

Prairie Drought under Natural and Anthropogenic Climate Change

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CWRA June 28, 2007



Outline

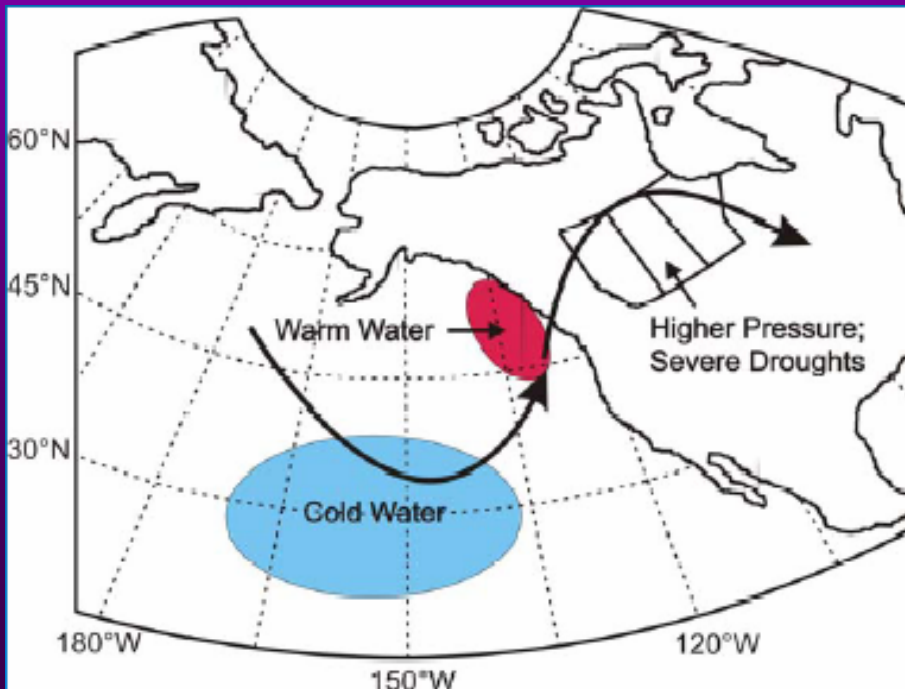
- **Background**
- **Causes**
- **Drought monitoring methods**
- **Past drought occurrence**
- **Future drought**
- **Future Research**

Background

- **Drought is a prolonged period of abnormally dry weather that depletes water resources for human and environmental needs**
- **Severity depends on: Area affected; duration, intensity, antecedent conditions; regions ability to adapt to water shortage**
- **A drought may occur in any season and last for several months over local or large geographic regions**
- **Drought are the single largest source of economic hardship to the farming community particularly to western Canada**
- **Past drought events: 1920-30's, 1961, 1984-85, 1988, 2001-02**

Causes

- **Large-scale circulation patterns associated with SSTs**
 - +PNA, +PDO, El Niño, Deep Aleutian Low (winter)
 - +PNA, +PDO, Meridional Flow (summer)
- **Below normal precipitation**
- **Above average temperatures (not season specific)**



**Drought of 2001-02:
lacked meridional flow &
positive temperatures**

Types/Indices

- **Meteorological drought: prolonged period of below-normal precipitation (rain or snow) often intensified by high temperatures**
 - PDSI Palmer Drought Severity Index
 - SPI Standardized Precipitation Index
 - CMI Climate Moisture Index
- **Agricultural drought: insufficient soil moisture to support crops**
 - CMI Crop Moisture Index; Computed Soil Moisture Index
- **Hydrological drought: reduced surface runoff and shallow groundwater supply**
 - SWSI Surface Water Supply Index; PHSI Palmer Hydro Severity Index
- **Socio-economic drought: effects society and economy**

Drought Impacts 2001-02



“...the drought years of 2001 and 2002 in Canada brought devastating impacts to many sectors of our economy, posed considerable adaptation challenges, and made history.” (Wheaton et al., 2005)

Drought Impacts 2001-02

- **Agricultural production** dropped an estimated \$3.6 billion
- **Gross Domestic Product** fell some \$5.8 billion
- **Employment** losses exceeded 41,000 jobs
- **Net farm income** was negative in Saskatchewan for 2002, and a zero for Alberta in 2002
- **Crop production losses**
- **Livestock production difficulty**
- **Water supplies** were negatively affected, included surface water such as streams, wetlands, dugouts, reservoirs and groundwater
- **Multi-sector effects** were felt in areas as wide-ranging as agricultural production and processing, water supplies, recreation, tourism, health, hydro-electric production, transportation, and forestry
- **Long-lasting impacts** included soil and other damage by wind erosion, deterioration of grasslands, and herd reductions

- **Bonsal, B. and M. Regier, 2007. *Historical comparison of the 2001/2002 drought in the Canadian Prairies*. Climate Research, 33, 229-242.**
- **Bonsal, B. and M. Regier, 2007. *The 2001 and 2002 Canadian Drought: Historical Context and Potential Future Occurrence*. Environment Canada, 58pg**

