DETERMINANTS OF SUMMER WEATHER ON PRAIRIE REGIONS AND THEIR EFFECT ON WHEAT (GRAIN) YIELDS

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PRESENTED AT THE SASKATCHEWAN IRRIGATION ASSOCIATION PROJECT (SIPA) CONFERENCE

DECEMBER 5th, 2012

MOOSE JAW, SASKATCHEWAN

RATIONAL:

-The purpose: improve the climatic early warning system for Canadian Canadian Prairie Agri-business.

-The goal: To predict summer precipitation and temperature as related to grain yields.

-Lead time: A few weeks to a few months.

-Geographical areas of concern:
Prairies as a whole plus Peace River, Palliser North, Palliser Brown and Eastern Prairie zones.

- Annual value of grain is about $10 billion dollars per year.

STUDY AREA

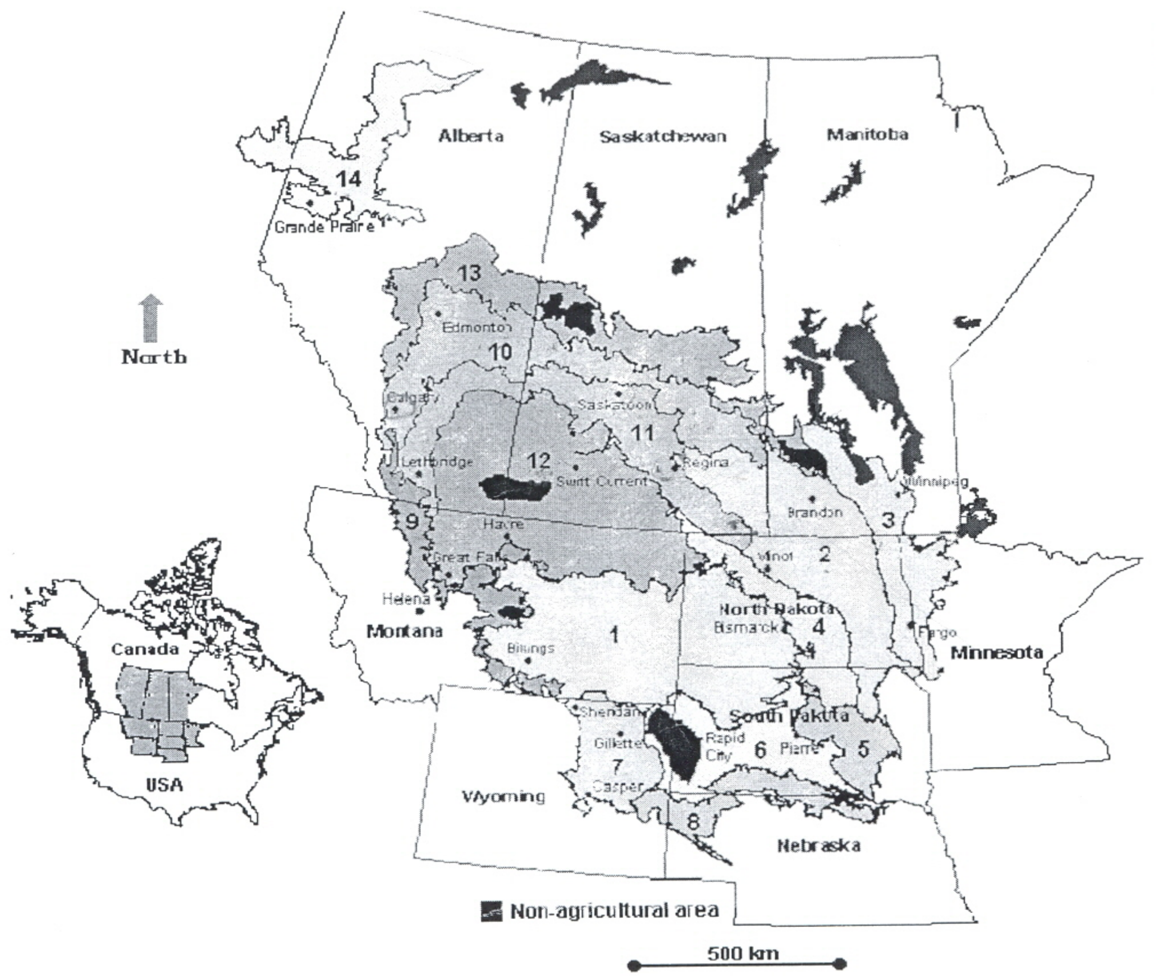


Figure 1. Agro-ecoregions of the northern Great Plains (Padbury et al. 2002, reprinted with permission).

DATA

Predictors:

170 Monthly **predictors** for September-August (Agricultural year) include:
Sunspot Number, API (geomagnetic), Global Cosmic Ray (GCR)
Quasi-Biennial Wind Oscillation 30 mb and 50 mb
Southern Oscillation (SOI) and five other teleconnection indices
Pacific Decadal Oscillation, North Pacific Index ,Madden Julian Oscillation,
and North American Snow Cover extent.

Predictands:

Monthly Precipitation, Temperature, July Palmer Drought Severity Index (PDSI)

(Data set lengths range from 1979-2009 to 1900-2009)

Conceptual Model of El Nino and La Nina

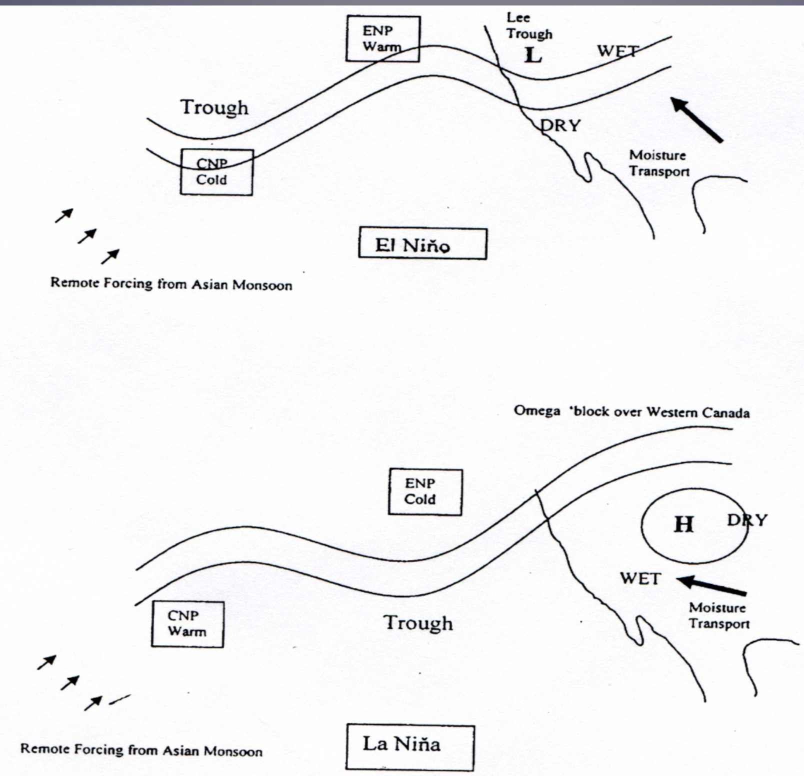
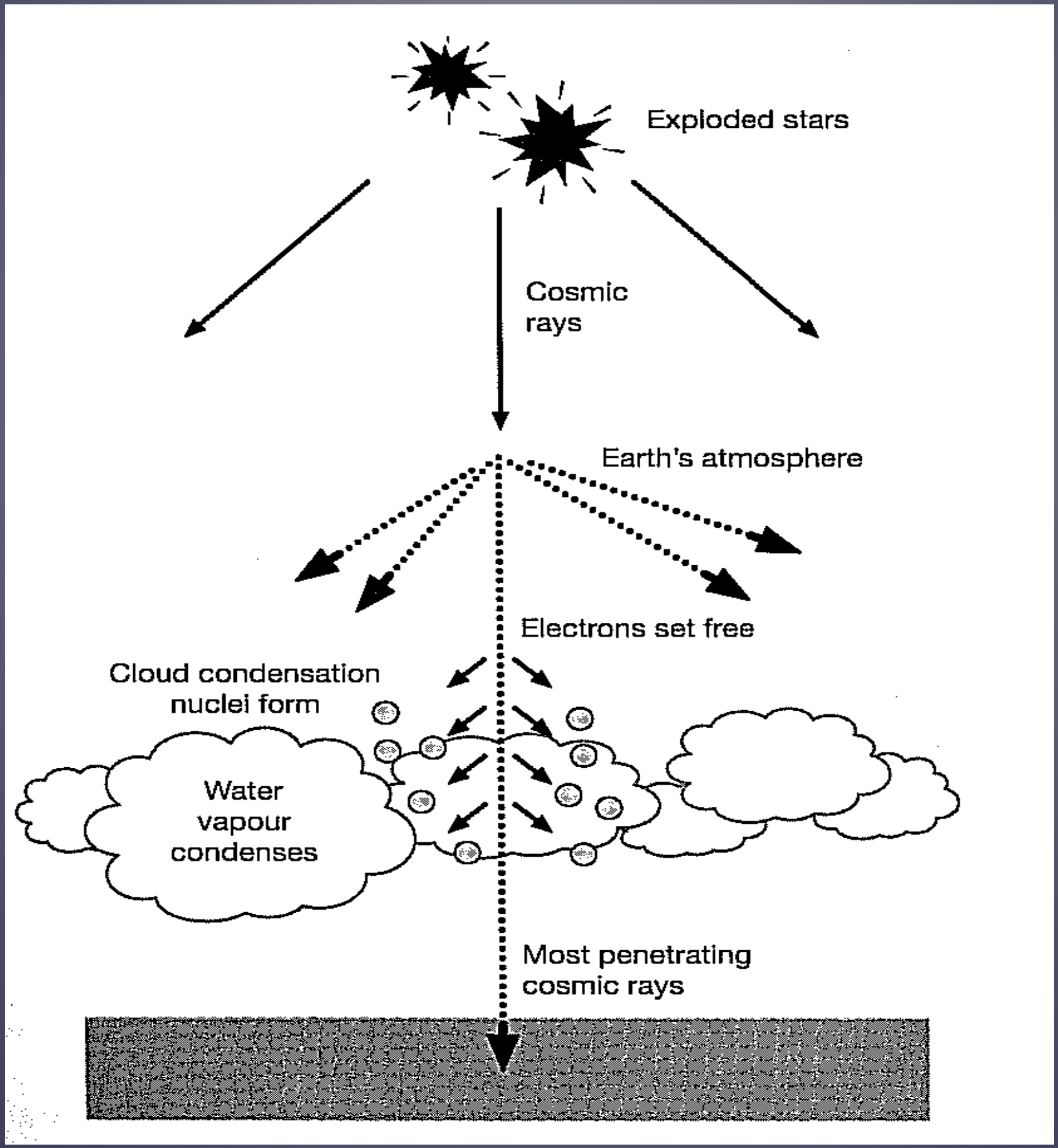


