

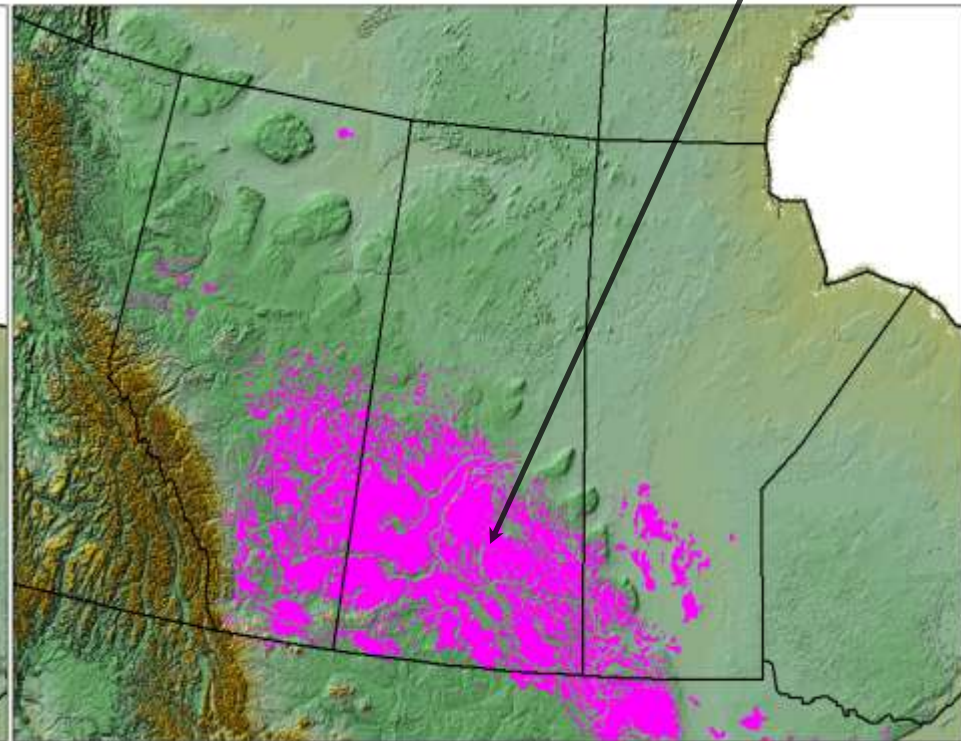
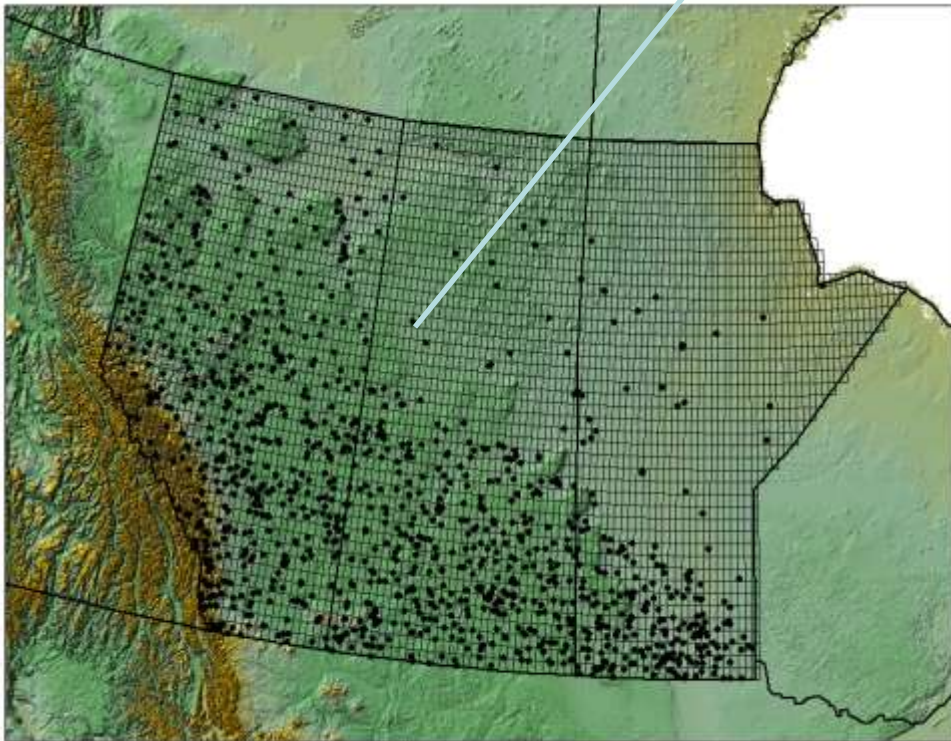
# Modeling Soil Moisture with the VIC Model During Drought

Lei Wen<sup>1</sup>, Charles A. Lin<sup>1,2</sup>, John Pomeroy<sup>3</sup>

# 1. VIC prairie soil moisture modeling

- **three soil layers** (0-20 cm, 20-100 cm, 0-100 cm), **0.25 °** x **0.25 °** , daily time step
- starting on 1 January, **1950**, real-time forecasting with a lead time up to 35-day
- meteorological forcing: **1,167** stations + operational Canadian GEM forecast + operational 40-number super ensemble forecast + operational CMC ensemble seasonal forecast
- VIC soil moisture + its **60-yr climatology** (1950-2009) → calculating a soil moisture index **SMAPI** (Soil Moisture Anomaly Percentage Index)
- VIC SMAPI compares favorably with **three** independent drought datasets, can explain historical drought events in the Prairies
- VIC soil moisture is **updated daily** at present; SMAPI results are publicly accessible online (<http://www.meteo.mcgill.ca/~leiw/vic/prairies/>)

1,167 met stations (black dot) on the Prairies



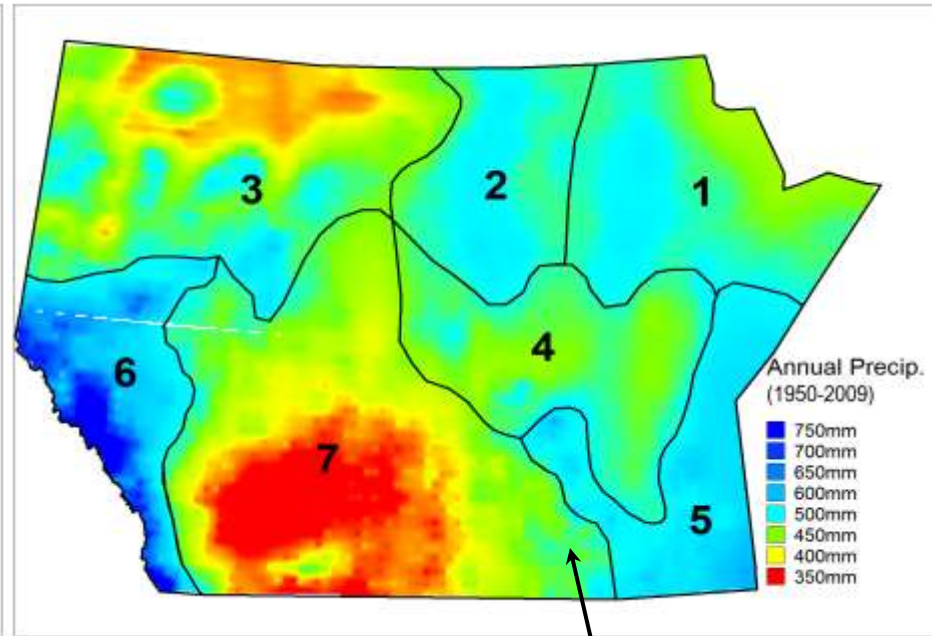
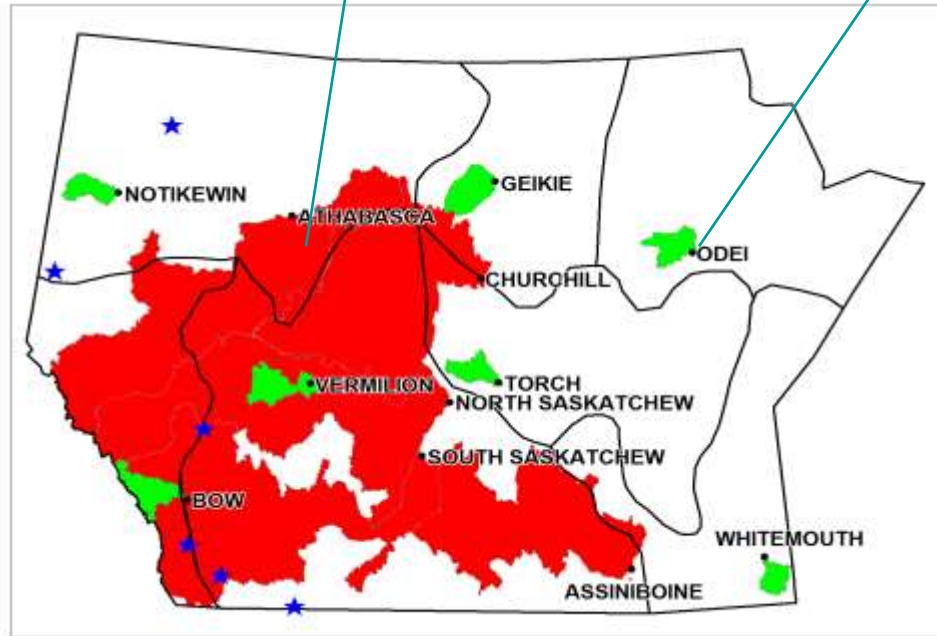
4393 grid points,  $0.25^\circ \times 0.25^\circ$

Flat terrain and **non-contributing** drainage areas, which brings challenges to hydrological modeling

# VIC calibration and validation

5 additional validation catchments in **red**

7 calibration catchments in **green**;



➤ We calibrate the six VIC user-calibrated hydrological parameters using observed daily hydrographs at the outlets of each of the 7 calibration catchments.