Study Area

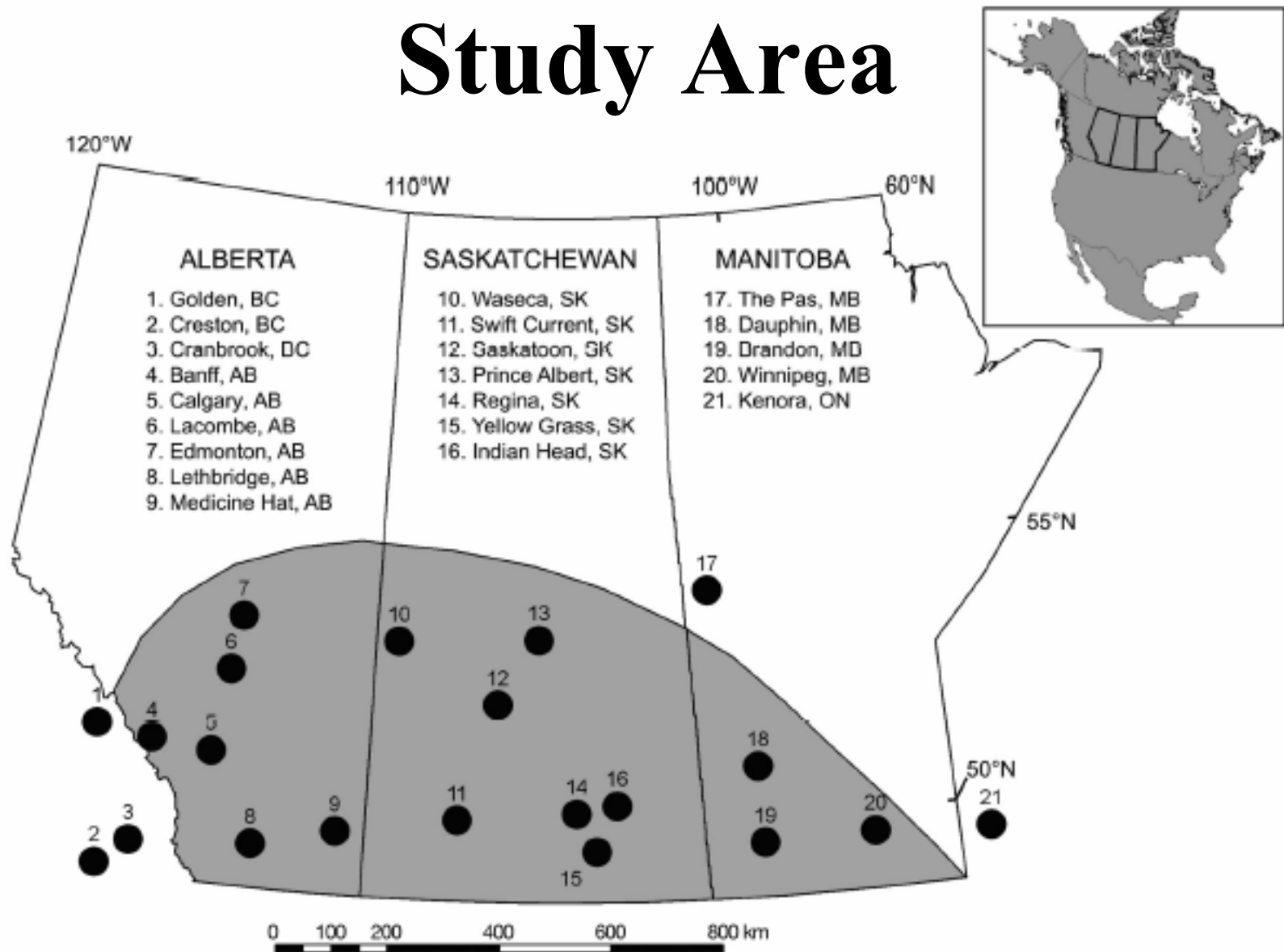
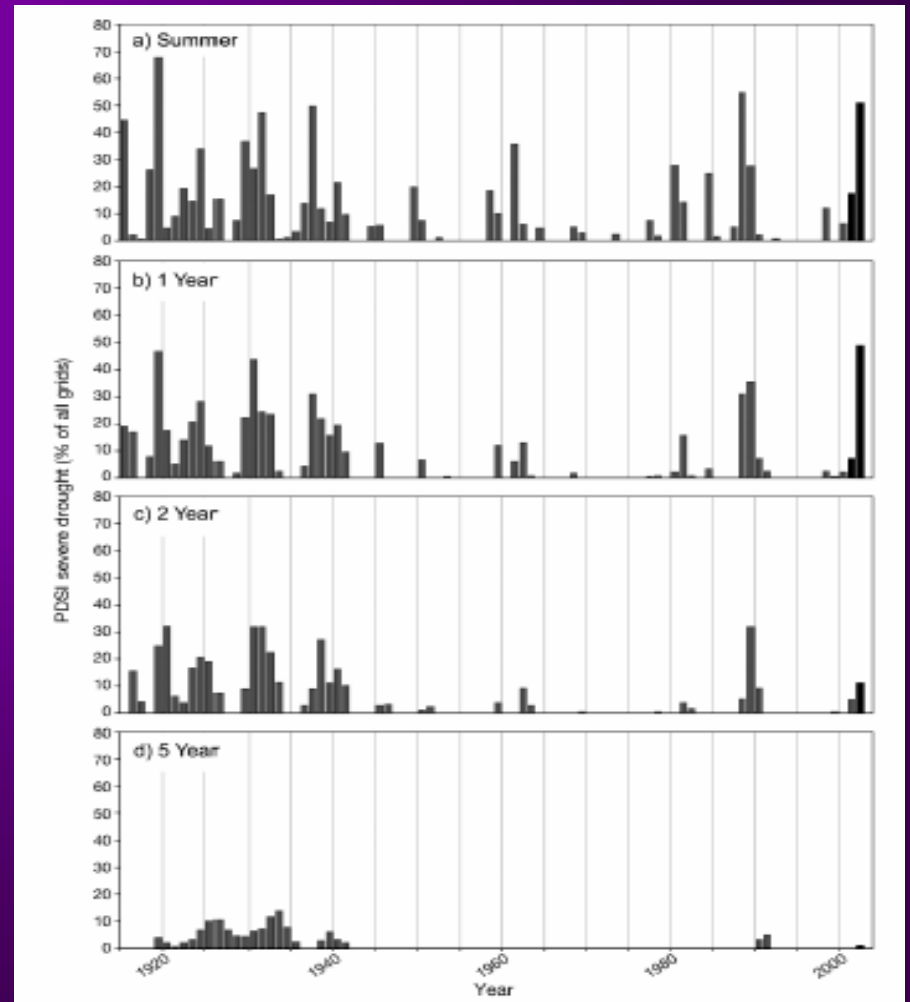
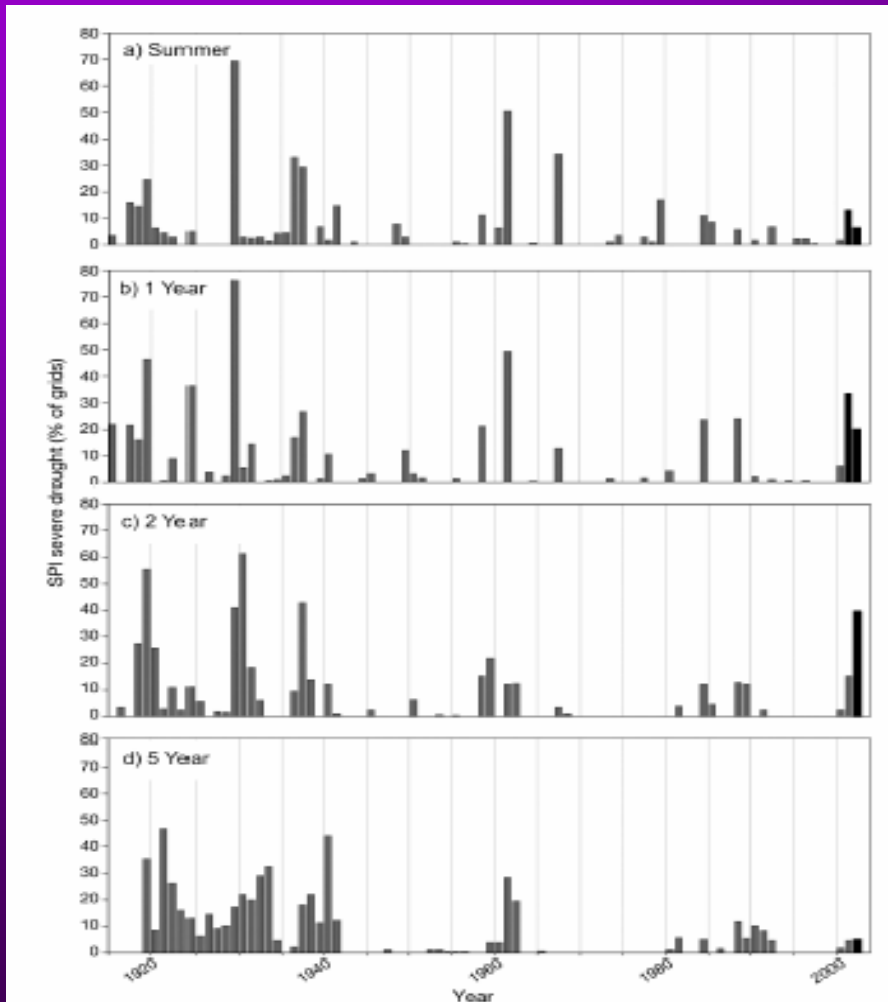