Figure 3.5 **Conceptual model of large-scale atmospheric flow for a wet (top) and dry (bottom) summer on the Canadian prairies in conjunction with SST patterns over the equatorial Pacific and North Pacific**

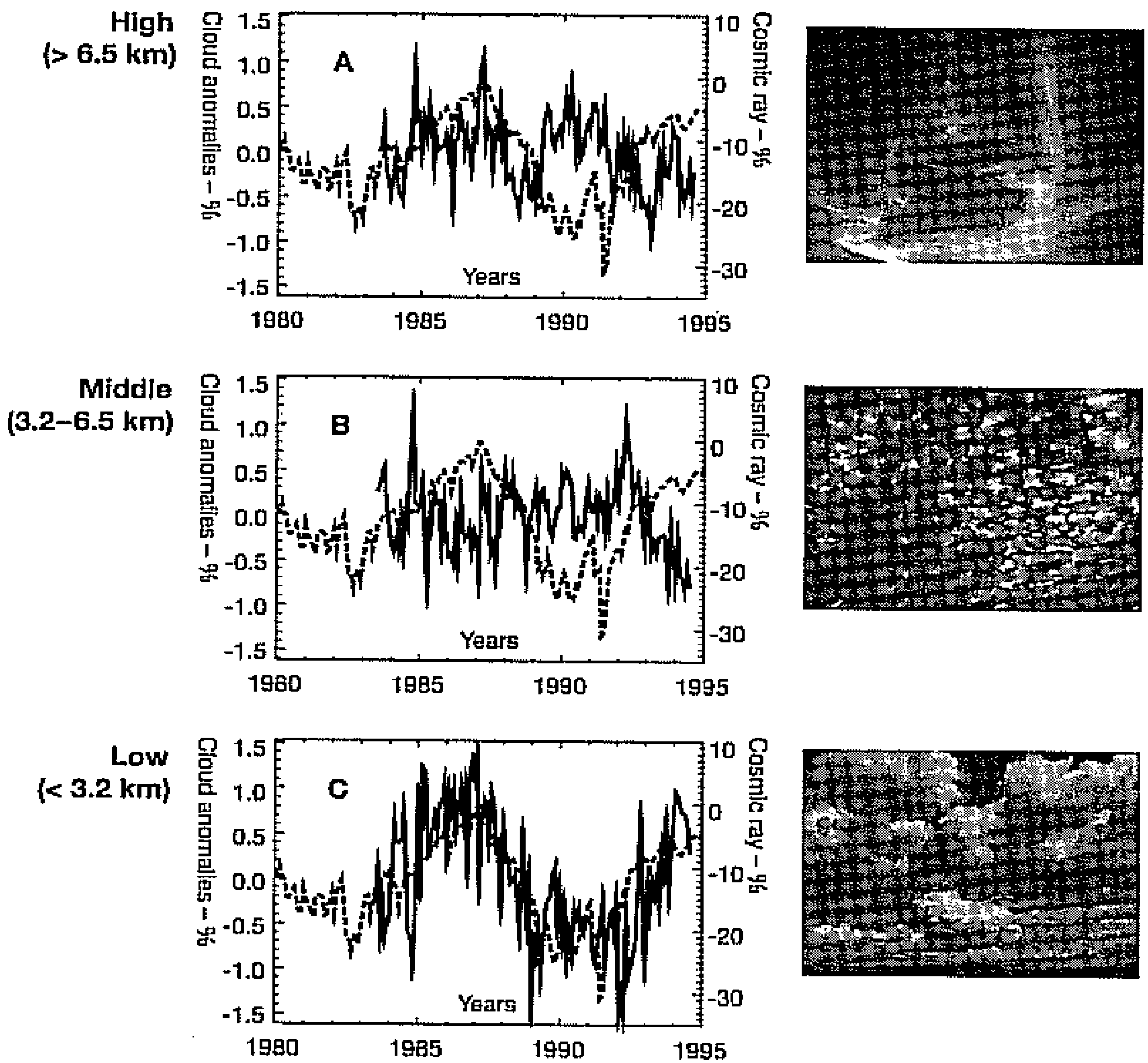
The wet summer is preceded by an El Nino event while the dry summer is preceded by a La Nina event in the equatorial Pacific and central and eastern North Pacific. CNP - central North Pacific; ENP - eastern North Pacific (adapted from Castro et al., 2001).

Source: Castro,C.L. T.B. McKee and R.A. Pilke, Sr. 2001: The relationship of the North American Monsoon to tropical and North Pacific sea surface temperatures as revealed by observational analyses. *J. of Climate,* 14, 4449-4473.

Svensmark's Cloud Forcing Theory



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



Source: Svensmark and Calder 2007. *The Chilling Stars: 'A New Theory of Climate Change'. Icon Books Ltd., Cambridge U.K.*

Conceptual model of four drivers of prairie climate

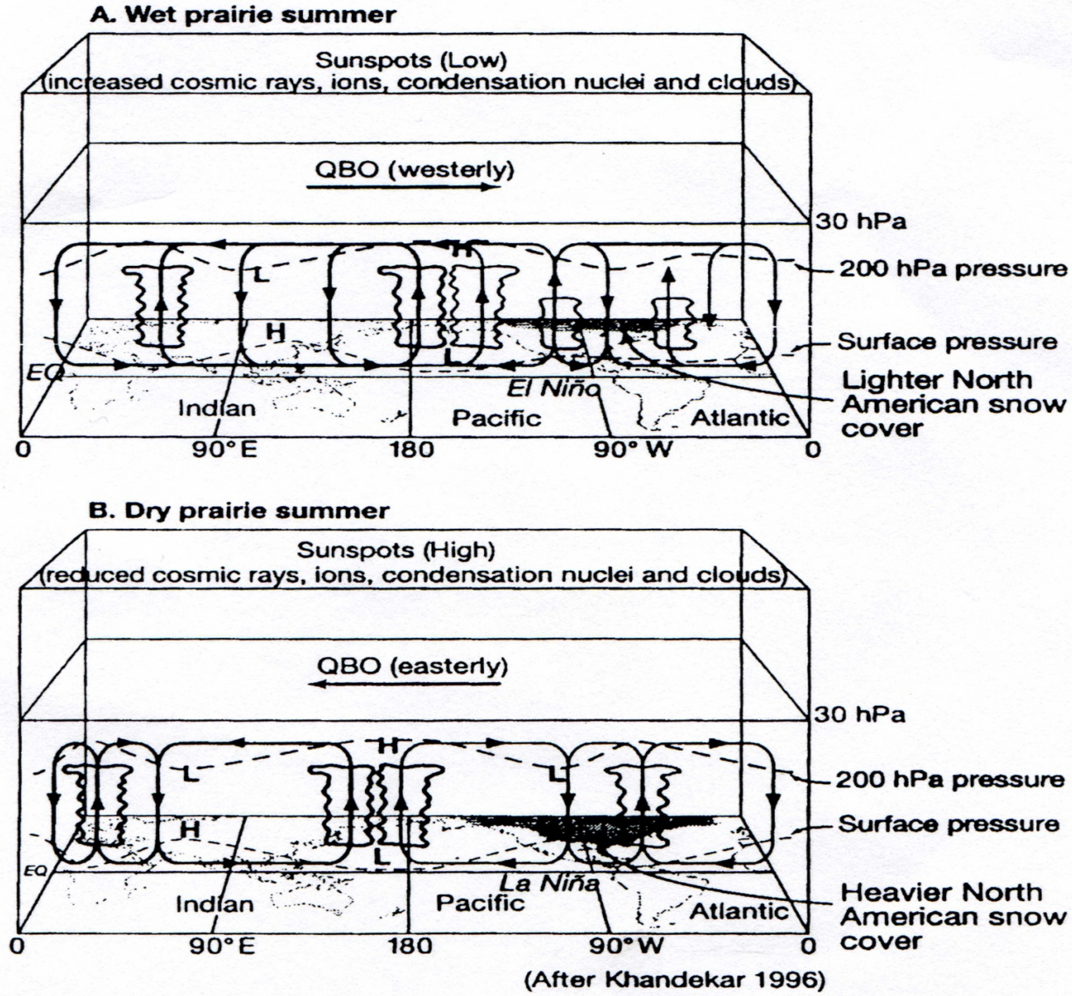


Fig. 2. Conceptual model of factor producing wet and dry prairie summers. H: high, L: low pressure system

Source: Garnett,E.R., Nirupama,N, Haque, C.E. and Murty, T.S. 2006. Correlates of Canadian Prairie summer rainfall: Implications for crop yields. *Climate Research* 32 25-33

Solar, stratospheric, Nino-3 and North American snow cover composites

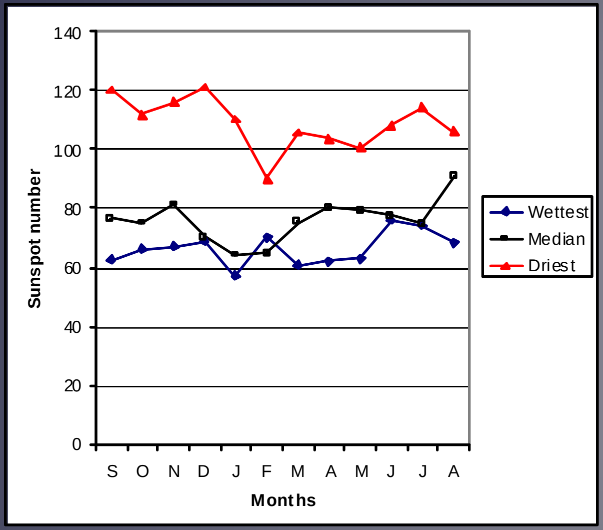


Fig 4. Number of Sunspots before, during and after the 5 driest, 5 near-median and 5 wettest May-Julys

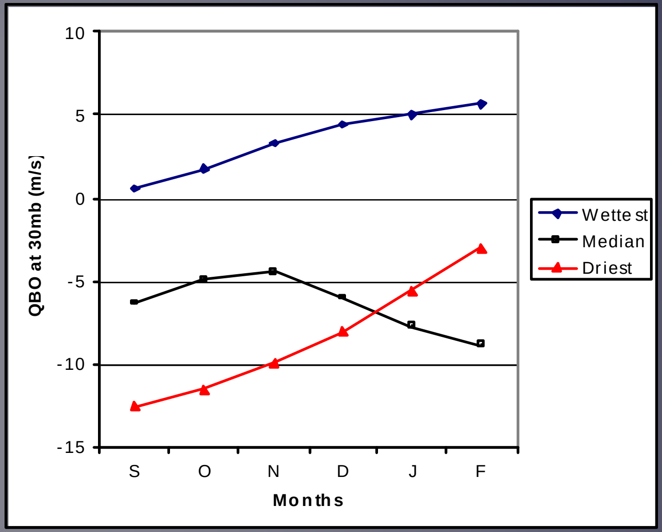


Fig 5. Stratospheric wind composite during the fall and winter months prior to the 5 wettest, 5 median and 5 driest May-Julys

