PEACE RIVER

N	**Predictors**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**
	Type				Months								
40	PNA	-.20	-.24	-.26*	-.00	.13	-.04	.02	.34*	.30*	-.06	.13	.11
40	PDSI	.51***	.52***	.54***	.54***	.55***	.55***	.49***	.60***	.76***	.93***	NP	NP
40	PRPPT	-.01	.21	.32*	.12	-.07	.17	.07	-.04	.49***	.49***	NP	NP



Svensmark and Calder 2007. The Chilling Stars: 'A New Theory of Climate Change'.

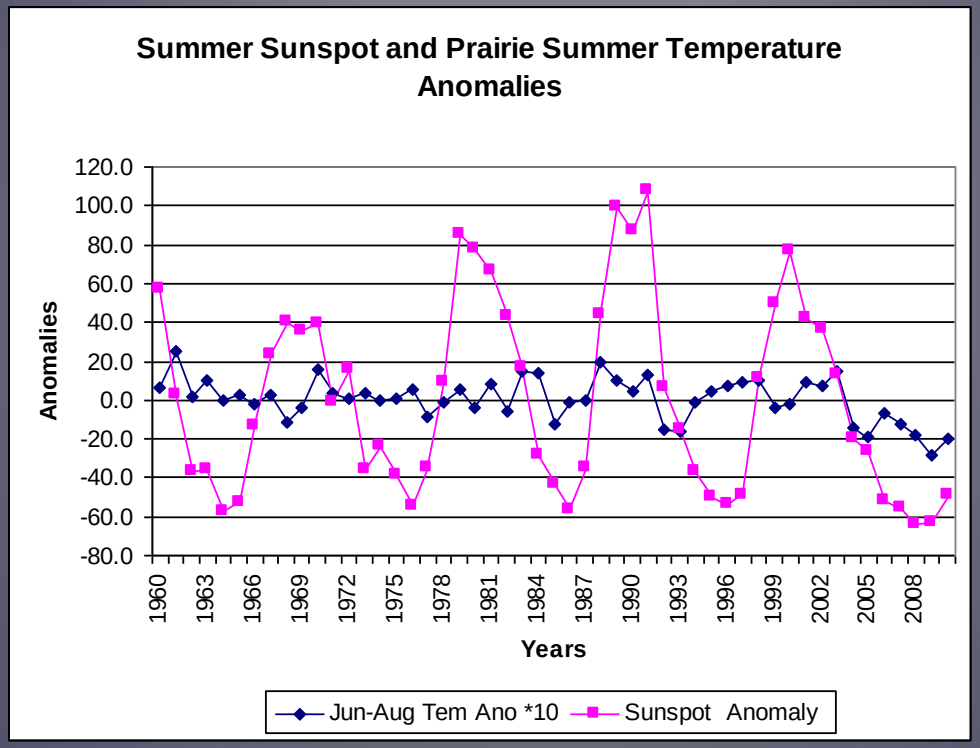
PRAIRIE MAY - JULY TEMPERATURES



Climate data sources: Ontario Climate Centre, 1980 – 2007, National Agro-climate Service (NAIS), Regina, SK 2008 – 2010, Environment Canada Website, 2011. Average of 403 good reporting stations.

Temperatures 2.5 degrees Celsius below normal May – Sept would bring insufficient heat units (1080 GDD's) to a mature spring wheat, comparable to 12 degrees Celsius on the above figure.