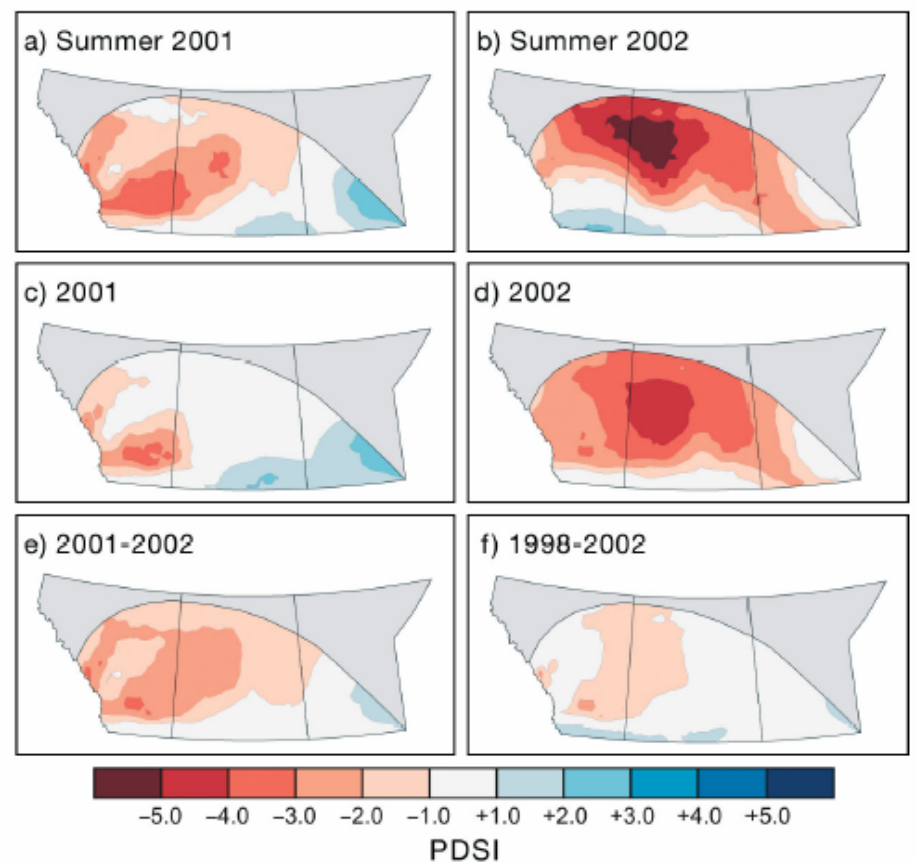
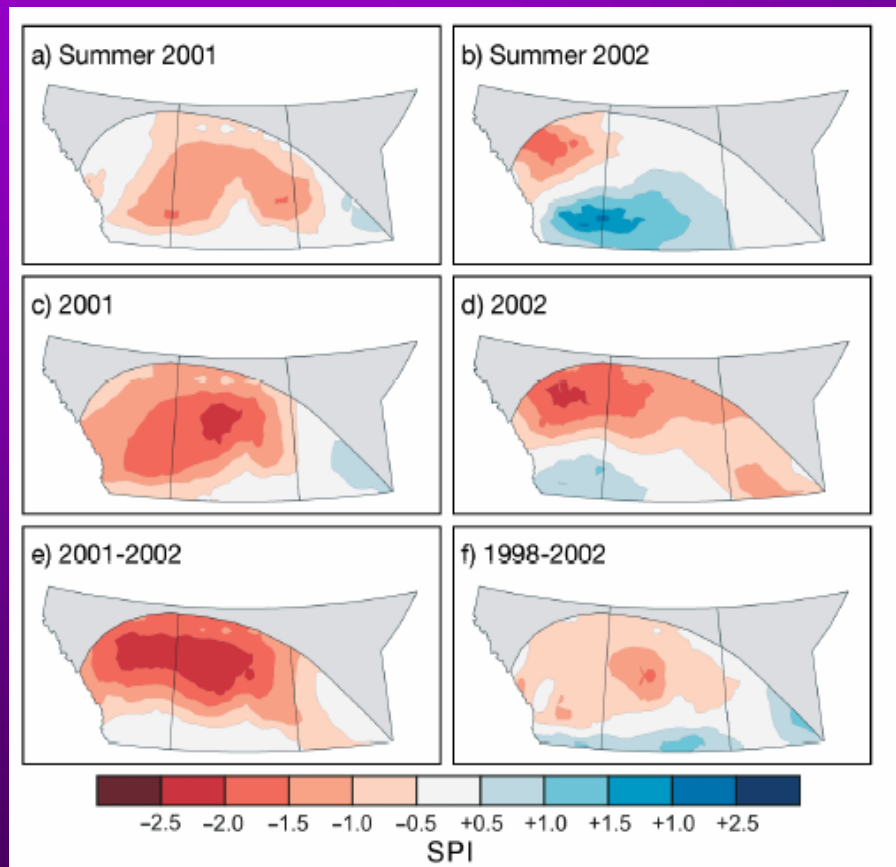
Fig. 1. Locations and names of climate stations used; shaded: Canadian Prairie study area. BC: British Columbia (Stations 1–3); ON: Ontario (Station 21)

Drought Occurrence: Southern Prairies (1915-2002)



severe drought based on values of the $SPI \leq 1.5$ $PDSI \leq -3$

2001-02 Drought Large Scale Variability



a) summer 2001, b) summer 2002, c) agricultural year 2001, d) agricultural year 2002, e) agricultural years 2001 to 2002, and f) agricultural years 1998 to 2002.

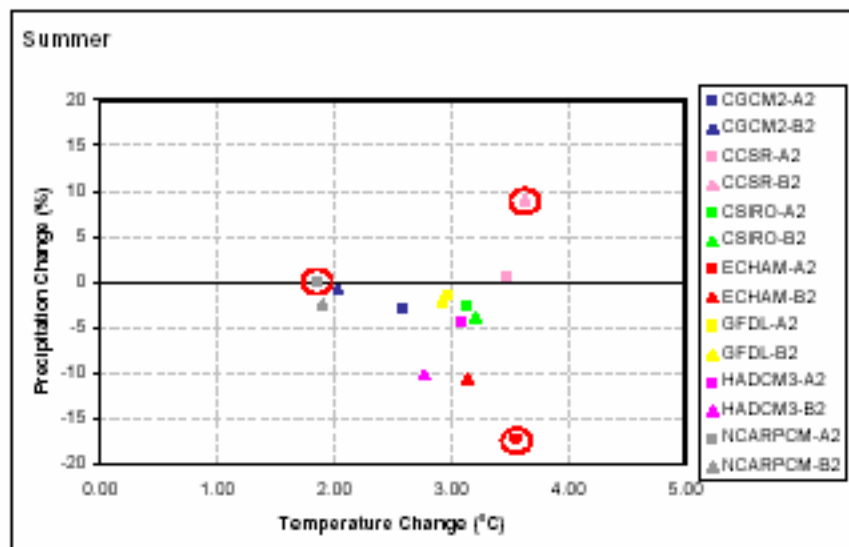
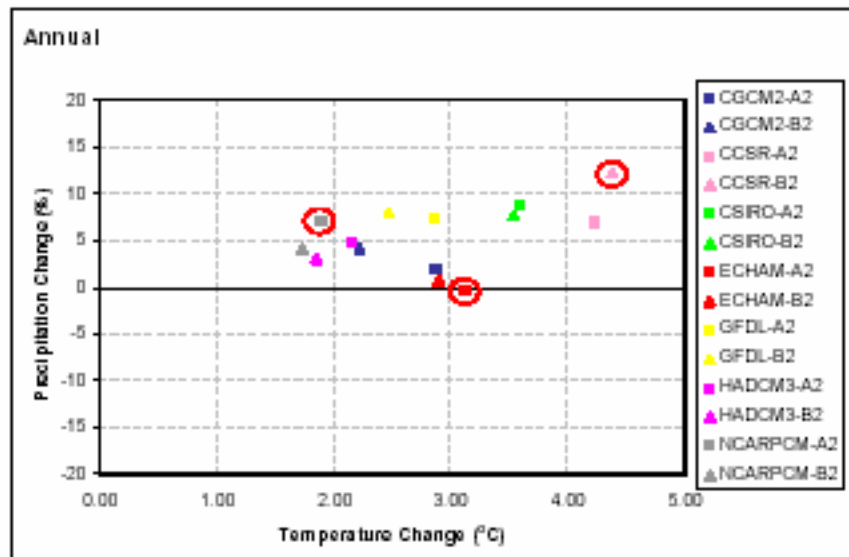
Climate Change Scenarios

Scatter plots showing average annual and summer projected temperature and precipitation changes for the 30-year period centred on the 2050s