➤ The validation of the calibrated VIC over the Prairies involves the following three parts.

1. First, we validate VIC using observed daily hydrographs from the same 7 calibration catchments taken over different periods than for calibration.

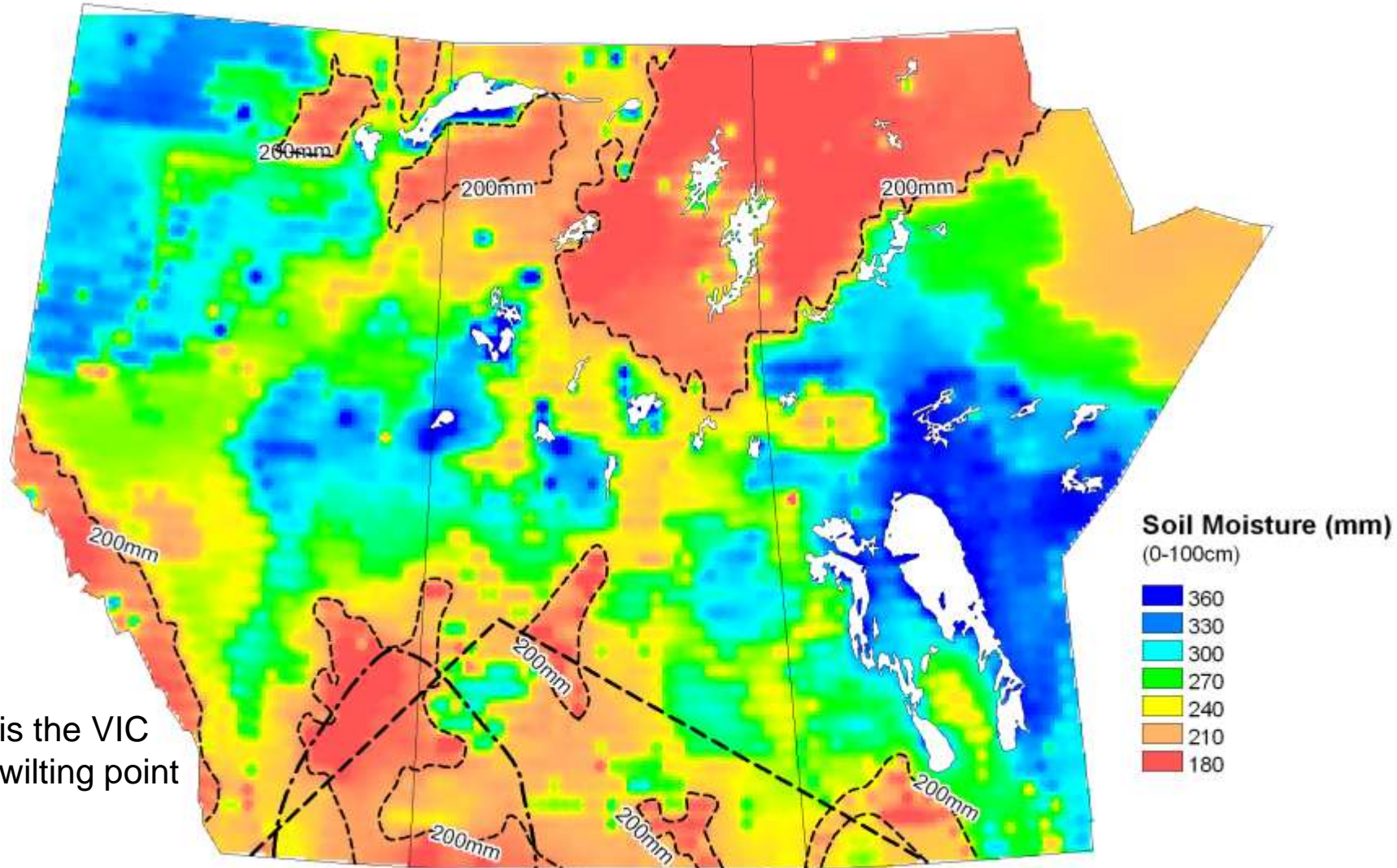
2. Second, we further validate VIC using observed daily hydrographs from 5 additional catchments.

3. Third, we compare simulated soil moisture anomalies with *in situ* observations from 6 Alberta sites.

We define 7 VIC simulation regions over the Prairies, which is based on the annual precipitation of 1950-2009

## 2. VIC soil moisture

**60-yr (1950-2009) average of soil moisture (top 1-m) over the Prairies**  
with the 200 mm soil moisture contour, showing modeled very dry areas



200 mm is the VIC  
average wilting point

----- Palliser Triangular, Geological Survey of Canada Definition

----- The Prairies Dry Belt, Jones, 1987

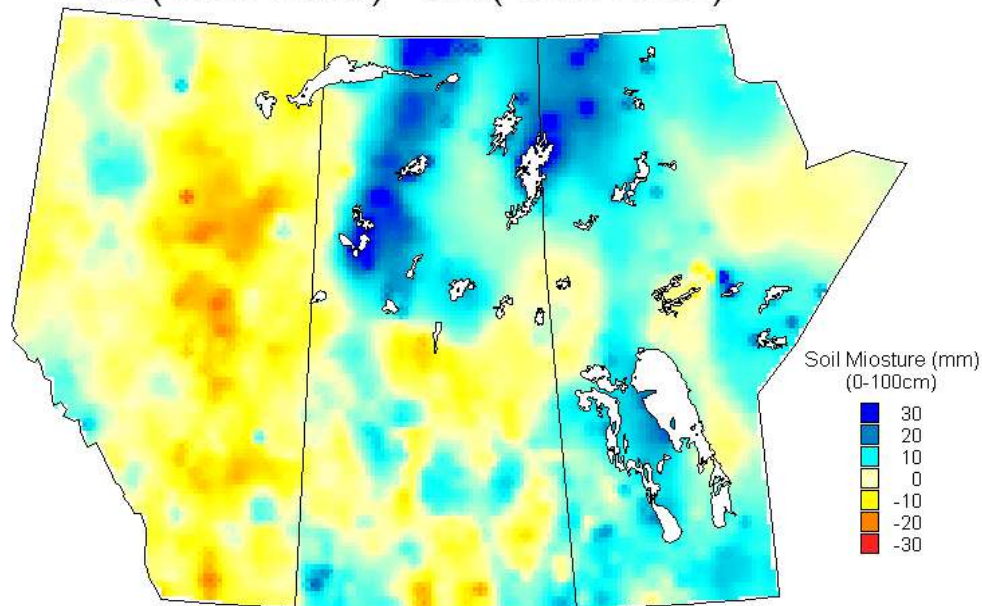
Identifications of the Palliser Triangle region and the Prairie Dry Belt (Jones, 1978) in South Prairies.

# DRI period

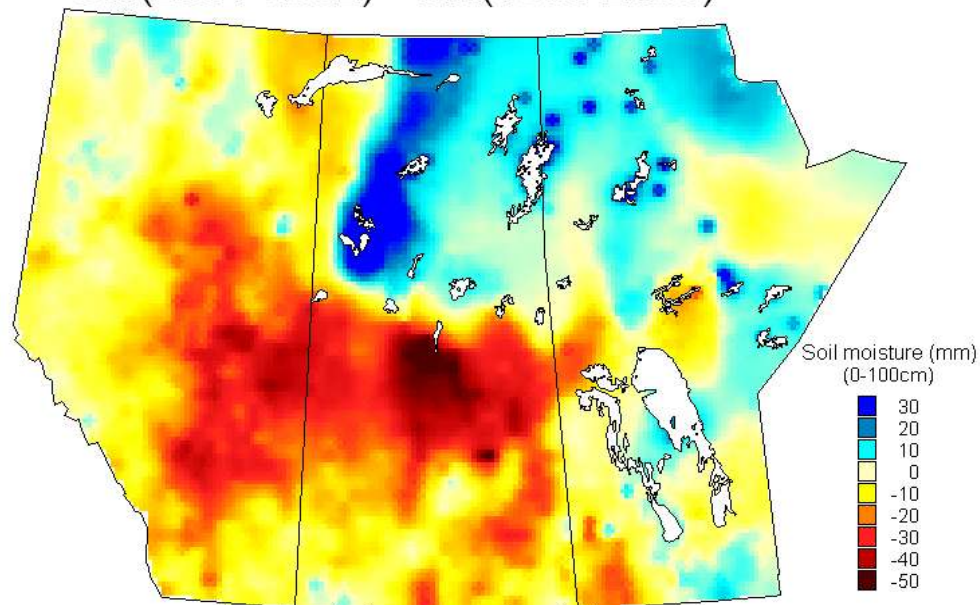
Soil moisture deficit of two periods with respect to the 60-year climatology:

- 1999-2005 (top)
- 2001-2002 (bottom)

SM(1999-2005) - SM(1950-2005)