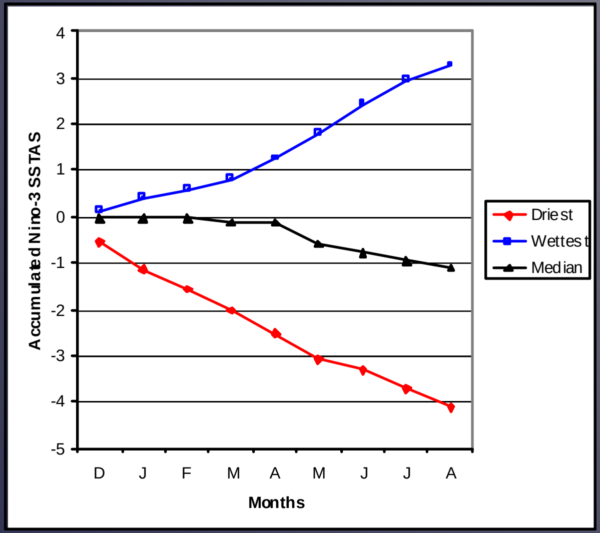


Fig 6. Accumulated Nino 3 sea-surface temperature anomalies (SSTAs) during the 5 wettest, 5 driest, and 5 near-median June-Julys

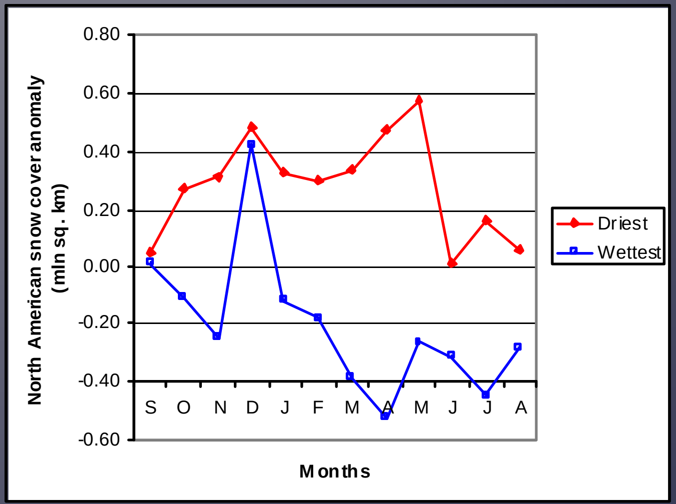


Fig 9. North America snow cover extent anomaly before, during and after the direst and wettest June-July periods over the Canadian prairies.

Source: Garnett, E.R., Nirupama, N., Haque, C.E., Murty, T.S. 2006. Correlates of Canadian Prairie summer rainfall: implications for crop yields. *Climate Research. 32 25-33*

Rainfall and temperature effects on Prairie yields

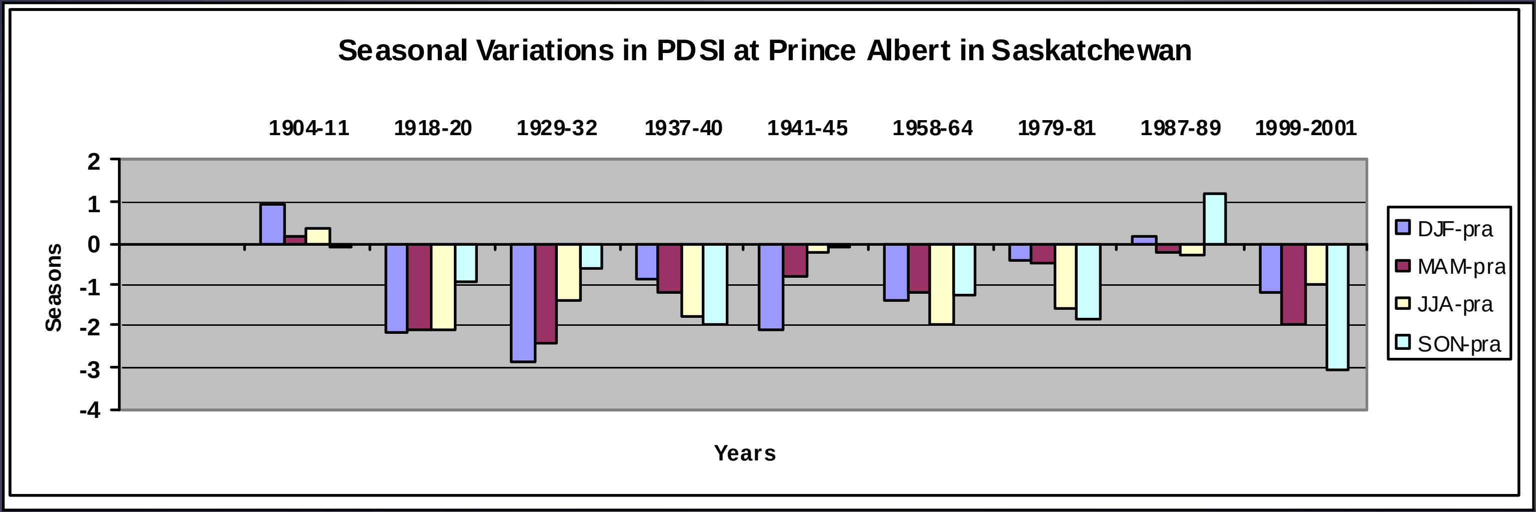
Correlation coefficients between climatic parameters and grain yields

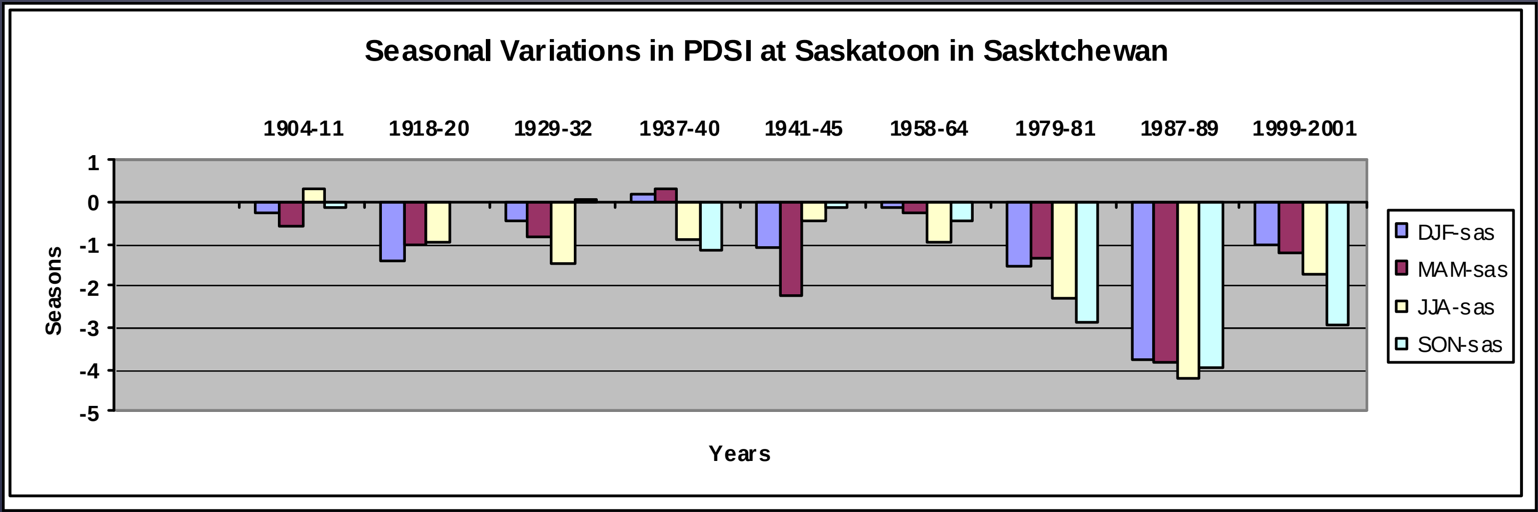
Parameter	Time Period	Correlations Wheat	Canola
Rainfall	May	0.31**	0.25*
	June	0.27*	0.18
	July	0.51**	0.28*
Rainfall anomaly		0.38**	0.34*
	May-June	0.38**	0.34*
	May-July	0.56**	0.42**
	June-July	0.62**	0.34**
Temperature anomaly			
	May-June	-0.34**	-0.36**
	May-July	-0.33**	-0.23*
	Jun-July	**-0.36****	**-0.38****

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

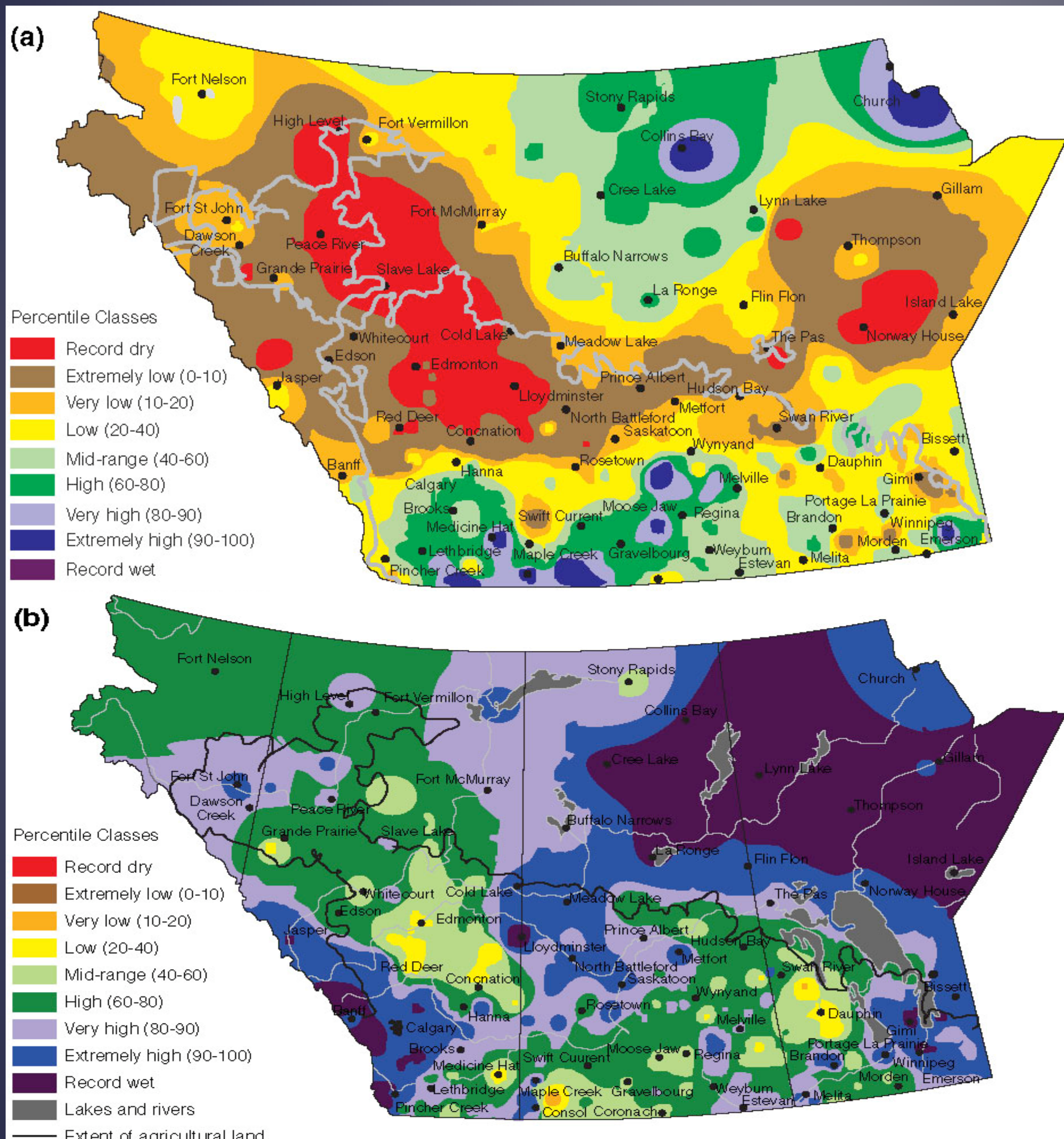
Source: Garnett,E.R., Nirupama, N, Haque, C.E. and Murty, T.S.2006. Correlates of Canadian Prairie summer rainfall: Implications for crop yields. *Climate Research* Vol.32 25-33 2006