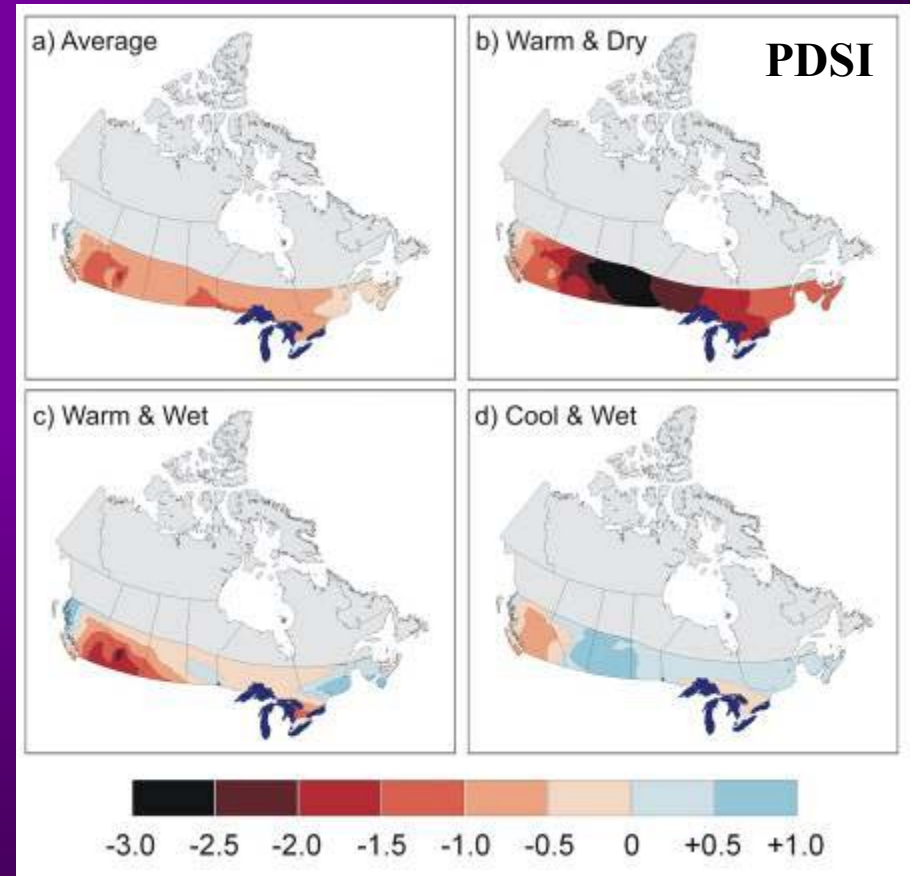
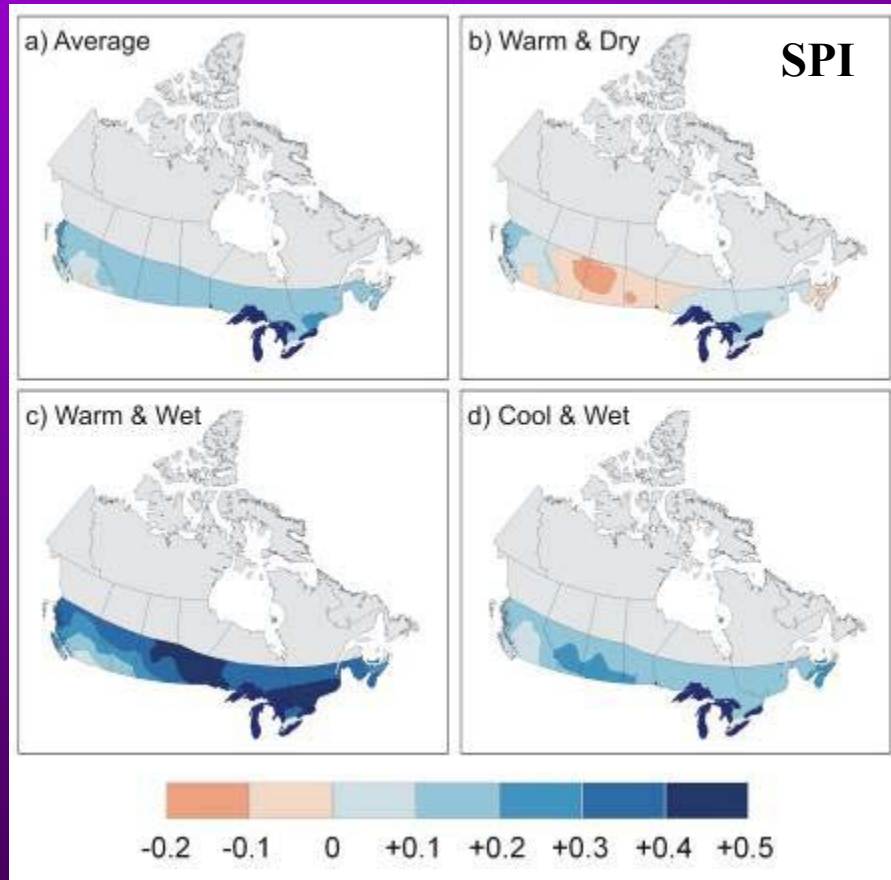
Warm-dry: CCSIRO B21

Warm-wet: ECHAM A2

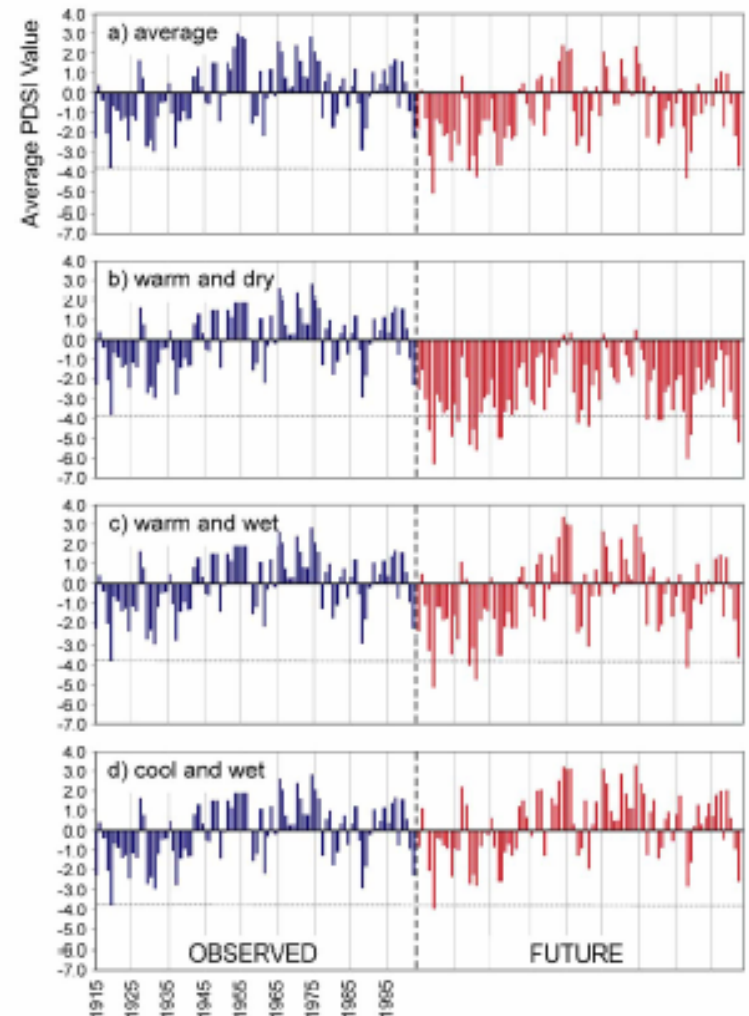
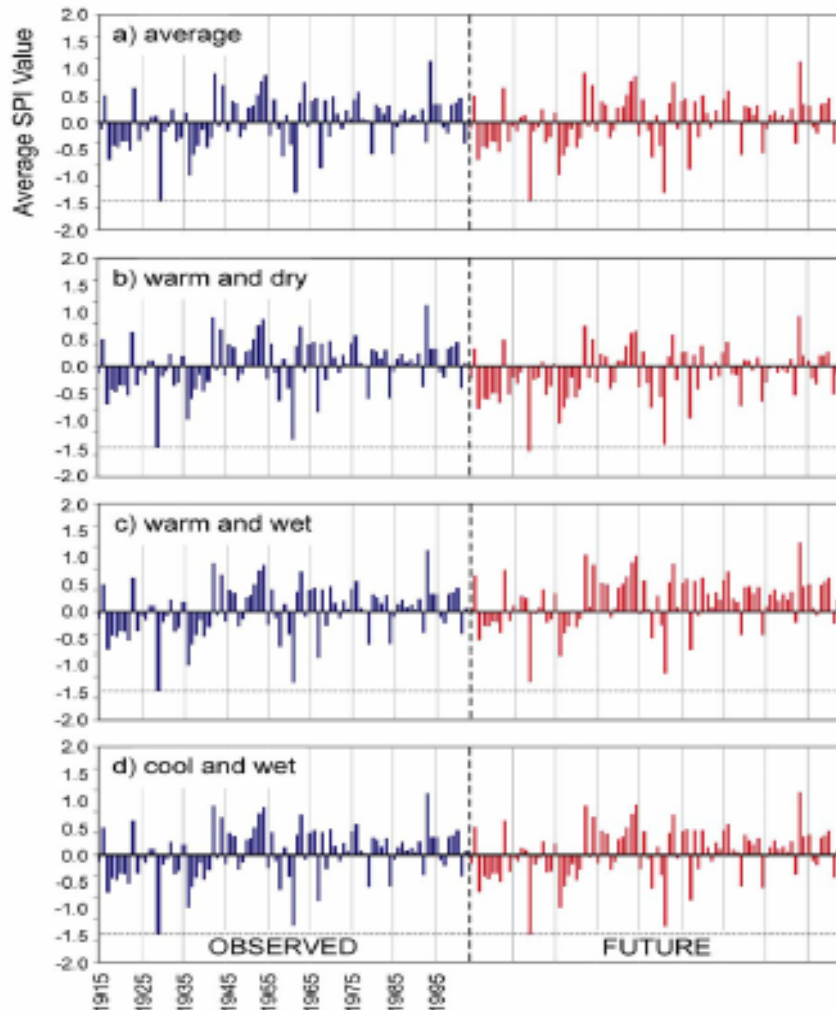
Cool-dry: NCARPCM A21