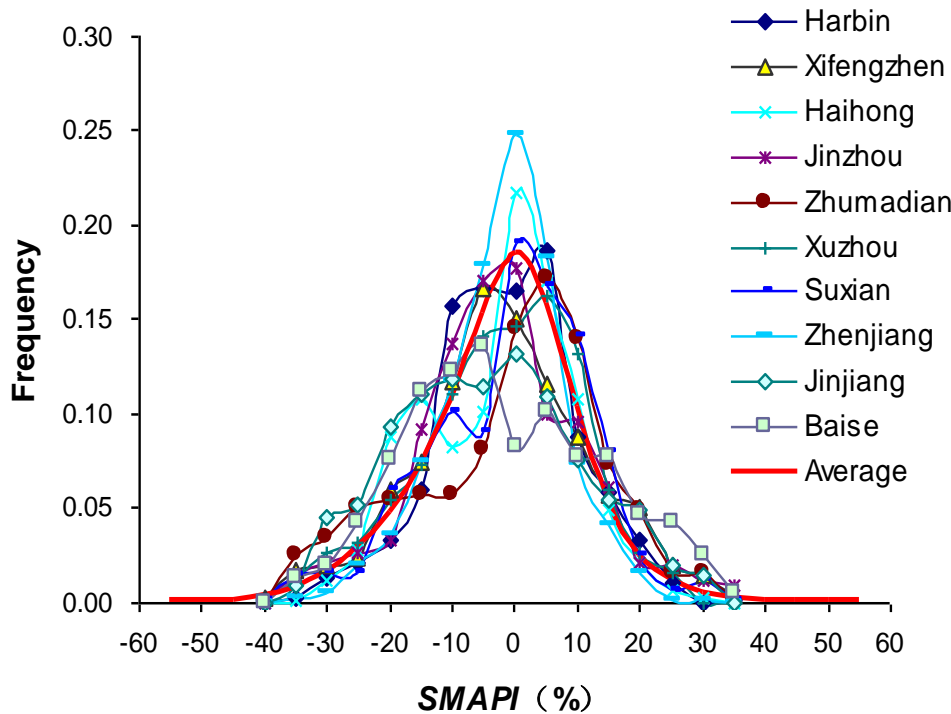
SM(2001-2002) - SM(1950-2005)



# 3. Soil Moisture Anomaly Percentage Index (SMAPI)

$$SMAPI = \frac{\theta - \bar{\theta}}{\bar{\theta}} \times 100\%$$

- The soil moisture climatology reflects local characteristics and mirrors the hydro-meteorological phenomena of a region
- Applying the concept of relative soil wetness for measuring drought severity
- Keyantash and Dracup, BAMS, 2002 (second highest ranking among the five evaluated indices for agricultural drought)



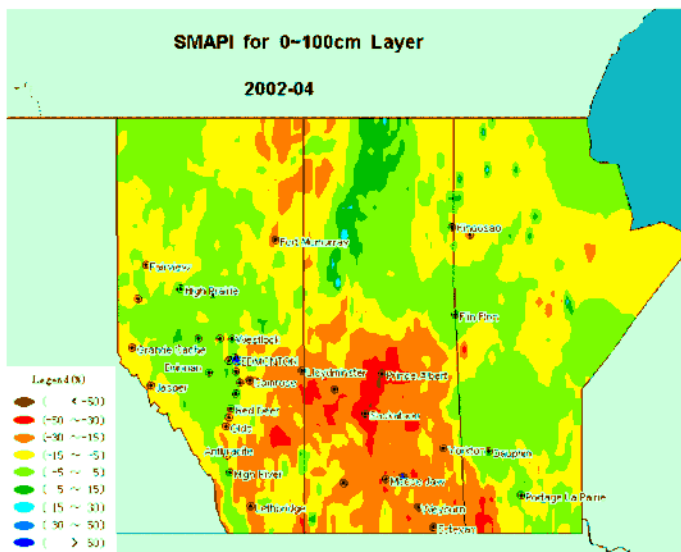
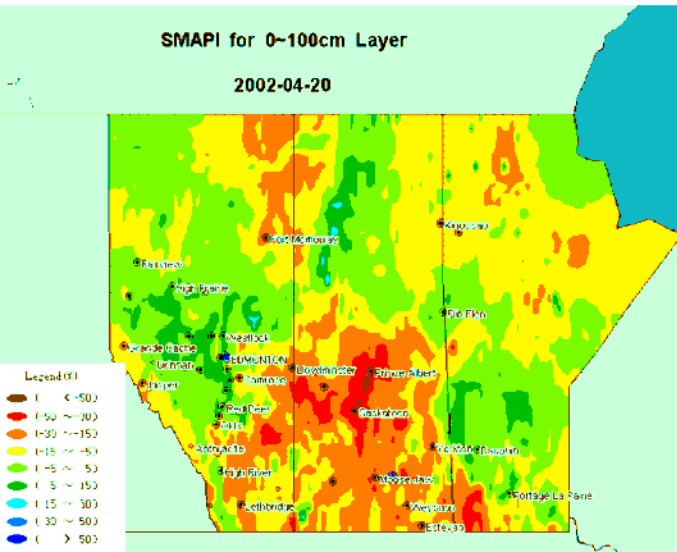
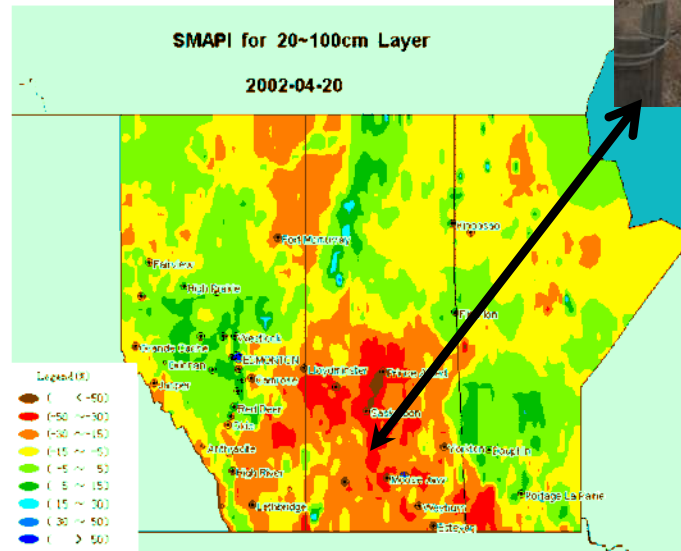
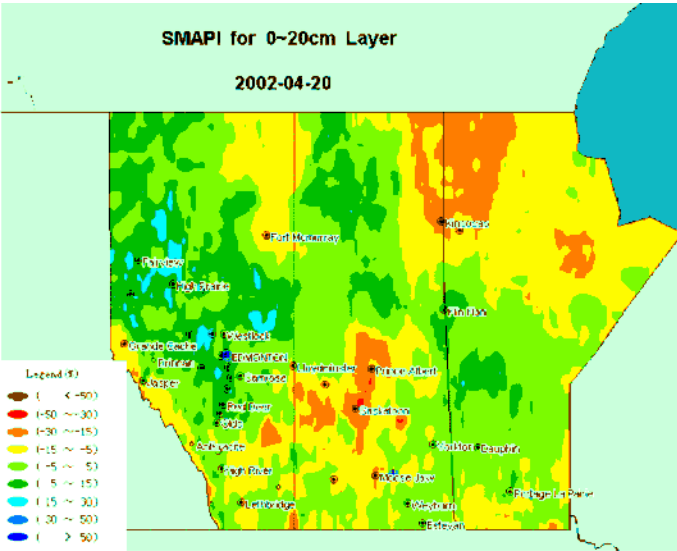
Drought classifications based on SMAPI

Category	SMAPI	Average Frequency
extreme drought	$\leq -50\%$	0.005
severe drought	-50% to -30%	0.020
moderate drought	-30% to -15%	0.100
mild drought	-15% to -5%	0.200
near normal	-5% to 5%	0.350
slightly wet	5% to 15%	0.200
moderately wet	15% to 30%	0.100
very wet	30% to 50%	0.020
extremely wet	$> 50\%$	0.005