A Glimpse of Climate as Measured by the Palmer Drought Severity Index





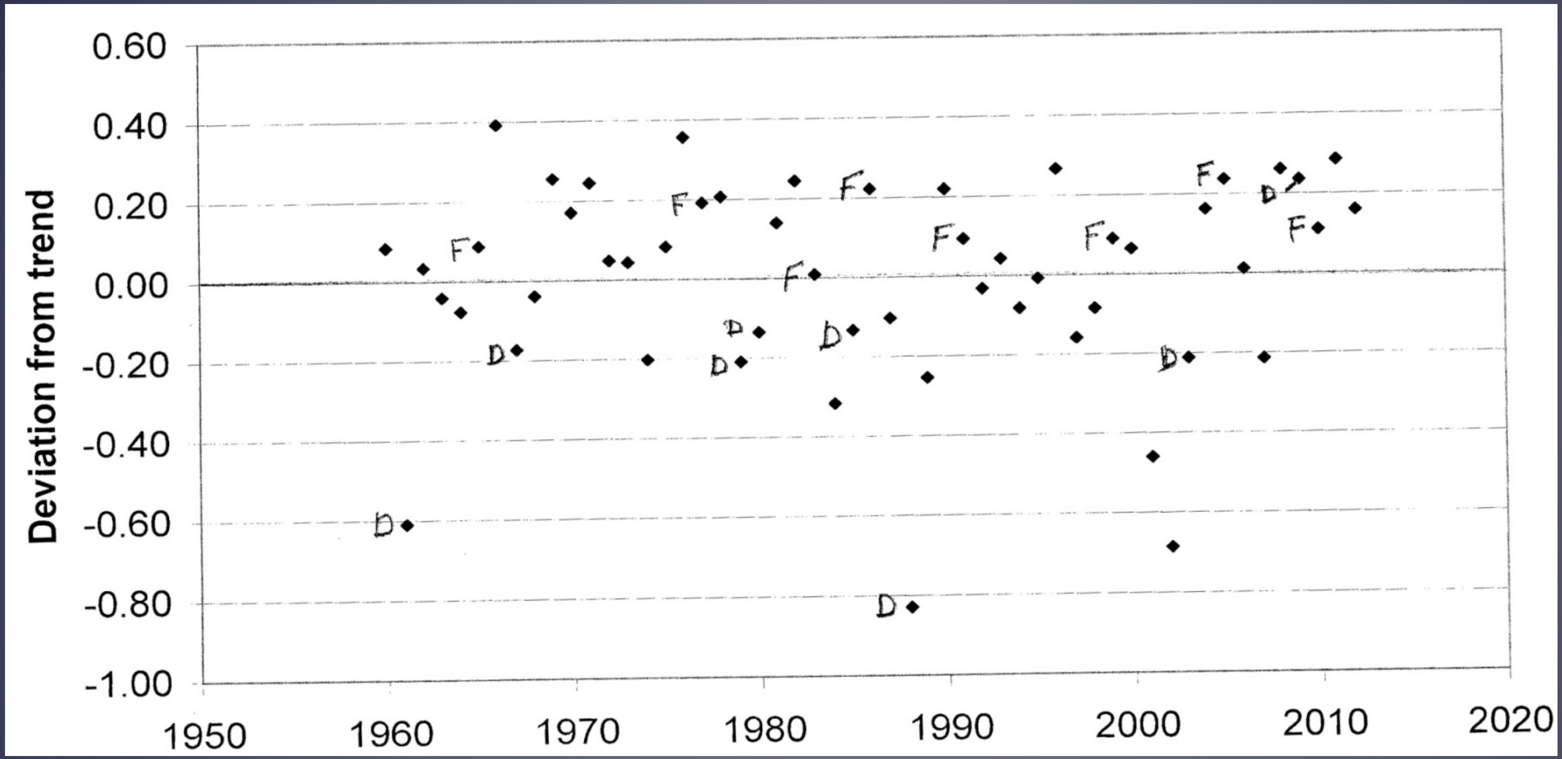
Source: Dr. M.L. Khandekar



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).

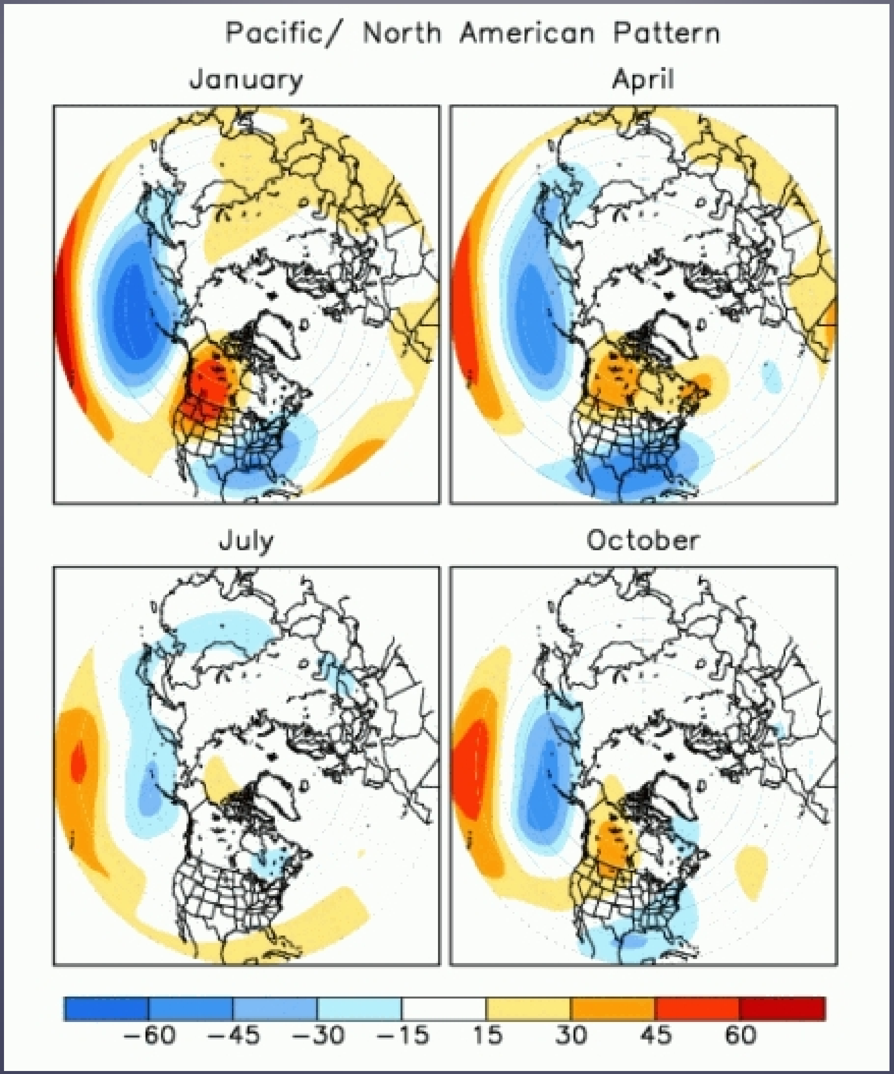
Source: Dr. M.L. Khandekar

Flood and Drought years 1960-2012
based on May-July rainfall with wheat yields

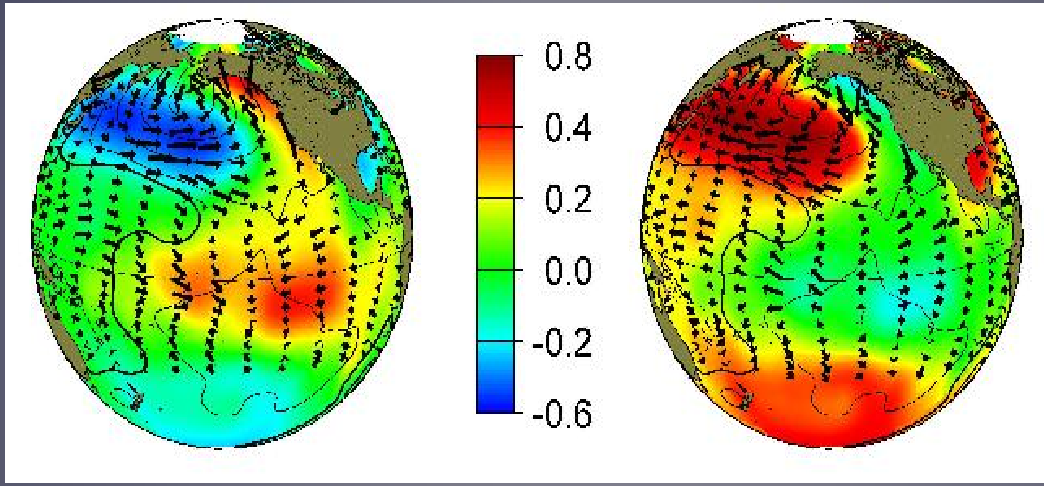


Floods (mm)		Droughts (mm)	
1991	89	1967	31
2010	88	1961	38
1999	86	2009	47
1993	83	1985	47
2005	83	2003	49
1965	79	1980	51
1977	78	1979	51
1986	77	1988	53