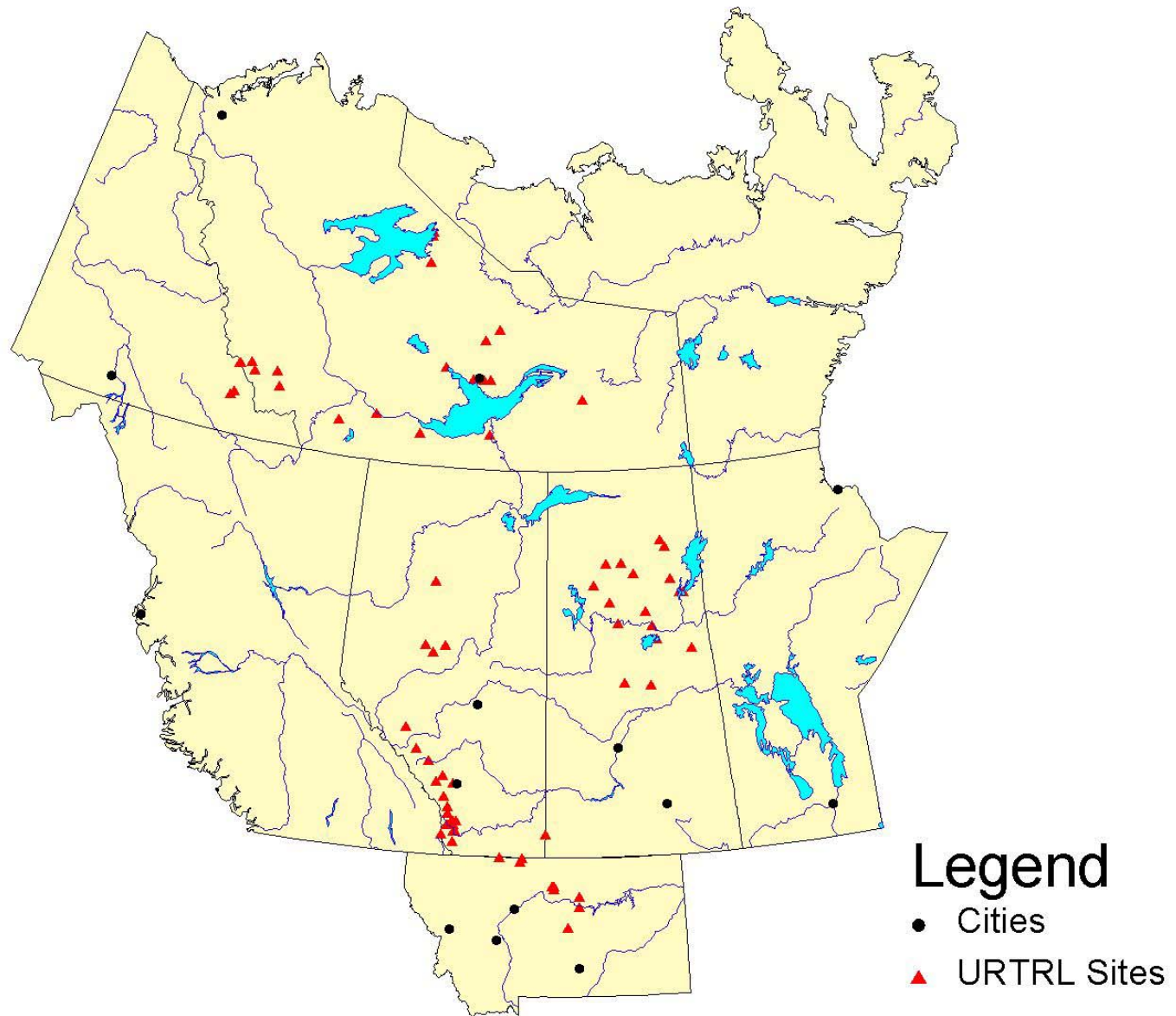
Future Drought: 2050s



Future Drought – Summer Prairies

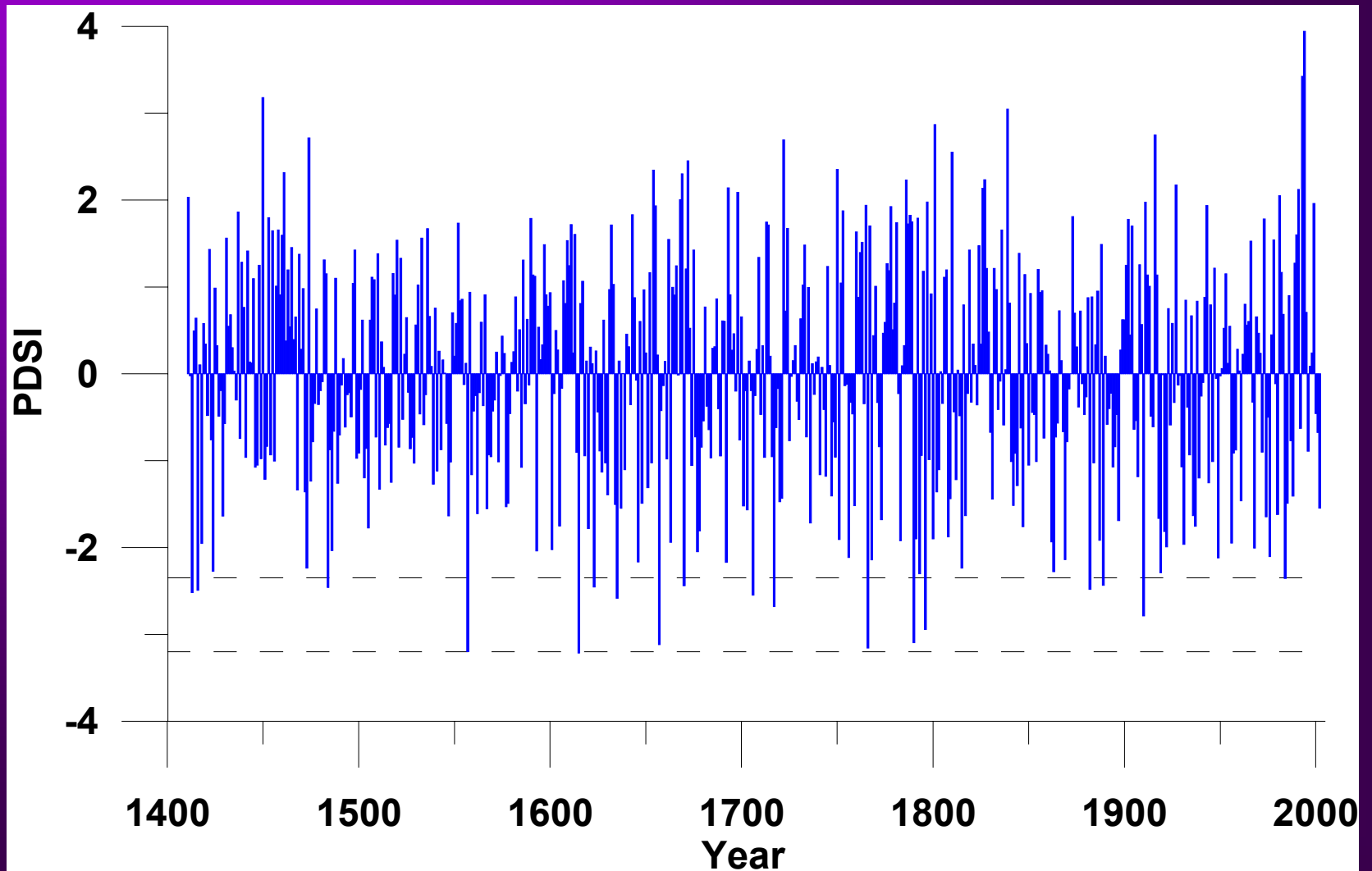


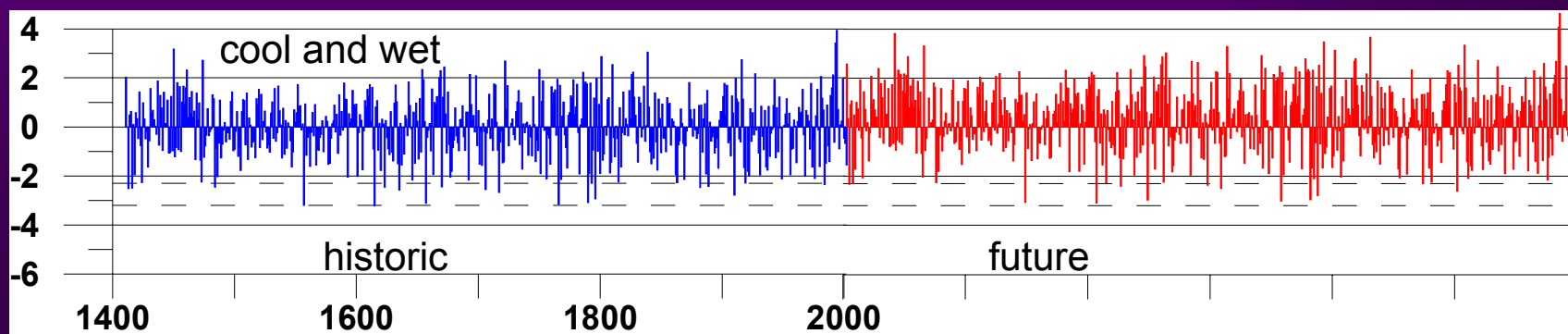
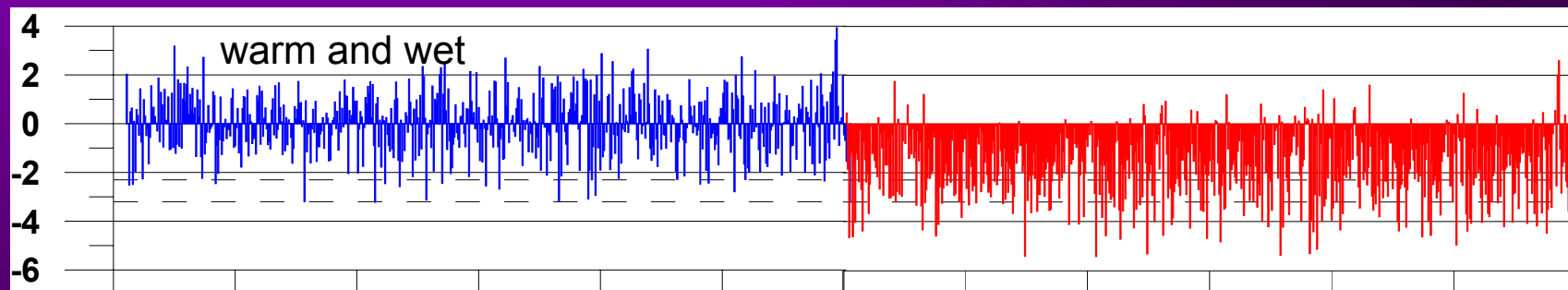
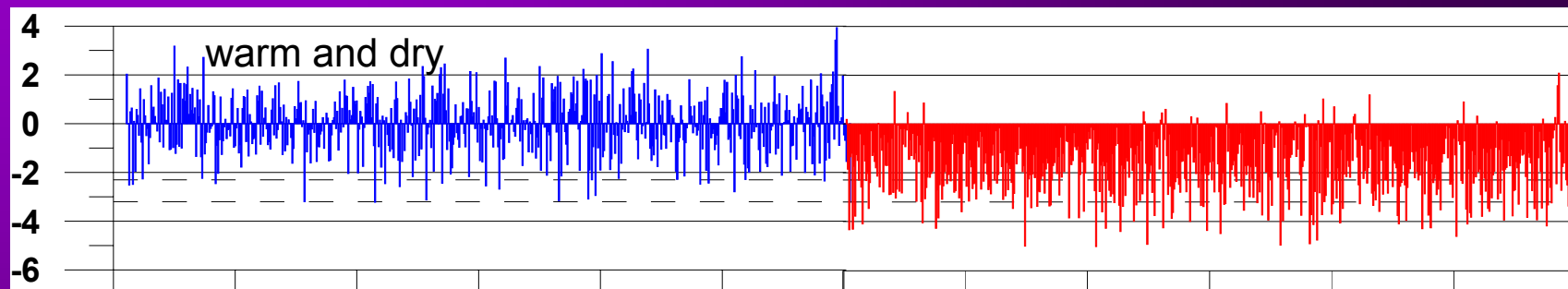
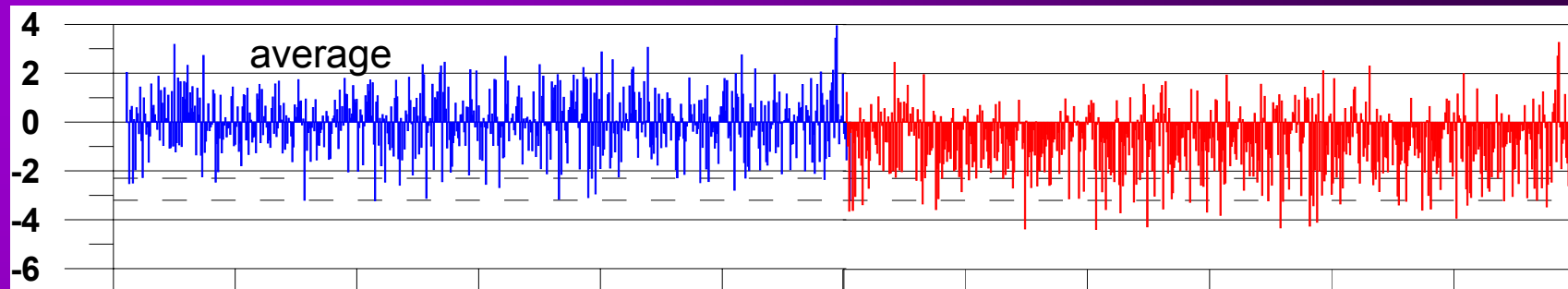
Tree-Ring Sites – www.parc.ca/urtreelab



Calgary 1411-2002

Wildcat Hills





Conclusions

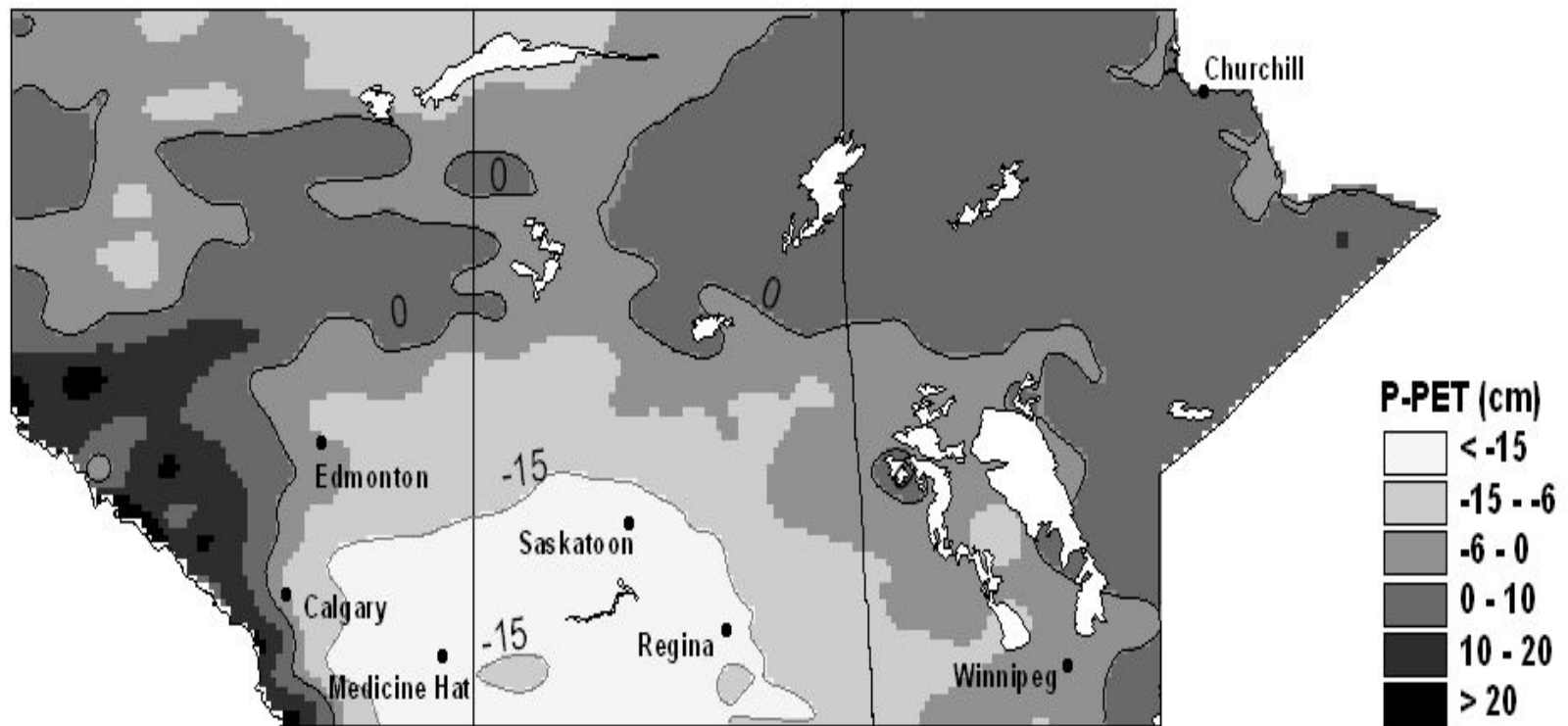
- Severe droughts occurred in the early part of the 20th century observed record
- Spatial extent and severity of the 2001 and 2002 drought generally ranked below these early century droughts (top 10)
- Worst drought for several decades making the impacts worse
- Reconstructed record show more severe droughts than observed
- First-order insight into future drought occurrence since it assumes the exact same temporal variability in the future as that observed from 1915 to 2002, adjusted based on GCM changes for the 2050s