# Reconstructing prairie drought history



Southern Saskatchewan, April 2002;  
Taken from Stewart

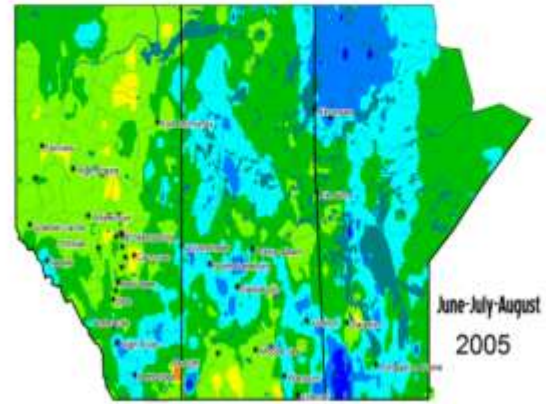
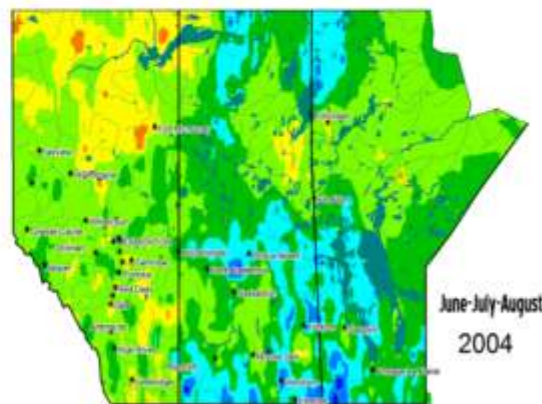
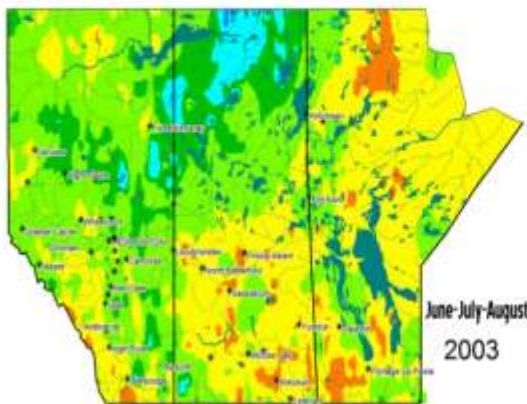
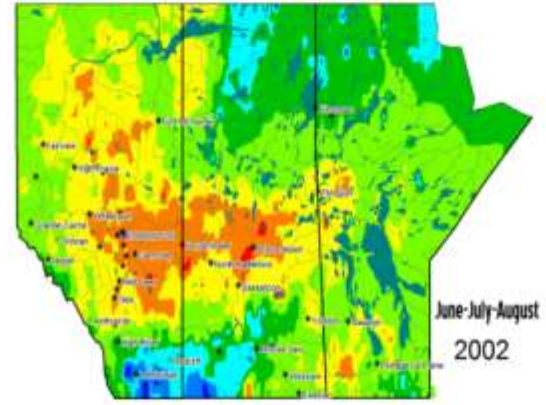
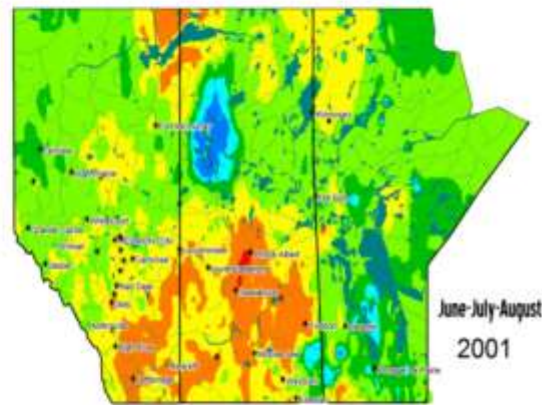
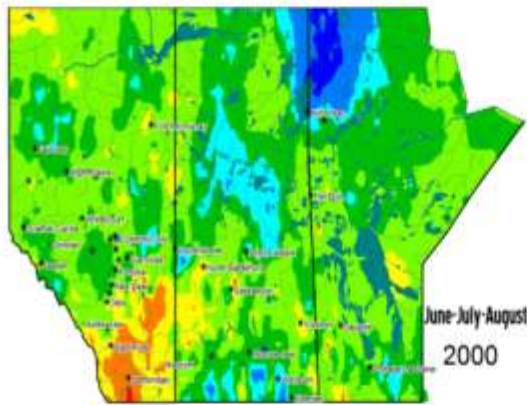
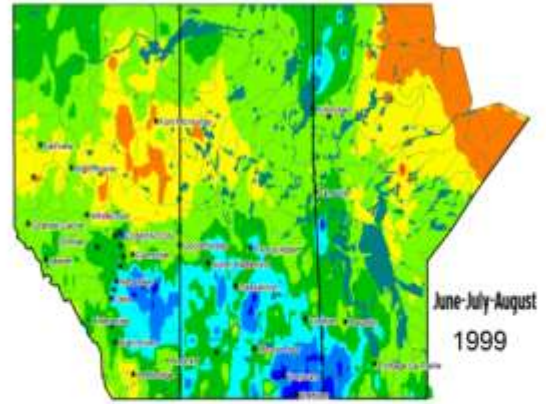
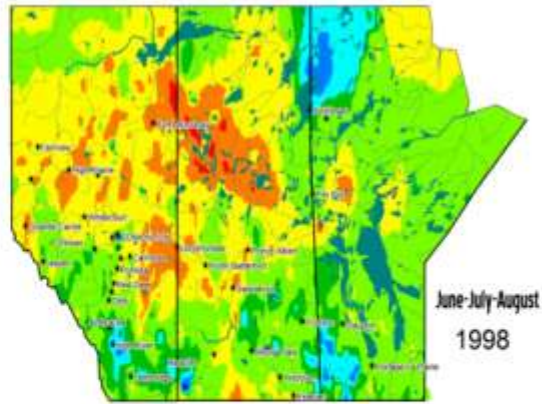
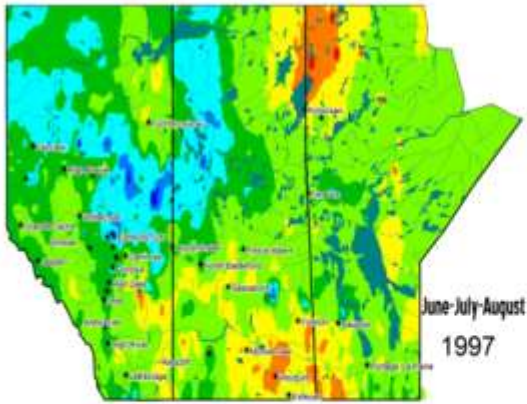


## Example

**Daily SMAPI distributions of the three soil layers for April 20, 2002, together with the April-2002 average**



# Annual SMAPI for the period of 1997-2005








# 4. Comparing SMAPI with three datasets


## a. North American Drought Monitor (NADM)

### NADM

#### Intensity:

	D0 Abnormally Dry
	D1 Drought - Moderate
	D2 Drought - Severe
	D3 Drought - Extreme
	D4 Drought - Exceptional

#### Drought Impact Types:

 Delineates dominant impacts  
 A = Agriculture  
 H = Hydrological (Water)  
 (No type = Both impacts)

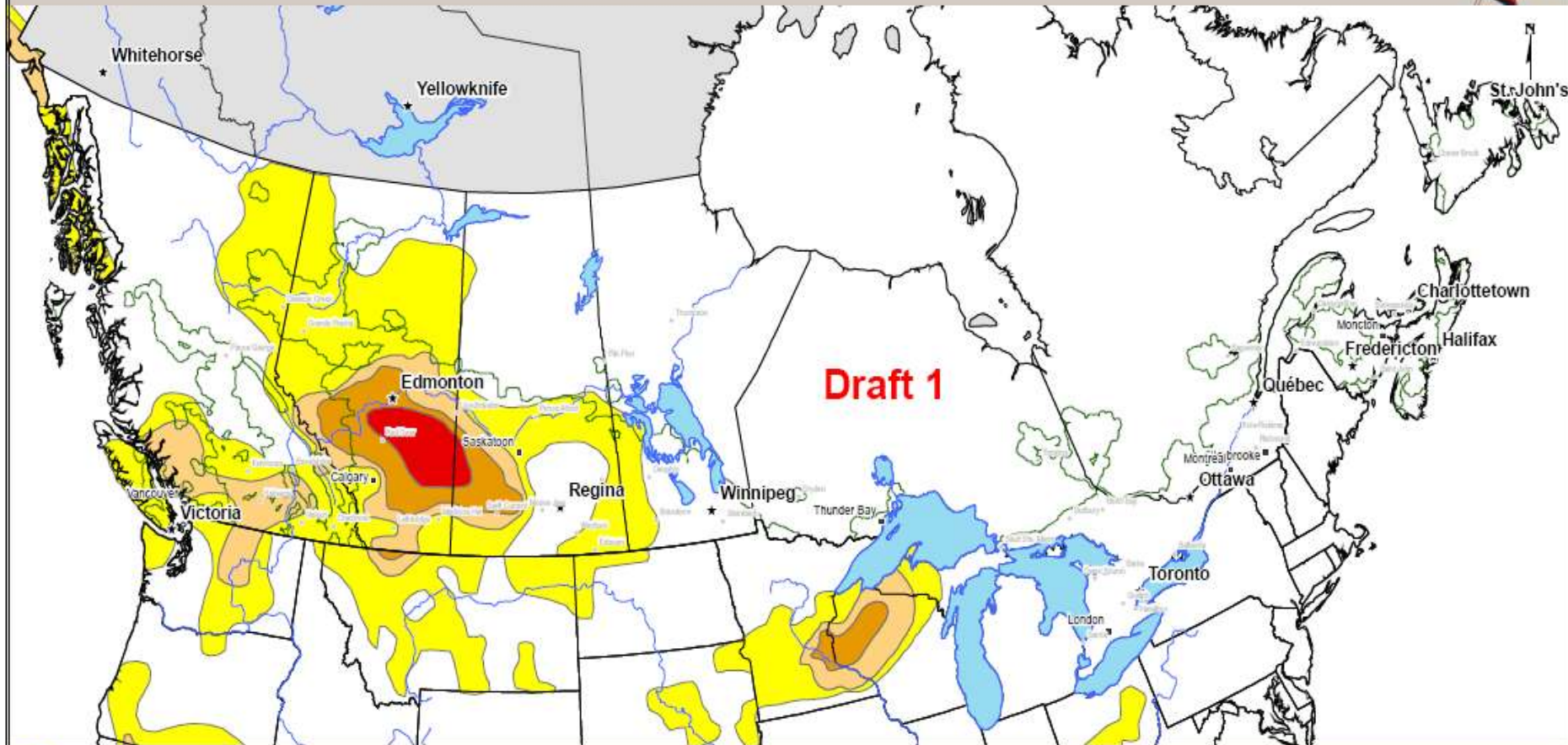
### SMAPI

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extreme drought	$\leq -50\%$	0.005
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near normal	-5% to 5%	0.350
slightly wet	5% to 15%	0.200
moderately wet	15% to 30%	0.100
very wet	30% to 50%	0.020
extremely wet	$> 50\%$	0.005



# NA-DM Worksheet for June 30, 2009

(Used for Canadian Interpretation)



Canadian draft drought assessment for March NA-DM with U.S. Shapefiles for June 23, 2009.