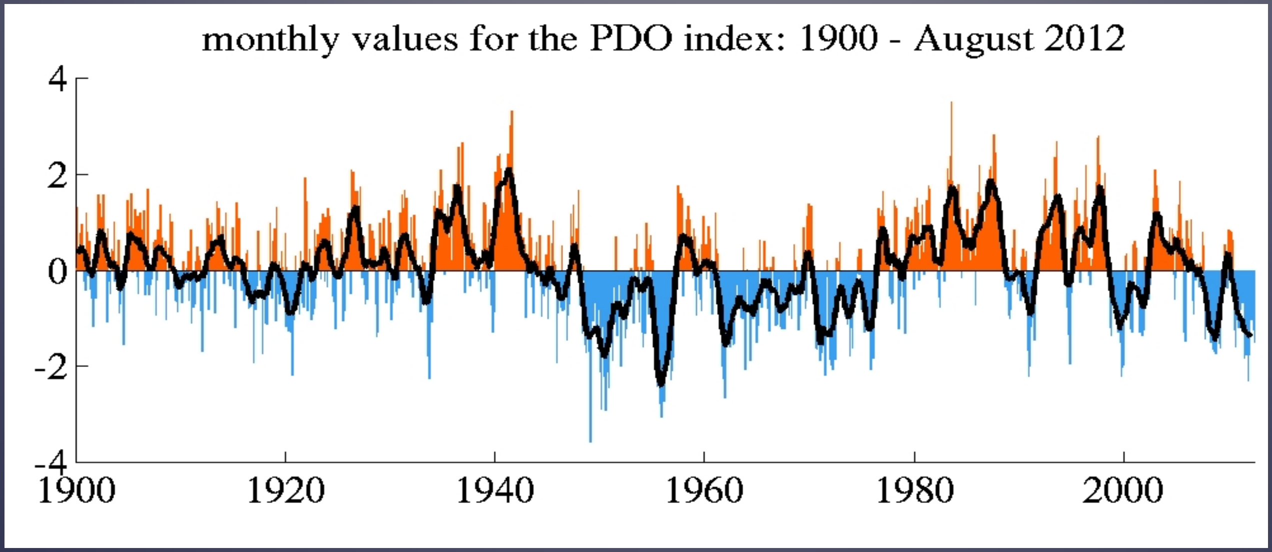
Positive phase of the Pacific North American (PNA) index
(a derivative of the El Nino/Southern Oscillation phenomenon)



Conceptual Model of the Pacific Decadal Oscillation (PDO)



Warm Phase (+) Cold Phase (-)



Principal Storm Track associated with Peak rainfall period near June 20-25 as part of the annual cycle

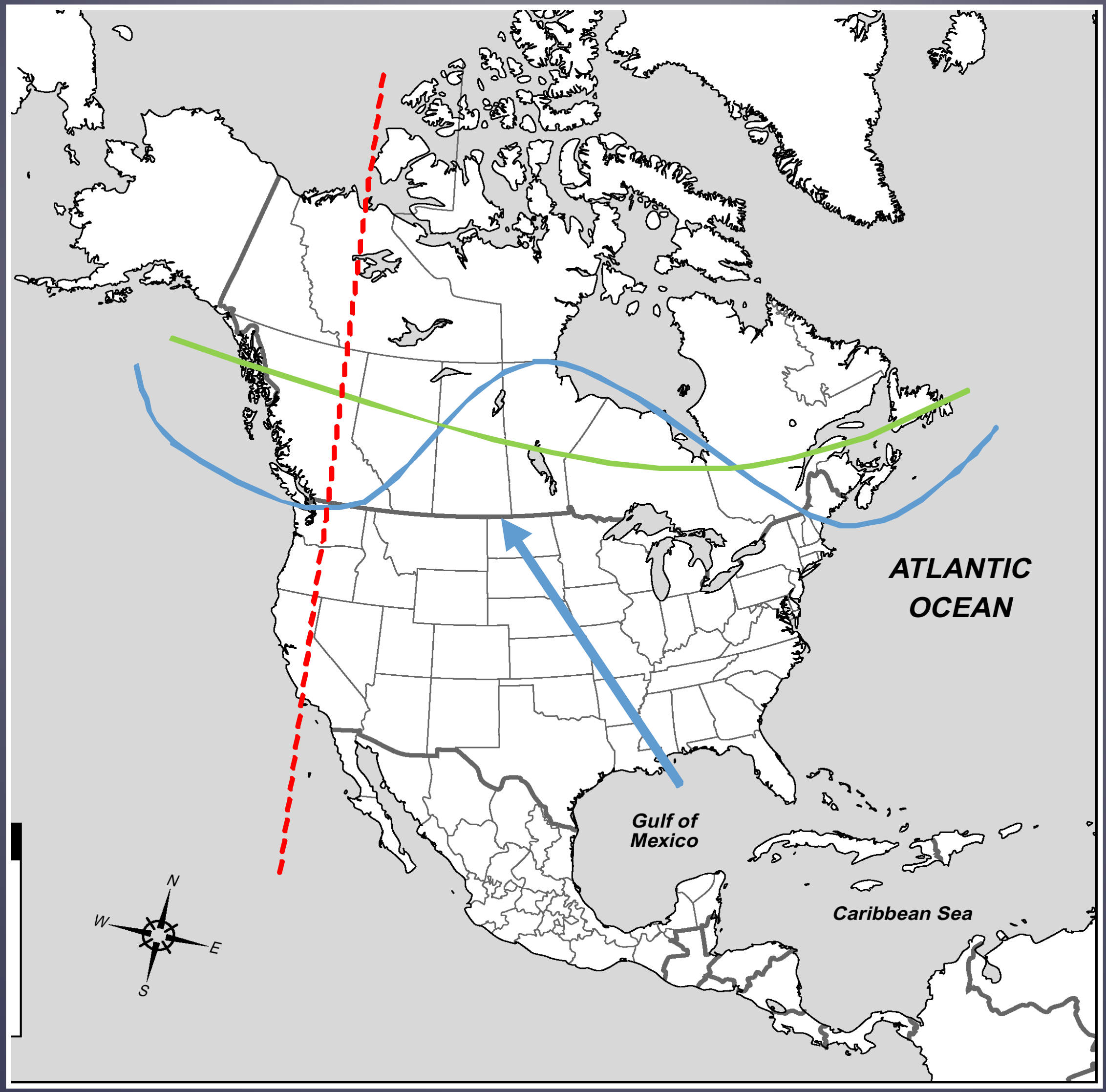
Zonal

versus

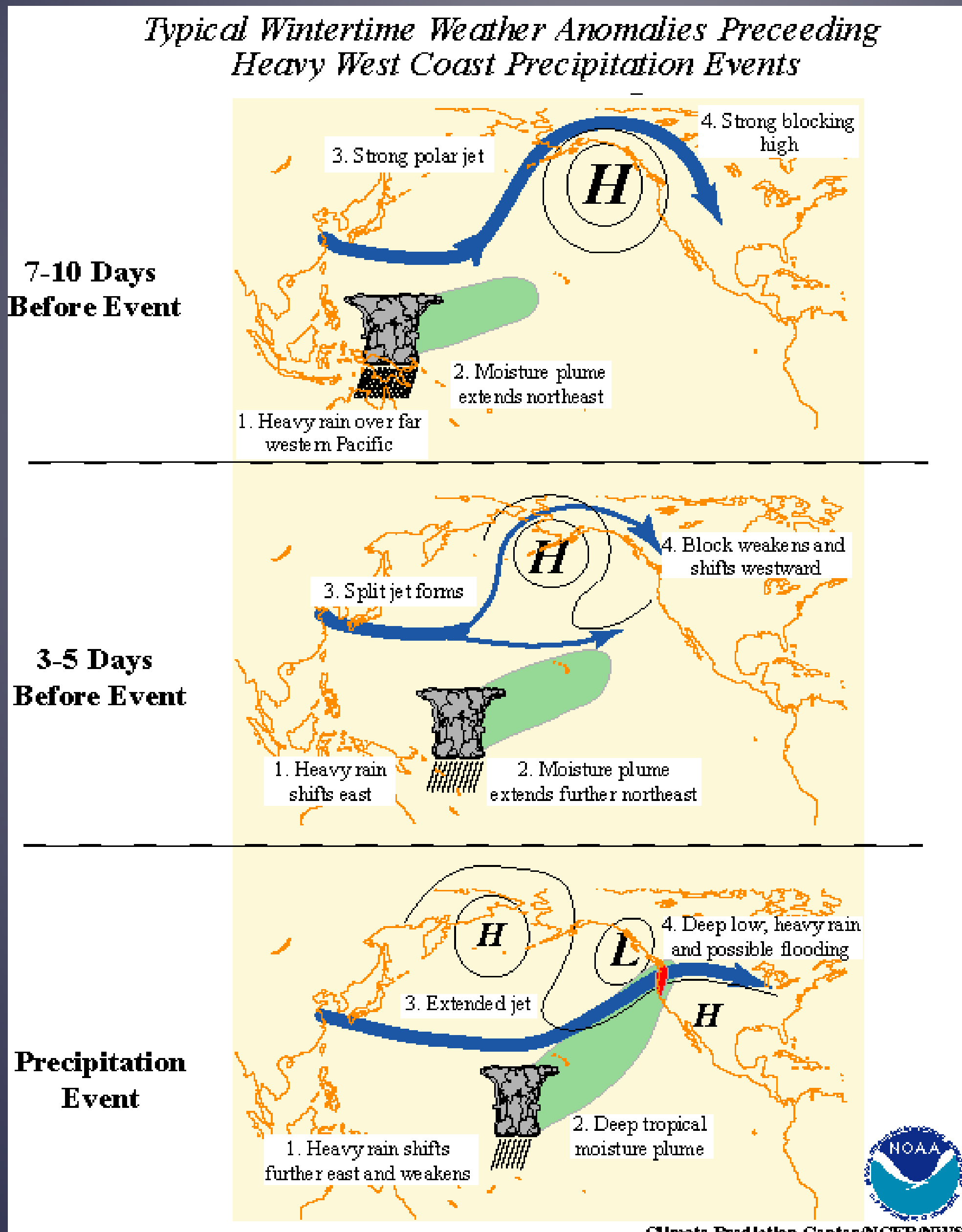
Meridional

Flow

MJO Data Collected at 120 W. Longitude.