Climate Moisture Index

Historical / Future

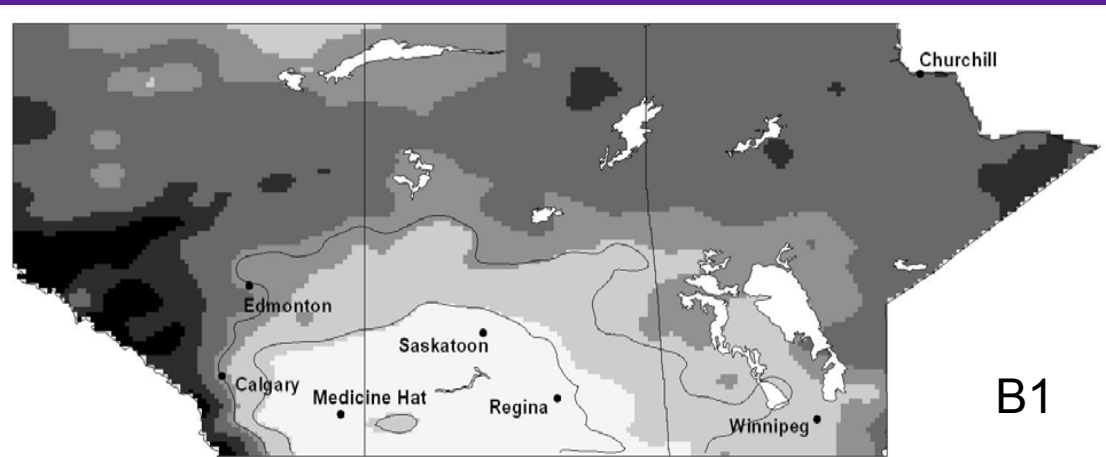
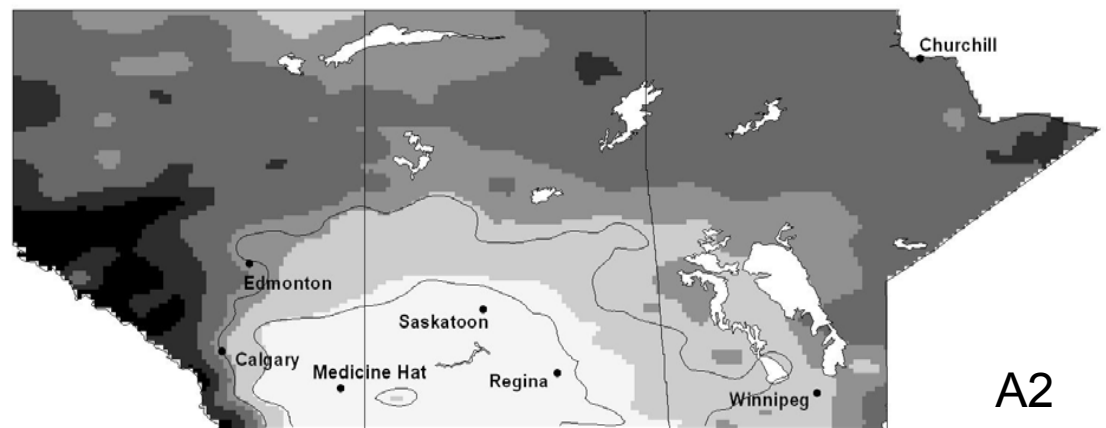
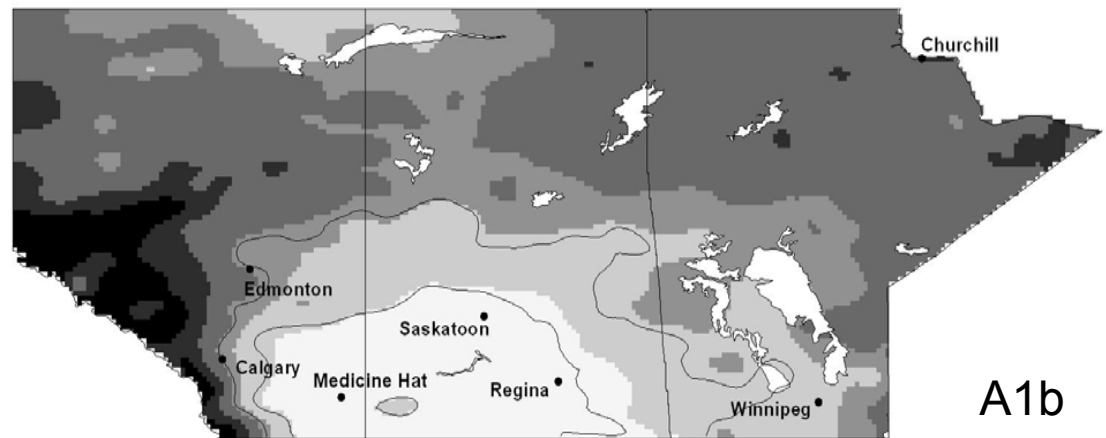
- **Monthly precipitation minus potential evapotranspiration as a deficit (P-PET)**
 - (Thornthwaite Method)
- **Identify ecozones in Canada (grassland, parkland)**
 - (Hogg 1997)
- **CGCM3 Future Scenarios**

Observed 1961-90 P-PET (cm) August - July

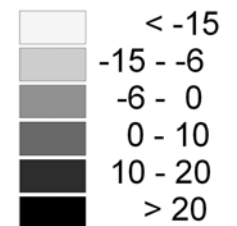


-15 cm: mixed grasslands & semi-arid zone

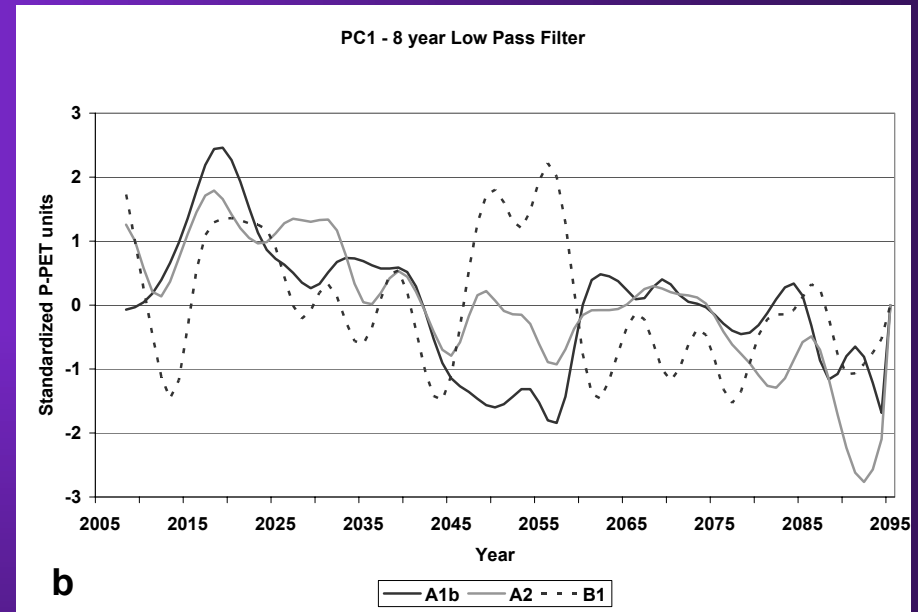
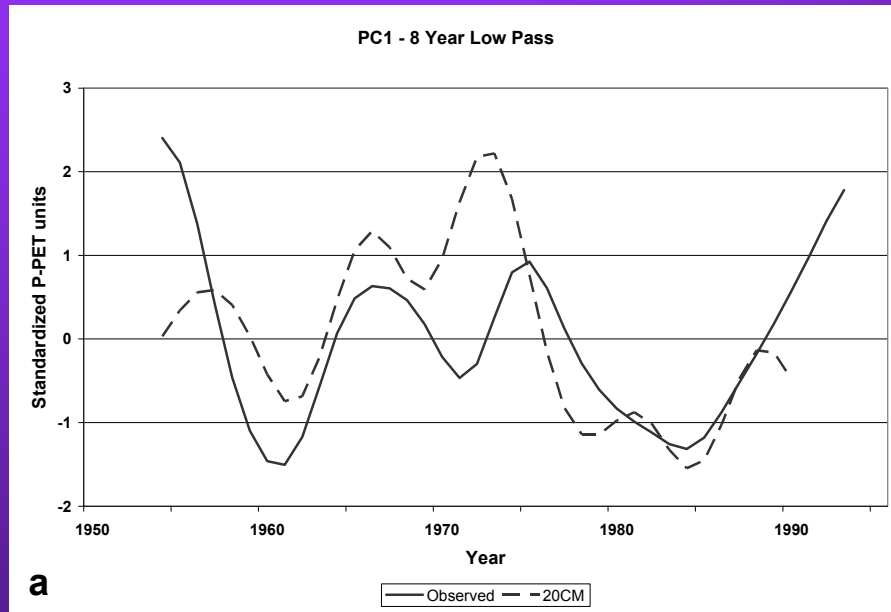
-6 cm: aspen parkland & dry sub-humid zone