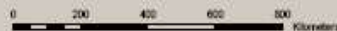
- D0 - Abnormally Dry
- D1 - Moderate Drought
- D2 - Severe Drought
- D3 - Extreme Drought
- D4 - Exceptional Drought
- Drought Impacts
- Area Not Analyzed
- Extent of Ag Land
- Lakes
- Rivers

Projection:  
North American Lambert Conformal Conic  
Central Meridian: -107.00  
Standard Parallel 1: 49.00  
Standard Parallel 2: 77.00

Datum:  
GCS - North American 1983

1:14,000,000

(when printed on 11" x 17" paper)



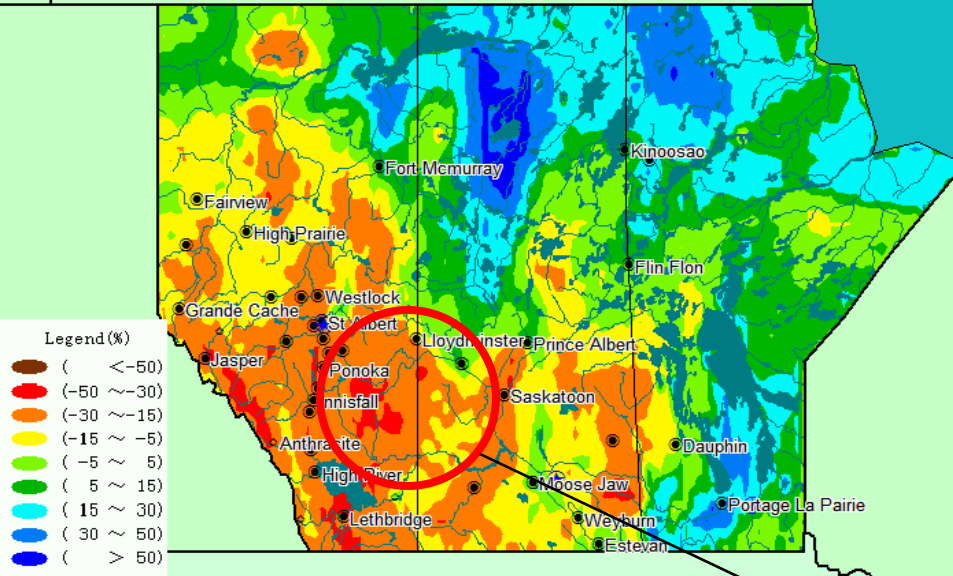
Source:  
<http://drought.unl.edu/dm/shapefiles/2009/>

Disclaimer:  
User assumes all responsibility for use, interpretation, and application of information contained on this map.

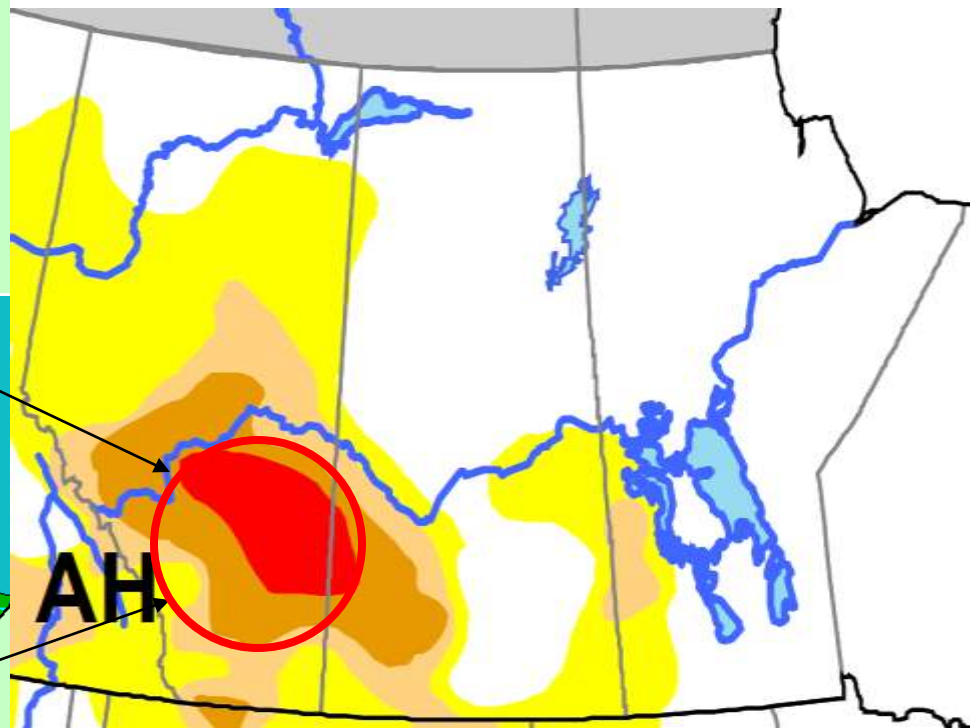


# SMAPI for 0~100cm Layer

2009-06-30

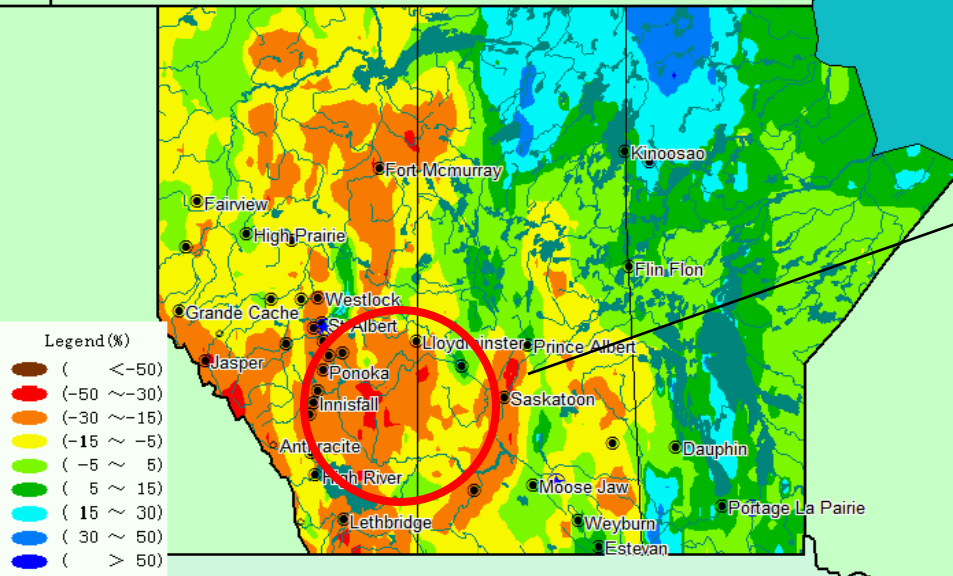


VIC SMAPI, June 30, 2009



# SMAPI for 0~100cm Layer

June, 2009



VIC SMAPI, June-2009 average



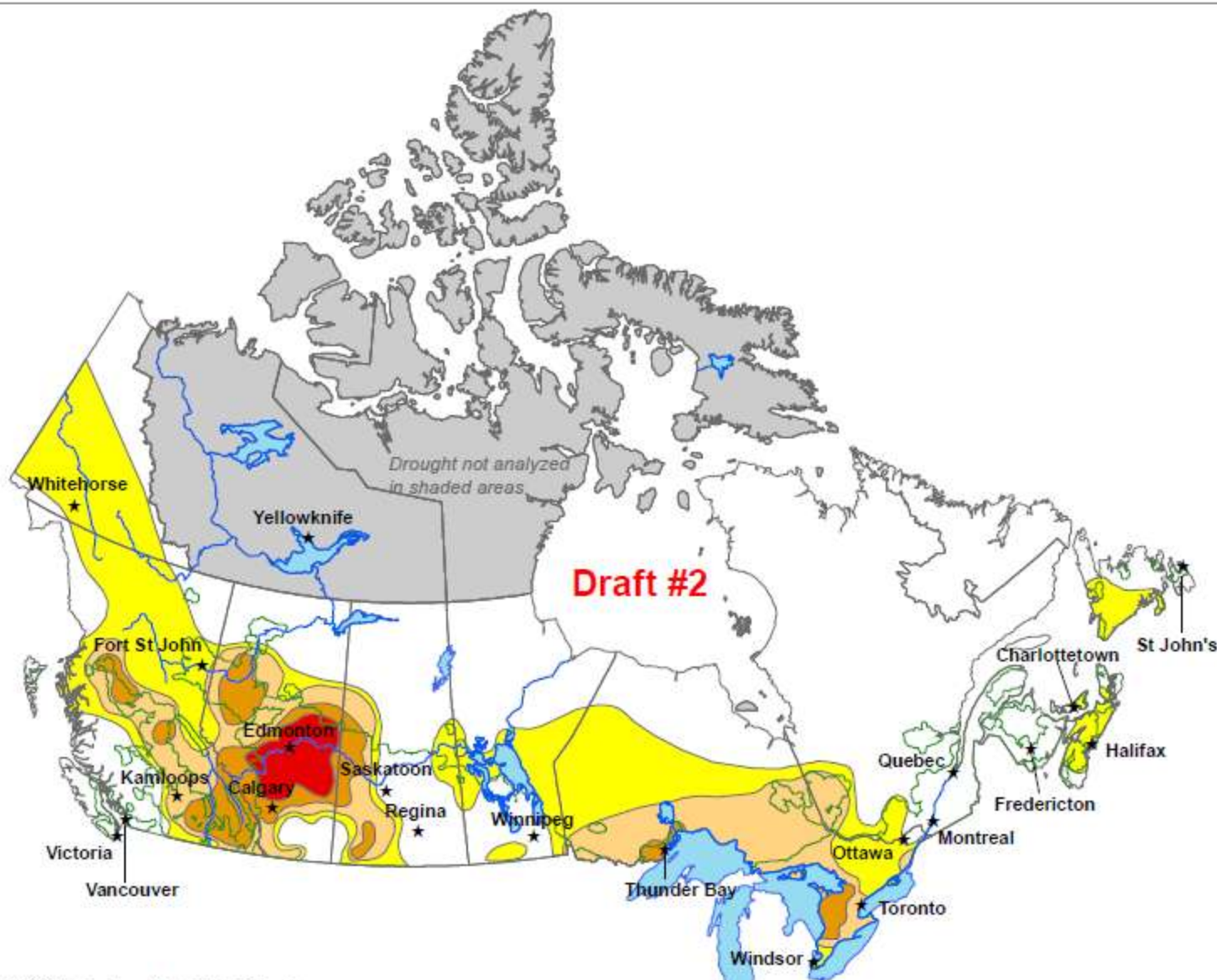
# Canadian Drought Monitor

Conditions as of April 30, 2010



## Drought Intensity

- D0 - Abnormally Dry
- D1 - Moderate Drought
- D2 - Severe Drought
- D3 - Extreme Drought
- D4 - Exceptional Drought
- Extent of Agriculture