Source: Prof. J.E. Newman, Purdue University



Conceptual Model of the Madden Julian Oscillation (MJO)

Forecasting Prairie summer rainfall

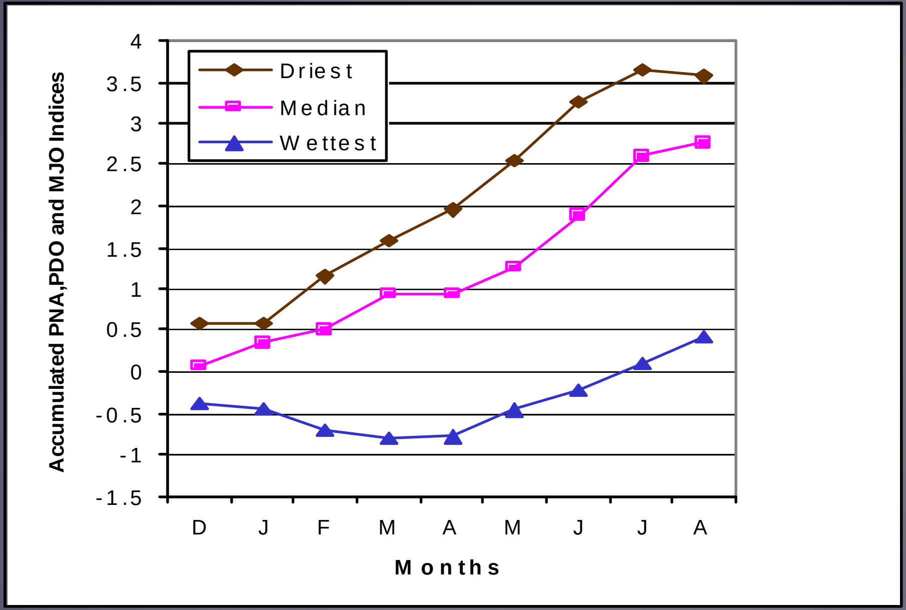


Fig. 2. Composite of accumulated PNA, PDO and MJO indices for the three driest (1979, 1984 and 2003), three median (1981, 1982 and 1983) and three wettest (1993, 2002 and 2005) June-August periods over the Prairies for the period 1979-2009

Table 2. Correlation coefficients of PNA, PDO and MJO vs. June-August rainfall

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	N
PNA	-0.16	0.07	0.07	-0.14	-0.27*	0.10	0.08	0.09	0.23	0.06	0.09	0.07	59
PDO	0.07	0.02	-0.10	-0.16*	-0.18*	-0.09	-0.02	-0.03	-0.02	0.01	0.10	0.13	109
MJO	0.13	-0.17	-0.13	-0.18	0.10	-0.47***	0.03	-0.32*	-0.01	-0.13	0.07	0.07	31
NP	0.02	0.02	0.02	0.12	0.11	-0.07	-0.03	-0.04	-0.07	-0.08	-0.18*	-0.05	109
AP	0.06	-0.08	0.09	-0.06	0.17	0.11	0.20*	0.12	-0.03	-0.02	-0.06	0.04	77

* Significant at the 5% , ** 1% level and *** .1% levels

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** Type	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**
					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

* Significant at the 5%, ** 1% level and *** .1% levels

Predicting July Moisture Conditions over the Prairies

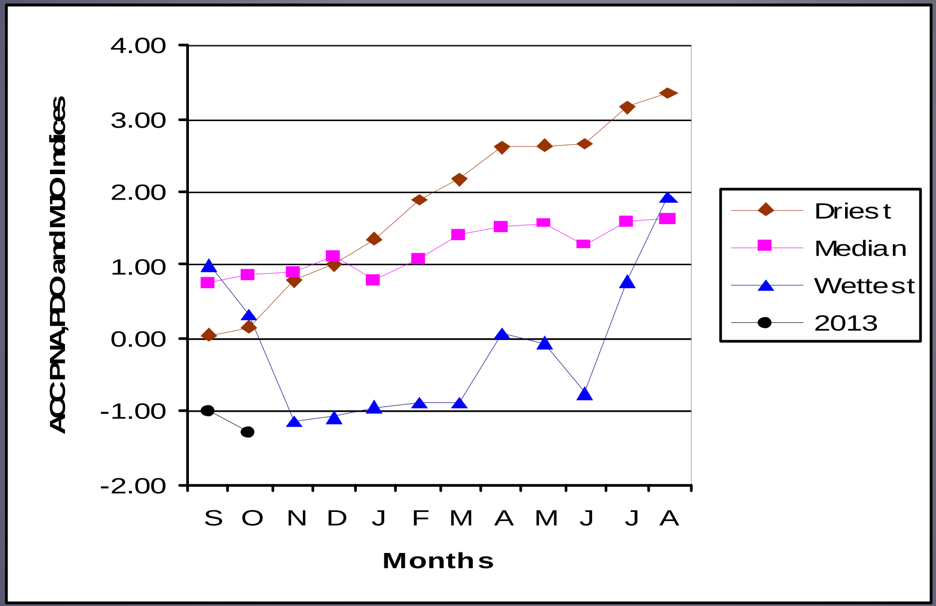


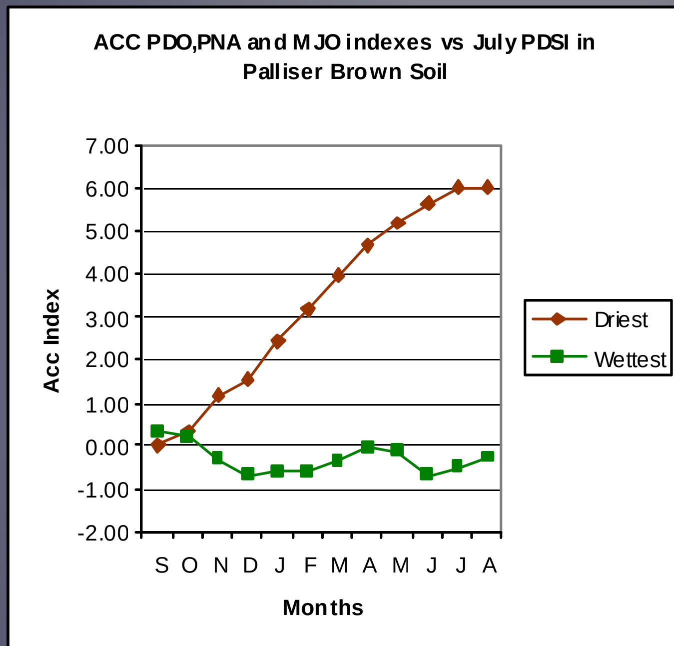
Fig. 2. Composite of accumulated PNA, PDO and MJO indices for the four driest (1980, 2002, 2003 and 1988), three median (1998, 1979 and 2008) and four wettest (1991, 1996, 1999 and 2007) Julys based on the PDSI.

Table 3. Correlation coefficients of PNA, PDO and MJO vs. July PDSI

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	N
PNA	0.02	-0.34*	-0.53***	0.01	-0.12	-0.16	0.05	0.21	0.25	-0.16	0.02	0.26	39
PDO	-0.08	-0.21	-0.35*	-0.28*	-0.26*	-0.25	-0.10	-0.06	0.05	0.07	0.13	0.01	39
MJO	-0.03	0.12	-0.43**	0.18	-0.02	0.05	-0.05	-0.11	-0.32*	-0.02	0.04	0.00	39

* Significant at the 5% , ** 1% level and *** .1% levels

Forecasting July Moisture conditions in the Palliser Brown Soil Zone



Composite of accumulated PDO, PNA and MJO indices for the the three driest (1984, 1985 and 1988) and three wettest (1991,1999 and 2010) Julys based on the PDSI.

Predictand July PDSI Palliser Brown Soil Zone

N		S	O	N	D	J	F	M	A	M	J	J	A
109	PDO	-0.22	-0.36*	-0.45***	-0.42***	-0.38**	-0.33*	-0.17	-0.13	-0.13	-0.07	0.08	-0.06
59	PNA	0.14	-0.14	-0.46***	0.10	-0.23	-0.14	-0.09	0.06	0.11	-0.29*	0.03	0.26*
31	MJO	0.12	0.25	-0.37*	0.02	-0.09	-0.09	0.04	-0.10	-0.36*	-0.09	-0.03	-0.02

* Significant at the 5% , ** 1% level and *** .1% levels

Forecasting Summer Temperatures

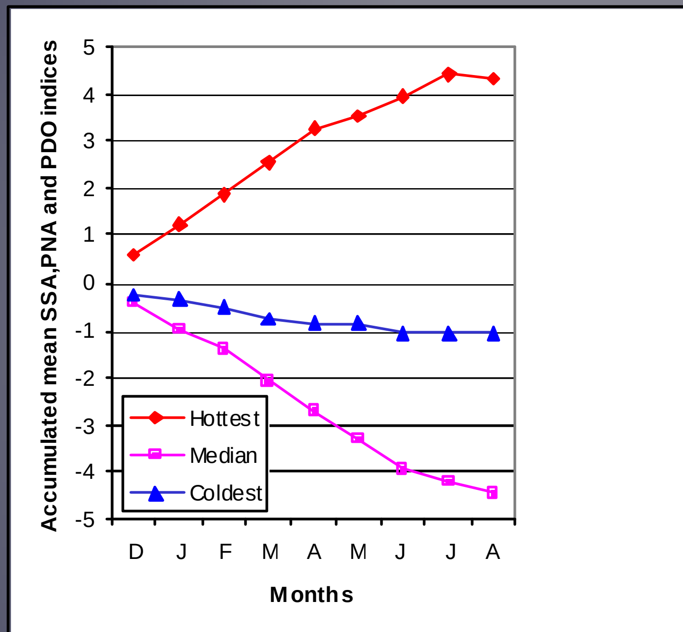


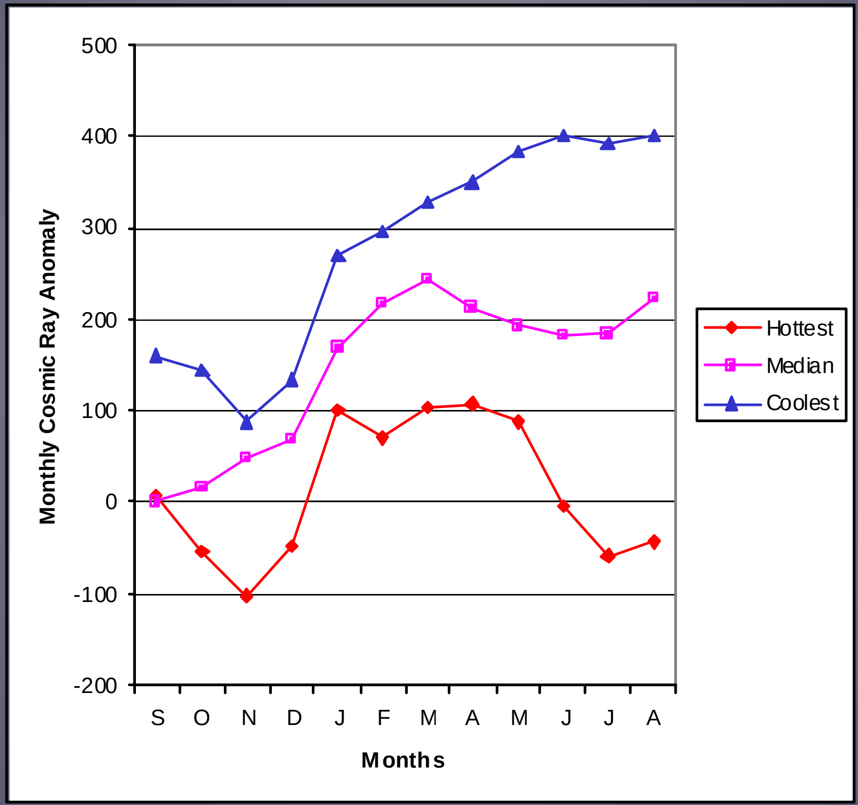
Fig. 5. Composite of accumulated SSA, PNA and PDO indices for the six hottest (1961, 1970,1983, 1984,1988, 2003) six median(1953, 1962, 1964, 1972, 1974 and 1975) and six coldest(1951, 1985, 2004, 2005, 2008 and 2009) June-August for the period 1951-2009.