2050s P-PET



Low-Frequency Variability



- a. Compares observed and CGCM3 20CM timescales trends.
- b. Compares future scenarios.

The first eigenvalue explains 86% of observed and over 95% of the GCM annual P-PET values.

Conclusions

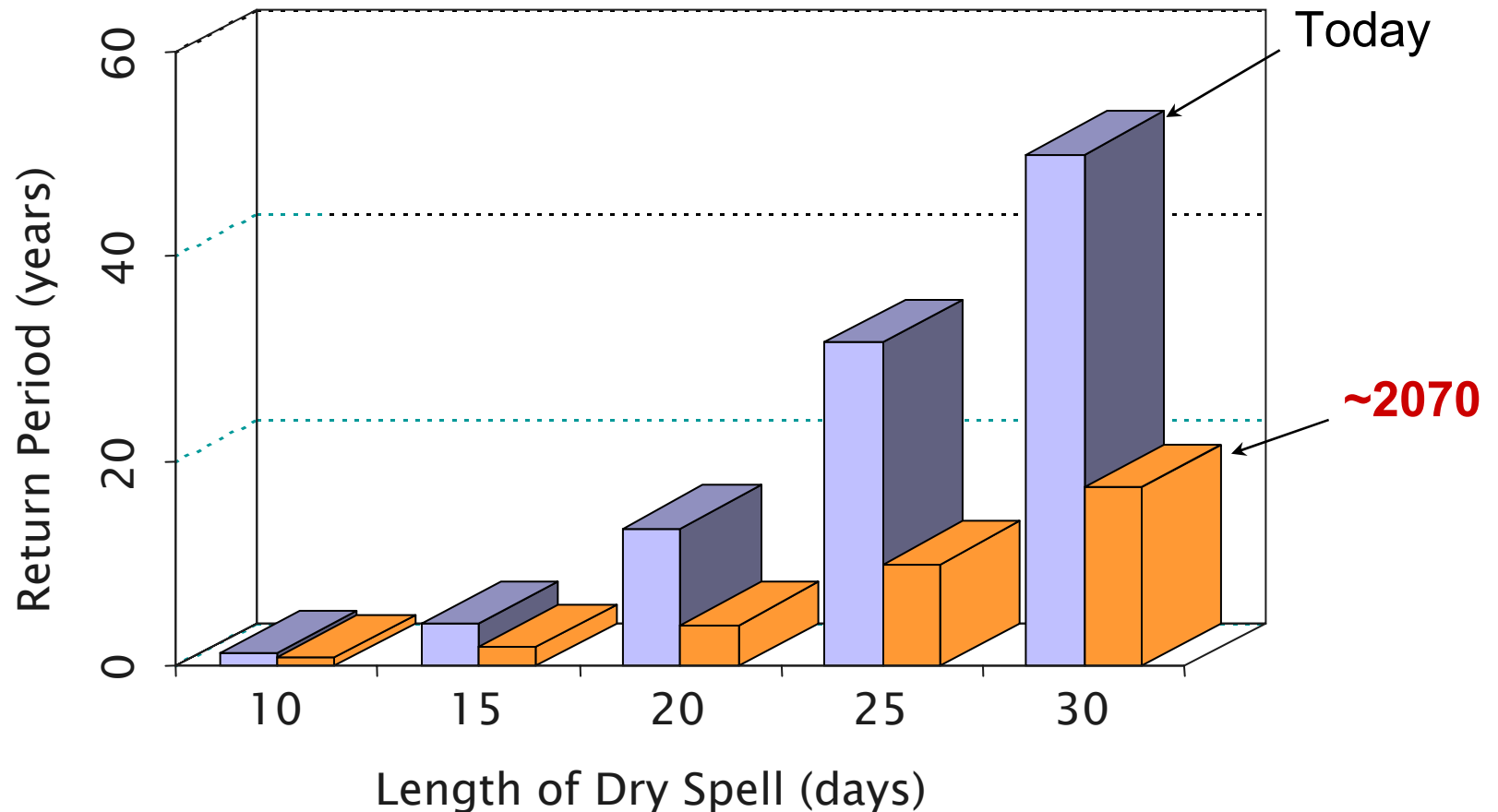
- **All three-future climate scenarios show an expanding aridity zone in the southern Prairies reaching further into Manitoba**
- **First step towards future drought indices that incorporates a variety of spatial and temporal scales that account for changes to climate variability**
- **Analyzes only the long-term trends and variability under future climate conditions, but it is also important to look at the inter-annual variability (ENSO)**
- **Observed record too short to identify low-frequency variability; use reconstructed indices for longer perspective and assess GCM control run simulations**
 - **Model verification, drift**

Future Drought Projections

- **PDSI differs from SPI drought projections: PDSI to increase in both spatial extent and severity**
- **All GCMs are projecting increased temperatures = greater evaporation and more severe droughts; likely the spatial extent and severity be frequently exceed 2001-02 drought**
- **Long memory of PDSI results in uncertainty with regard to future drought projections; future severe droughts tend to persist for long periods**
 - **probable that the PDSI results overestimate future drought occurrence in Canada; *qualitatively droughts will be worse when temperature incorporated. Not to deter from using this method***
- **Choose an index that incorporates temperature (PET) but is not greatly influenced by a substantial lag in previous moisture conditions**

Increasing Drought Frequency

Central North America



Future Research

- **To better quantify future drought occurrence over a variety of spatial and temporal scales by incorporating several drought indices over Canada**
- **More in-depth analyses of both past and potential future drought occurrences**
- **Incorporate new approaches to applying GCM temperature and precipitation changes in the calculation of future drought indices and to account for changes in climate variability and trends**
 - (e.g. tree-ring, large scale circulation patterns, downscaling techniques)
- **To involve multiple GCMs and other PET methods**

Palmer Drought Index (Drought Model)

May 2007



PDI

- < -5.00
- -4.99 - -4.00
- -3.99 - -3.00
- -2.99 - -2.00
- -1.99 - -1.00
- -0.99 - 0.99
- 1.00 - 1.99
- 2.00 - 2.99
- 3.00 - 3.99
- 4.00 - 4.99
- > 5.00

Extent of Agricultural Land

Produced using near real-time data that has undergone initial quality control. The map may not be accurate for all regions due to data availability and data errors.

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Prepared by Agriculture and Agri-Food Canada's National Agroclimatic Information Service (NAIS). Data provided through partnership with Environment Canada, Natural Resources Canada, and many Provincial agencies.

Created: 6/11/07
www.agric.gc.ca/pfra/drought

Current Drought Conditions

ion Index (SPI)



SPI

- < -2.00
- -1.99 - -1.80
- -1.59 - -1.30
- -1.29 - -0.80
- -0.79 - -0.51
- -0.50 - 0.50
- 0.51 - 0.79
- 0.80 - 1.29
- 1.30 - 1.59
- 1.60 - 1.99
- > 2.00

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Prepared by Agriculture and Agri-Food Canada's National Agroclimatic Information Service (NAIS). Data provided through partnership with Environment Canada, Natural Resources Canada, and many Provincial agencies.

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The End