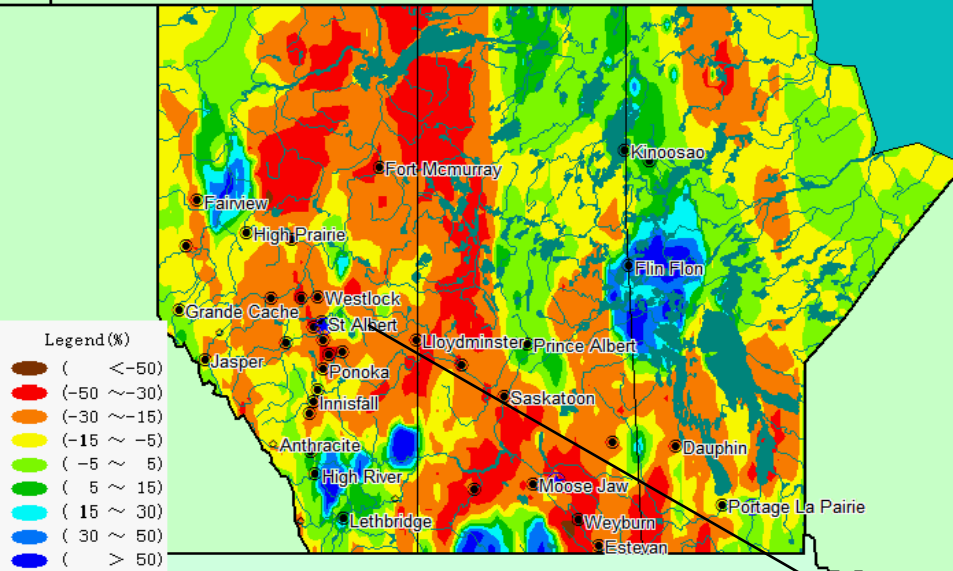


Regions in northern Canada may not be as accurate as other regions due to limited information.

The Drought Monitor focuses on regional scale conditions.

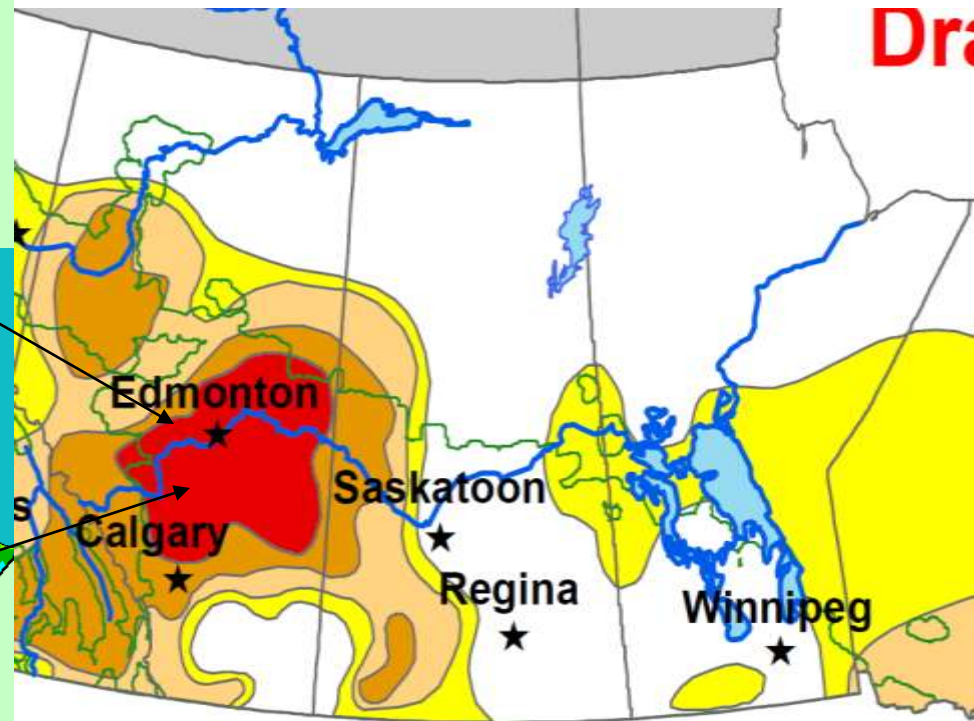
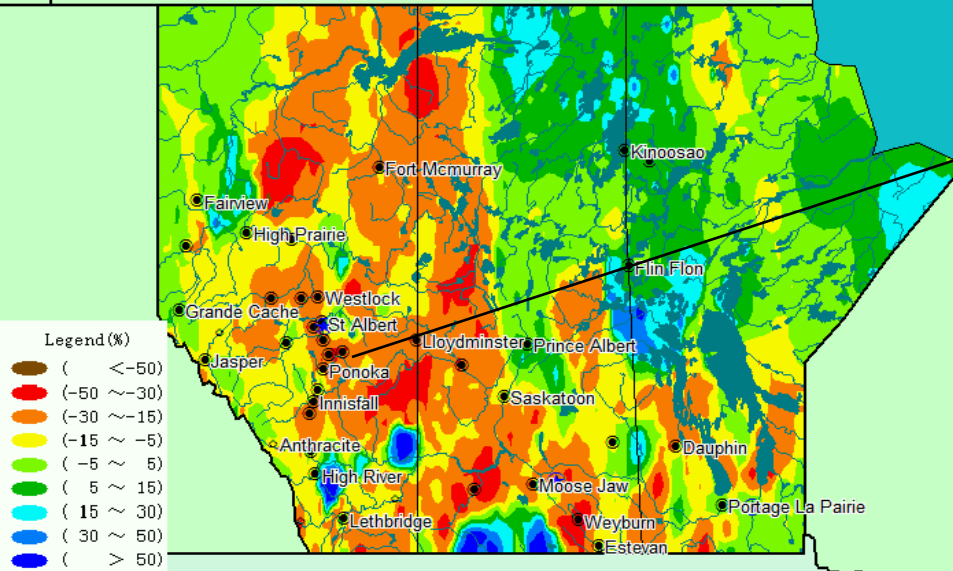
# SMAPI for 20~100cm Layer