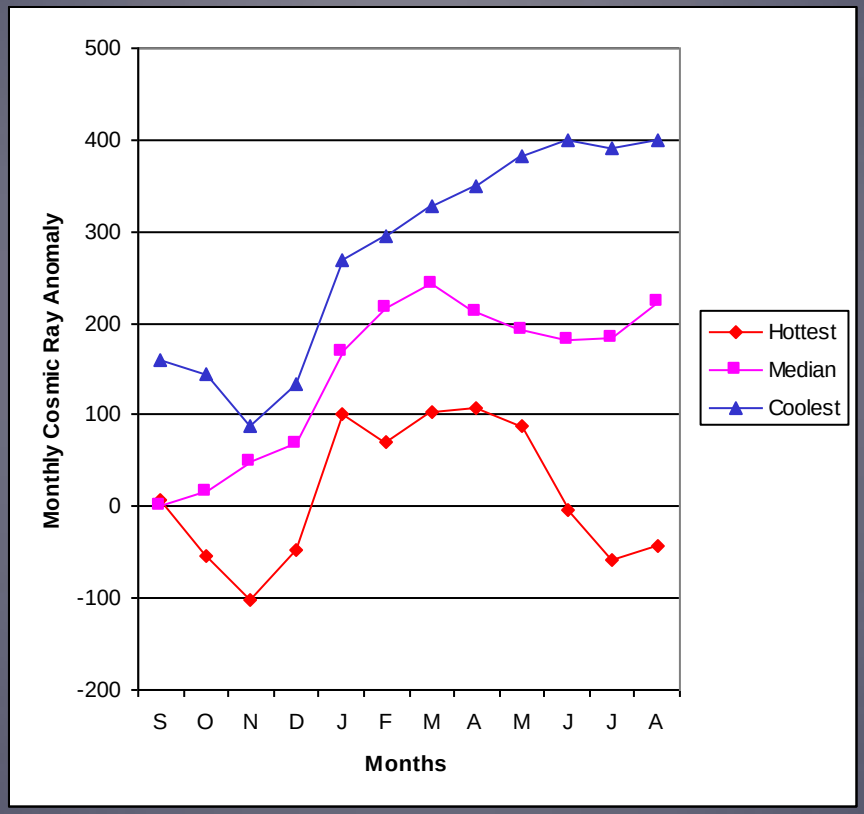
COMPOSITE JUNE-AUGUST SUNPOT ANOMALIES VERSUS JUNE-AUGUST TEMPERATURE ANOMALIES



CORRELATION MATRIX OF INDICES AND SUMMER TEMPERATURES

N	Predictor Type	S	O	N	D	J	F	M	A	M	J	J	A
56	SSA	.24*	.20	.20	.19	.21	.16	.23*	.28*	.25*	.30*	.27	.31*
50	CRA	-.22	-.24*	-.20	-.25*	-.22	-.21	-.27*	-.34**	-.33**	-.35**	.19	-.33**
55	API	.18	.20	.07	.12	-.03	.06	.34**	.33**	.28*	.28*	.22*	.30*

* Significant at the 5% level, ** Significant at the 1% level,



Monthly Global Cosmic Ray anomalies prior to the four coldest, four median and four hottest June-Augusts for the period 1960-2010

Table 1. Correlation coefficients between solar related predictors and June-August temperatures over the prairies

	S	O	N	D	J	F	M	A	M	J	J	A	
SSA	.24*	.20	.20	.19	.21	.16	.23*	.28*	.25*	.30*	.27	.31**	n = 56
API	.18	.20	.07	.12	-.03	.06	.34**	.33**	.28*	.28*	.22 *	.30*	n = 55
CRA	.22	-.24*	-.20	-.25*	-.22	-.21	-.27*	-.34**	-.33**	-.35**	.19	-.33**	n = 50

MAJOR FINDINGS

1. A regression model was developed for forecasting summer (June-August) precipitation over the Canadian Prairies with a lead- time of 2-3 months. This four variable model explains or accounts for close to 66% of the variation in summer rainfall.
2. Composites were developed for foreshadowing prairie July PDSI, Palliser Brown Soil July PDSI and prairie summer temperatures with lead times up to four months.
3. A three-variable model was developed for forecasting the July PDSI in the Palliser North zone. This model accounts for close to 66% of the variation of the July PDSI between 1971 and 2009.
4 New and dominant predictors that emerged in this research were the Madden-Julian Oscillation (MJO), the Western Pacific Teleconnection index and solar related predictors such as the AP index. Better known predictors that came to the fore were Quasi-Biennial Wind Oscillation (QBO), Pacific North American teleconnection index (PNA) and Pacific Decadal Oscillation (PDO).
5.Solar related predictors were shown to influence Eastern Prairie March-May precipitation, Peace River June-July temperature, Eastern Prairie July PDSI and Prairie June-August temperatures with high (low) sunspot activity leading to a drier warmer (wetter, cooler) weather in each case.

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