Table 5. Correlation coefficients of SSA, PNA, PDO vs. summer temperatures

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	N
SSA	0.24*	0.20	0.20	0.19	0.21	0.16	0.23*	0.28*	0.25*	0.30*	0.27*	0.31**	56
PNA	-0.20	-0.04	0.01	0.23*	0.22*	0.11	0.07	-0.00	-0.19	0.03	0.00	-0.24*	59
PDO	0.14	0.15*	0.09	0.13	0.17*	0.15*	0.26*	0.11	0.05	0.09	-0.03	-0.01	109

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

Cosmic Rays versus Prairie Summer Temperatures -analysis supports Svensmark's theory



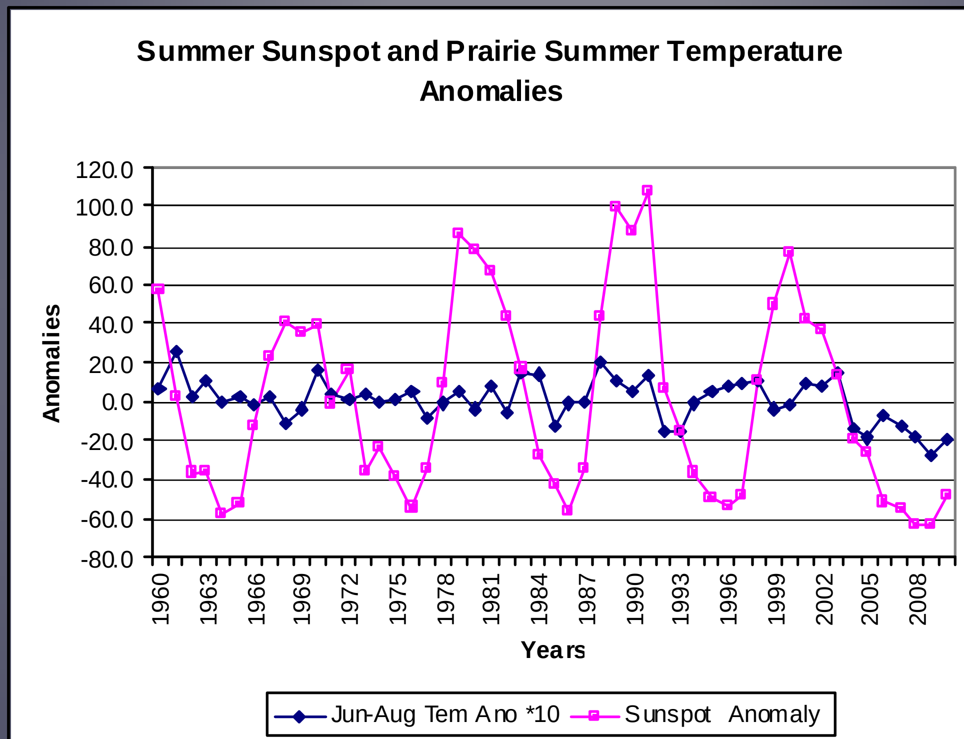
Monthly Global Cosmic Ray (GCR) anomalies prior to the four coldest, four median and four hottest June-Augusts for the period 1960-2010

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	N
SSA	.24*	.20	.20	.19	.21	.16	.23*	.28*	.25*	.30*	.27	.31**	56
API	.18	.20	.07	.12	-.03	.06	.34**	.33**	.28*	.28*	.22 *	.30*	55
CRA	.22	-.24*	-.20	-.25*	-.22	-.21	-.27*	-.34**	-.33**	-.35**	.19	-.33**	50

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

JUNE-AUGUST MEAN MONTHLY SUNSPOT ANOMALIES VERSUS JUNE-AUGUST TEMPERATURE ANOMALIES

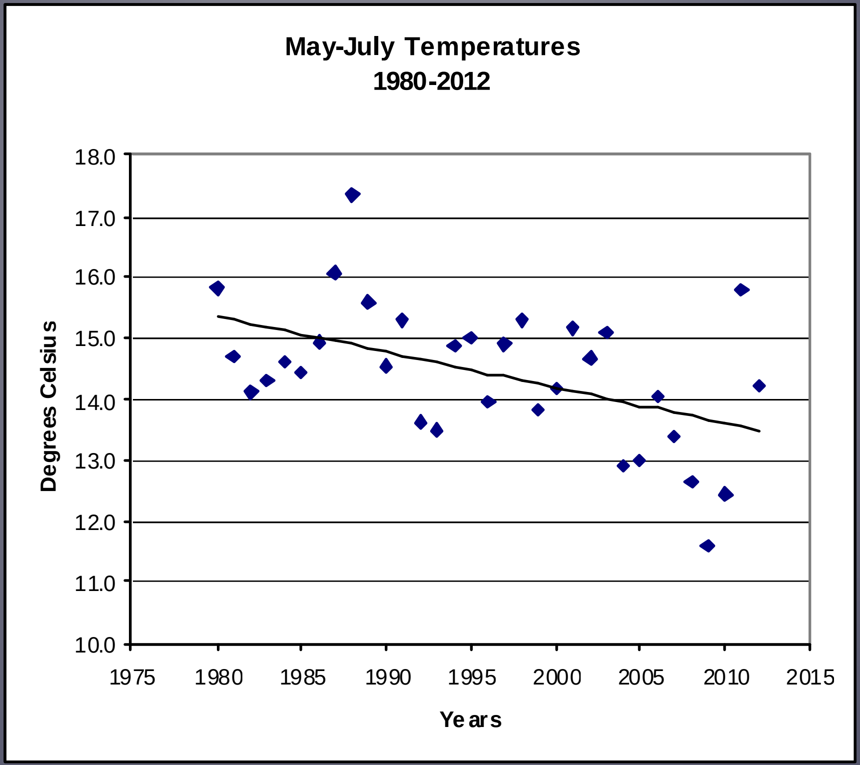


CORRELATION MATRIX OF INDICES AND SUMMER TEMPERATURES

N	Predictor	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%, ** Significant at the 1% level,

Prairie May-July temperatures 1980-2012



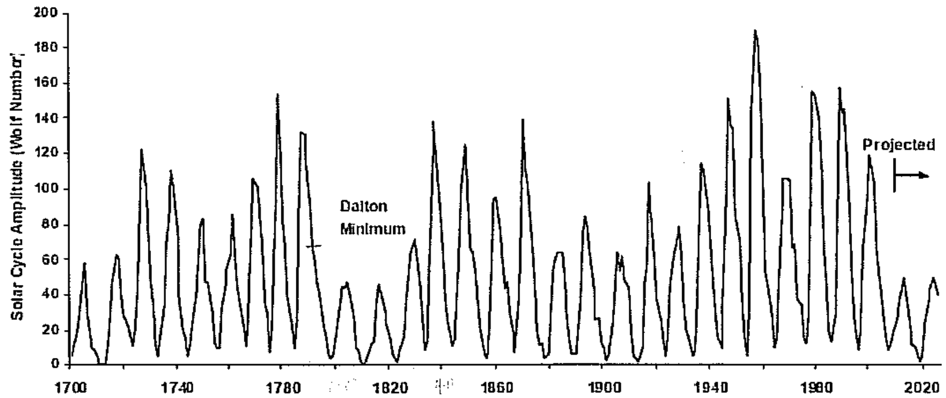
Climate data sources:

-Ontario Climate Center, 1980 – 2007 (400 stations),

-National Agro-climate Service (NAIS), Regina, SK 2008 – 2010 (155 stations),

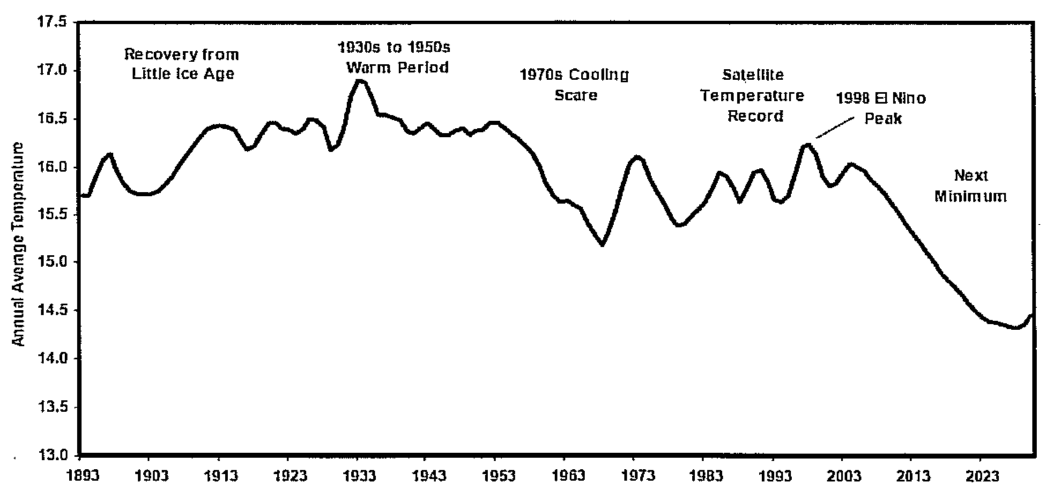
-Environment Canada 2011 and 2012 (30 stations).