2010-04-30

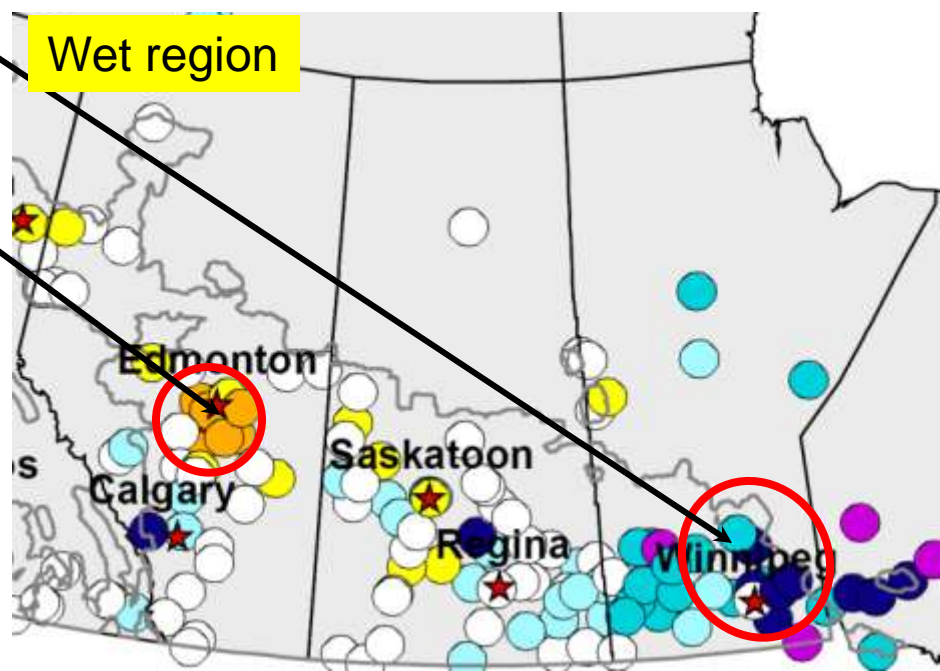
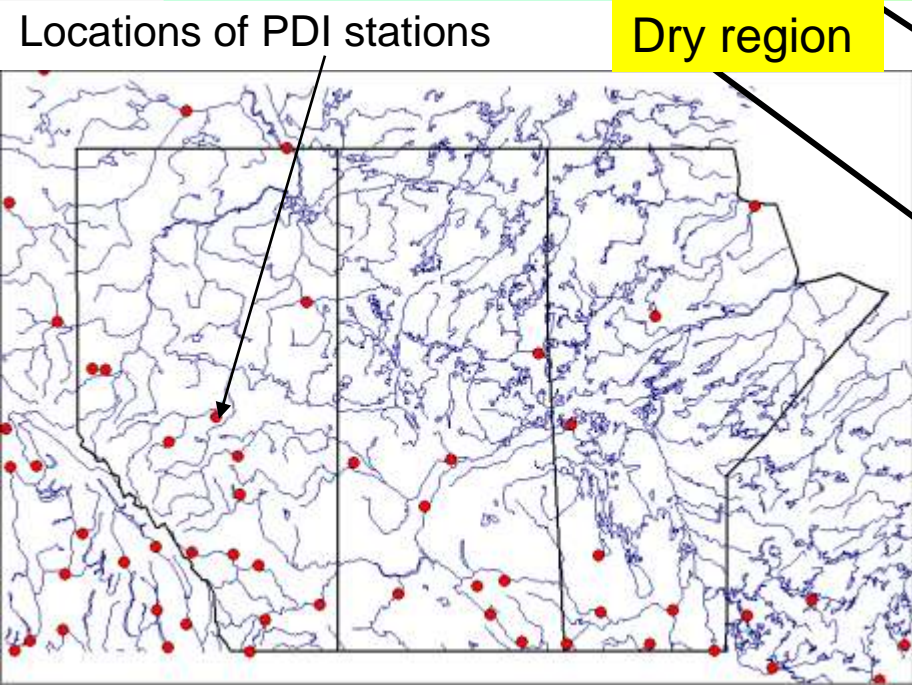
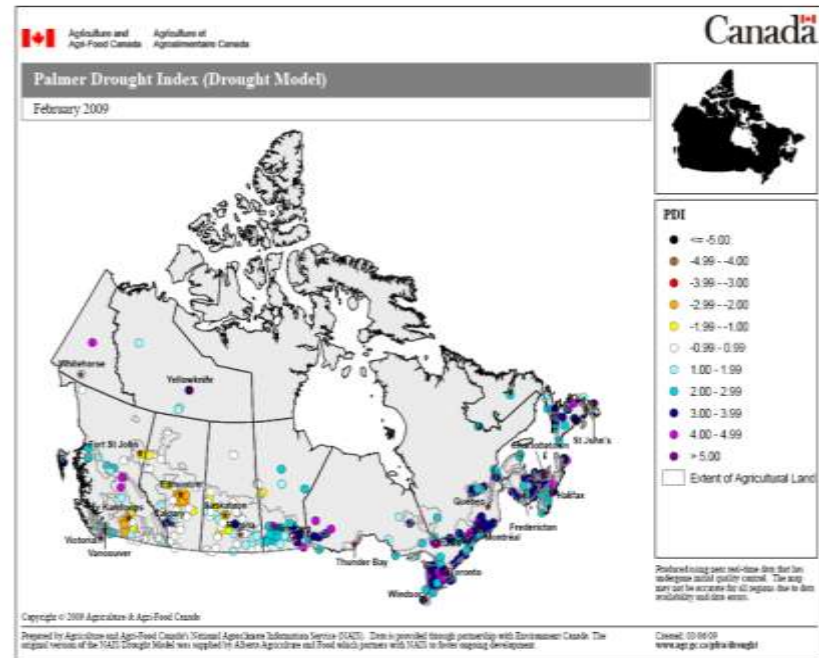
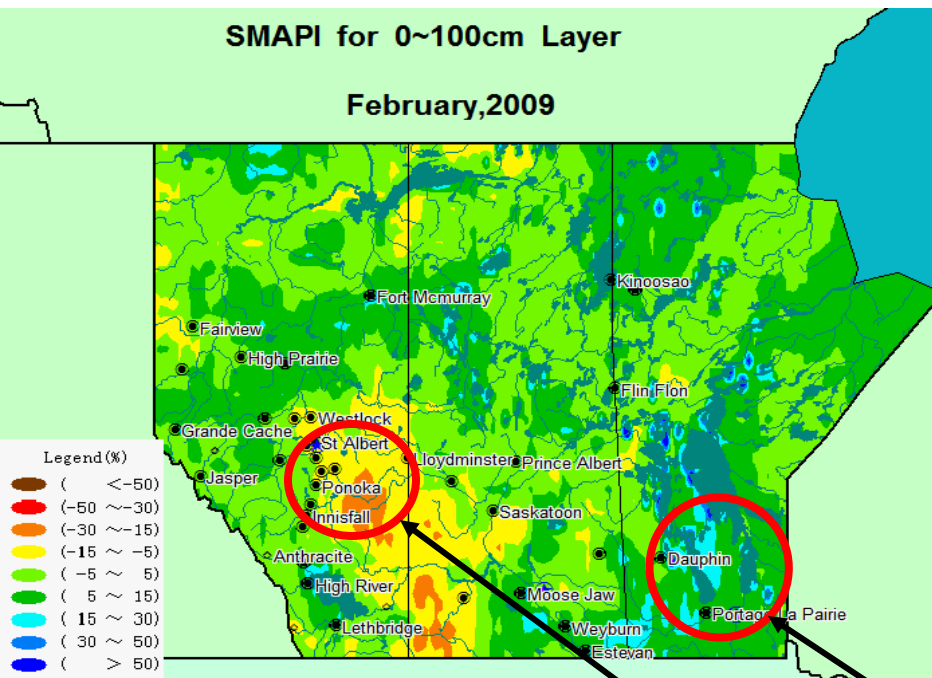


# SMAPI for 0~100cm Layer

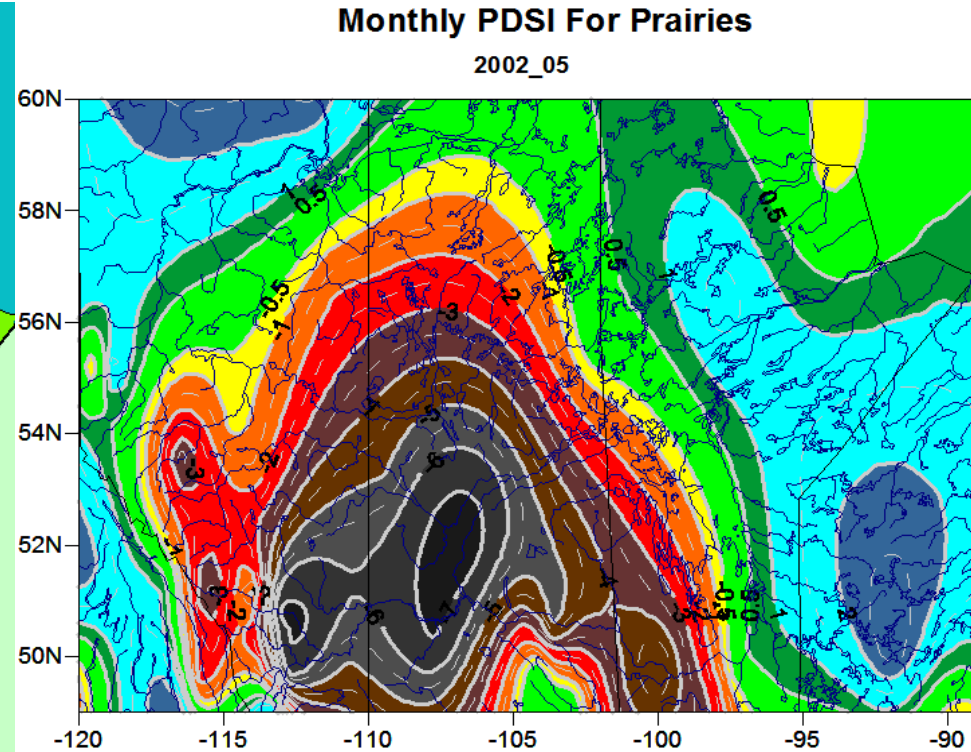
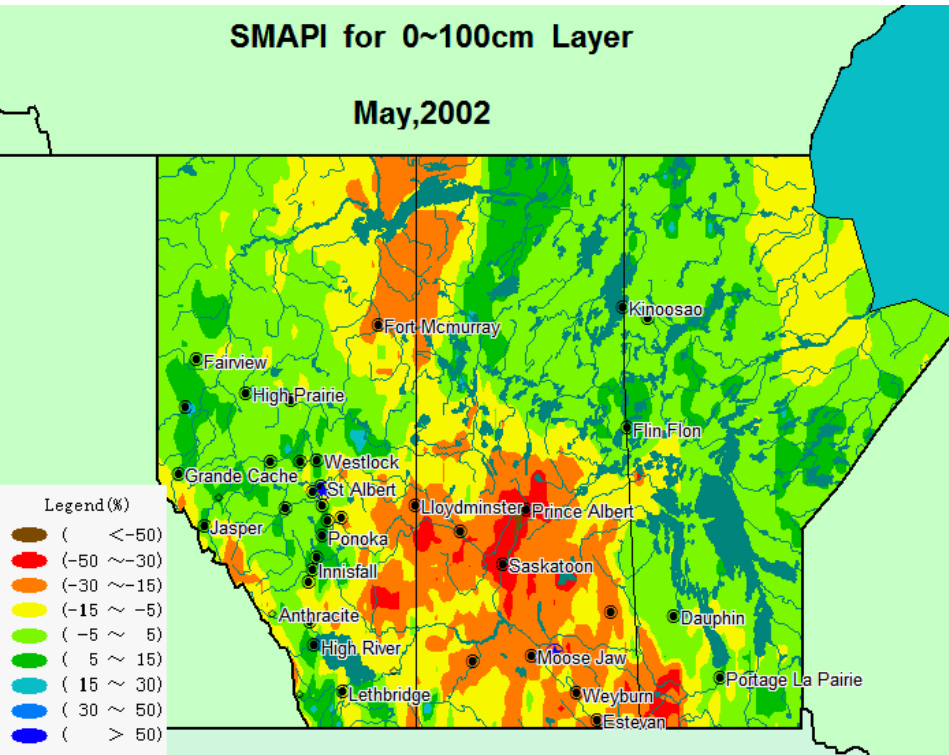
April, 2010