The Solar Driver



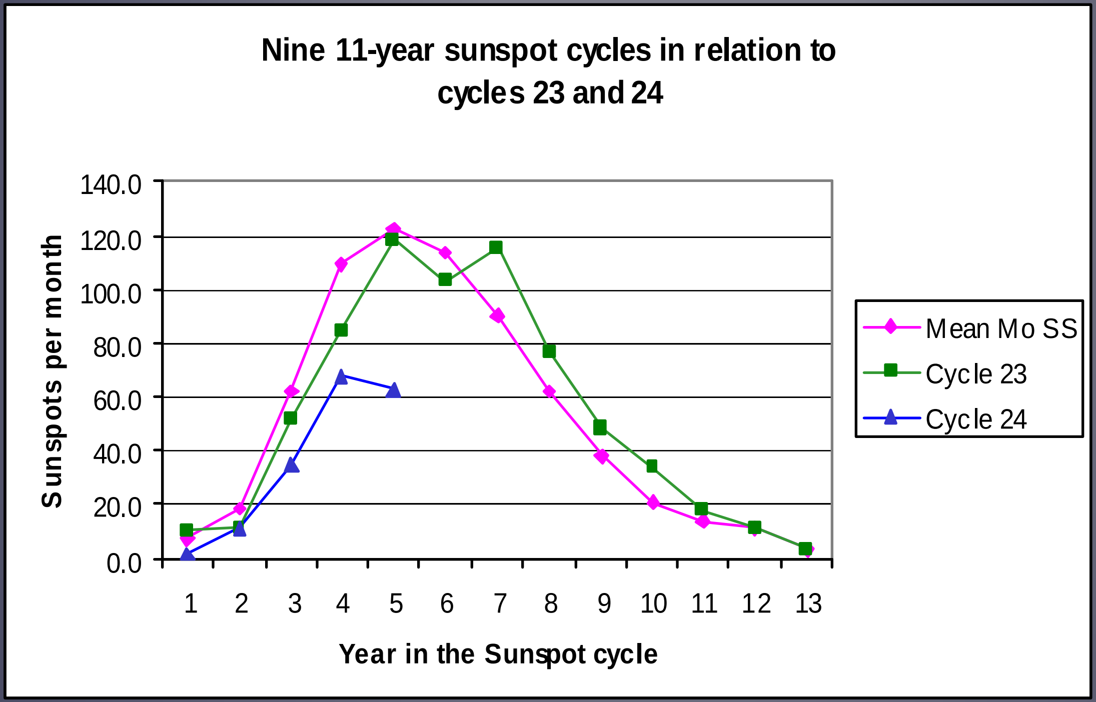
And his projection based on this solar forecast of temperature through 2030.

Projected Temperature Profile to 2030



Courtesy of Dr. M.L. Khandekar and J D'Aleo

A Australian Solar model predicts cycle 24 will peak this winter at 90 sunspots per month. Will it?



Solheim *et al.* 2012 forecast that the Northern Hemisphere annual average temperature will drop 0.9 Celsius during solar cycle 24.

CANDIDATE CONTIBUTORS TO CLIMATE CHANGE

A. COSMIC RAY CLOUD FORCING THEORY

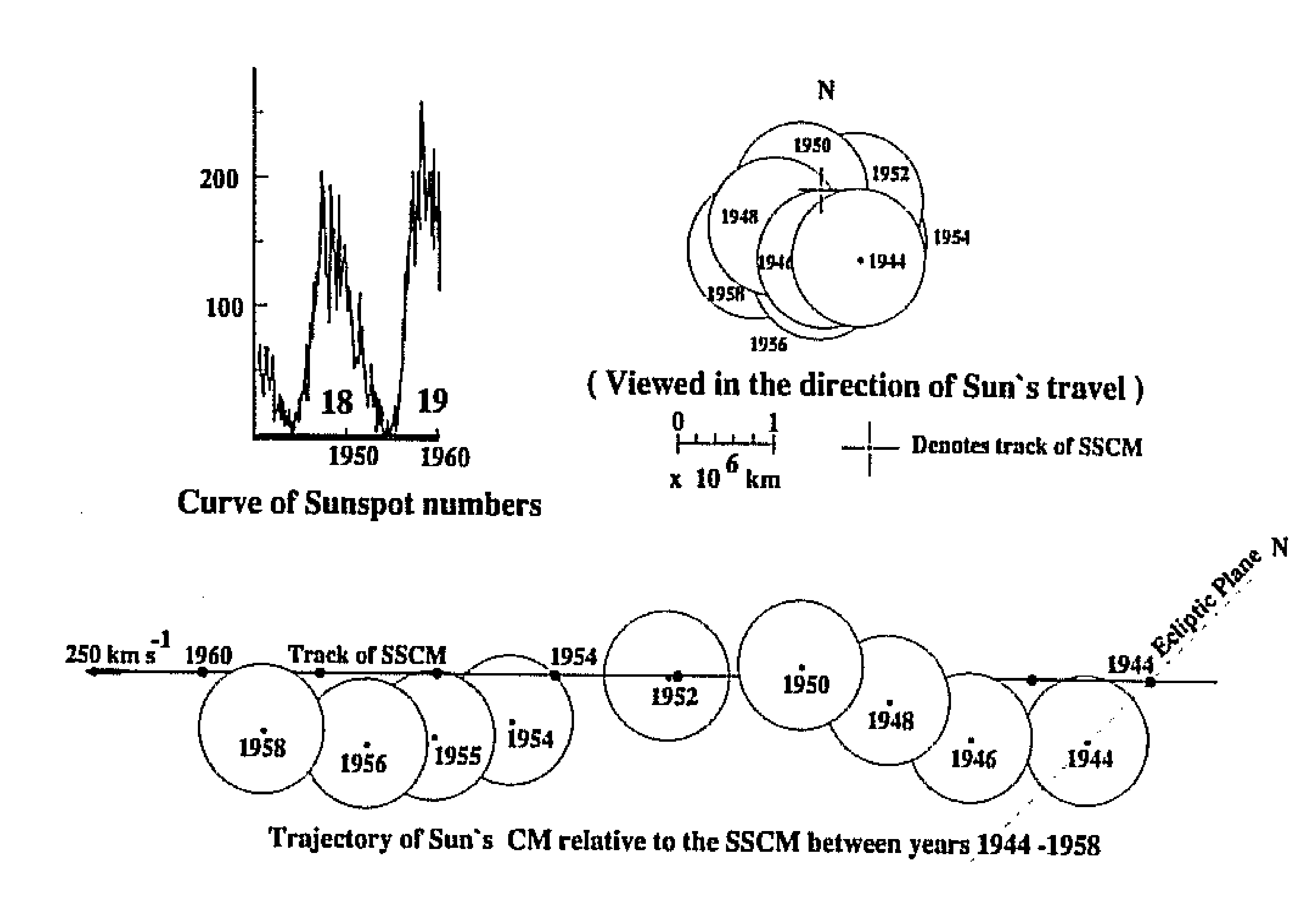
B. VOLCANIC ERUPTIONS AND EL NINO WARMING EVENTS

C. CHANGES IN THE AMOUNT OF DUST AND SMOKE IN THE AIR.

D. CHANGES IN OZONE, METHANE AND OTHER GREENHOUSE GASES.

E. ALTERED LAND USE DARKENING OF LAND BY VEGETATION FERTILIZED BY EXTRA CARBON DIOXIDE.

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



Bailey, F., 2007. *Textbook of Gravity, Sunspots and Climate*
– confirms a clear link between the movement of the sun and orbiting planets and consequent solar energy received on earth; hemispheric climatic responses.

CONCLUSIONS

1. New and dominant predictors that emerged in this research are the Madden-Julian Oscillation (MJO), the Pacific Decadal Oscillation (PDO) and solar related predictors.

2. Composites have been developed for anticipating extremes in summer precipitation, temperature and July moisture extremes with lead times up to four months.

3. A regression model has been developed for forecasting summer (June-Aug) precipitation over the prairies with a lead- time of 1-3 months.

4. Composites and regression models have been explored for forecasting climate over prairie sub regions.

5. These research results confirm the validity of Svenmark's cloud forcing theory and emphasize the importance of observing and understanding solar influences in future months and years.

ACKNOWLEDGEMENTS

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Supervisors: M.L. Khandekar and J.C. Babb Research Associate: E.R. Garnett

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Contact Information

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Predicting July Moisture Conditions over the Prairies

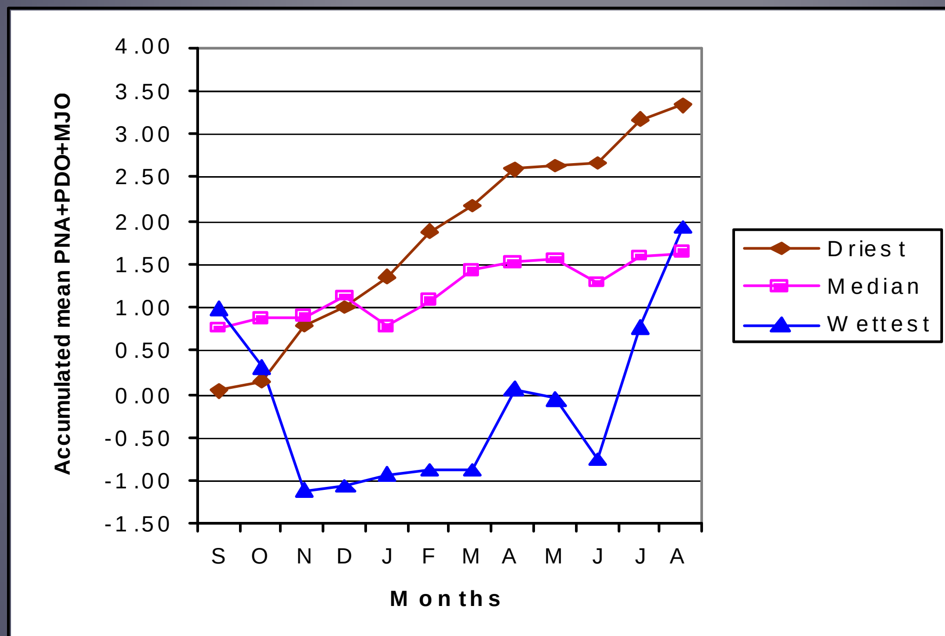

Fig. 2. Composite of accumulated PNA, PDO and MJO indices for the four driest (1980, 2002, 2003 and 1988), three median (1998, 1979 and 2008) and four wettest (1991, 1996, 1999 and 2007) Julys based on the PDSI.

Table 3. Correlation coefficients of PNA, PDO and MJO vs. July PDSI

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	N
PNA	0.02	-0.34*	-0.53***	0.01	-0.12	-0.16	0.05	0.21	0.25	-0.16	0.02	0.26	39
PDO	-0.08	-0.21	-0.35*	-0.28*	-0.26*	-0.25	-0.10	-0.06	0.05	0.07	0.13	0.01	39
MJO	-0.03	0.12	-0.43**	0.18	-0.02	0.05	-0.05	-0.11	-0.32*	-0.02	0.04	0.00	39

* Significant at the 5% , ** 1% level and *** .1% levels