## b. National Drought Indices (PDI) of Agriculture and Agri-Food Canada



## c. Environment Canada PDSI



[http://www.meteo.mcgill.ca/~leiwon/vic/prairies/month-seasonal-annual/index\\_compare.html](http://www.meteo.mcgill.ca/~leiwon/vic/prairies/month-seasonal-annual/index_compare.html)

For the period 1950-2005 (monthly)



## Red River flooding

Play Slideshow Gallery

1 of 48

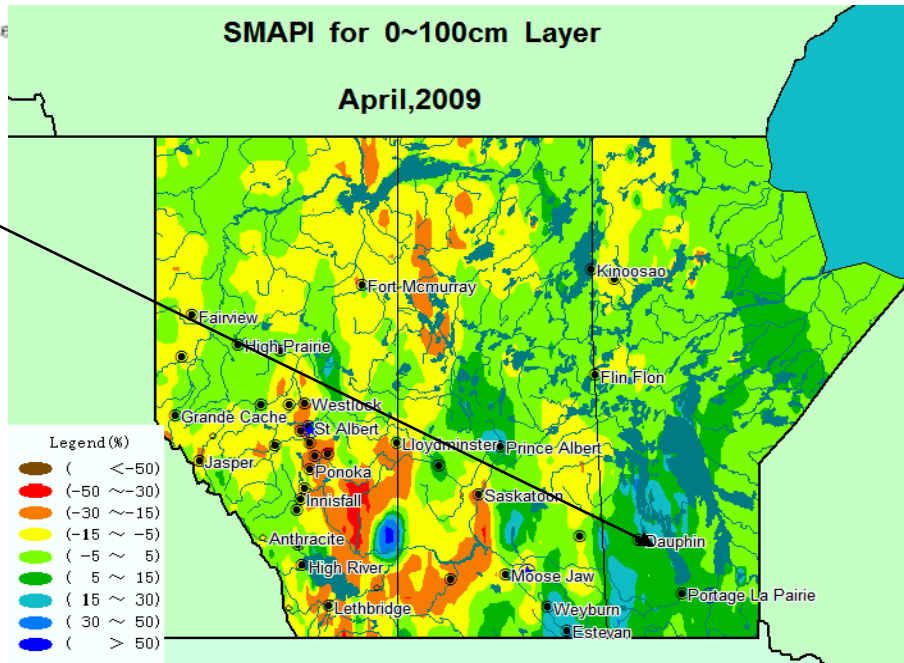


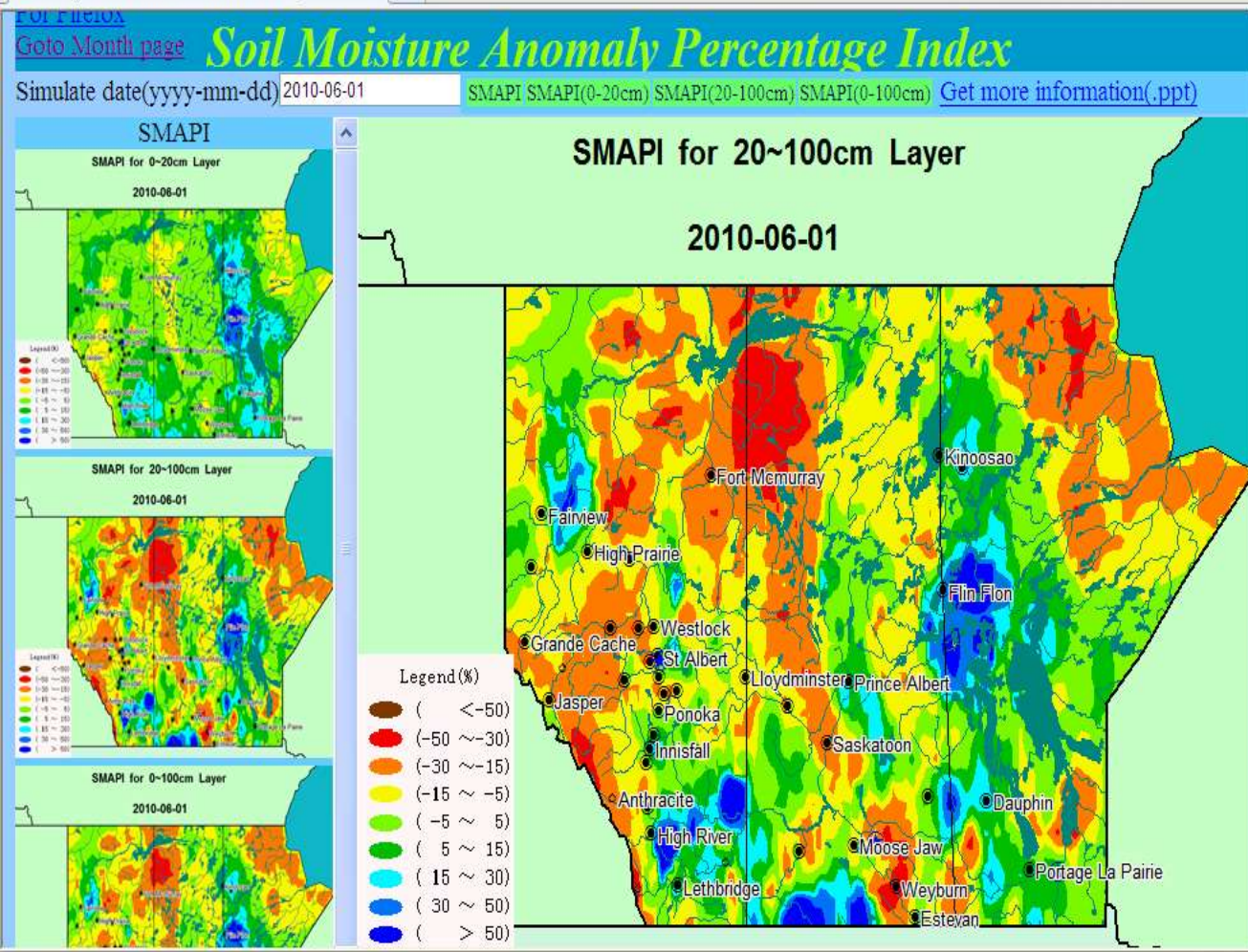
The province has activated the Red River Floodway. Officials had said the flood diversion channel wouldn't be used until all of the ice was off the Red River near the floodway gates south of Winnipeg, but water levels inside the city were just getting too high.

Email | IM | Print

Recommend No use

# Monitoring and forecasting Winnipeg 2009 flooding

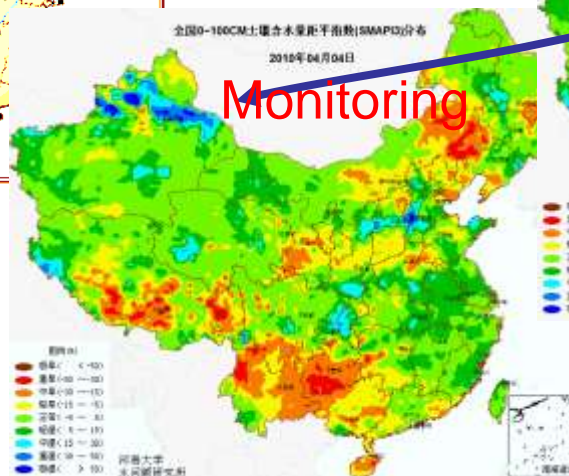
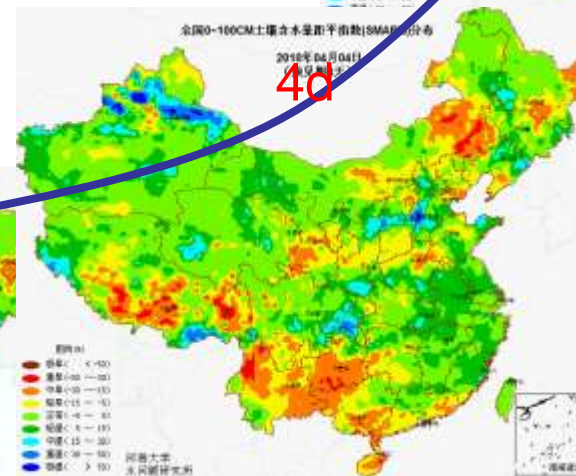
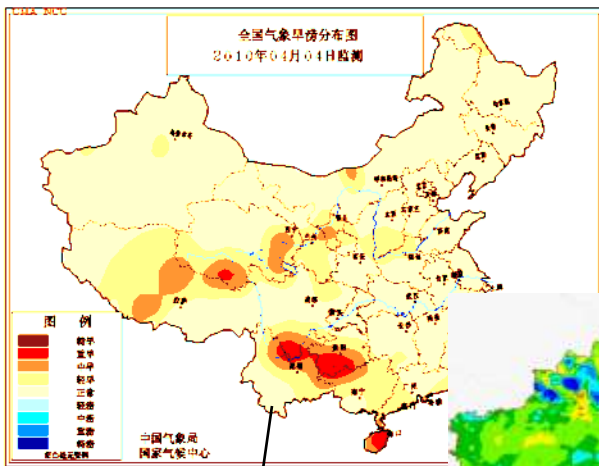
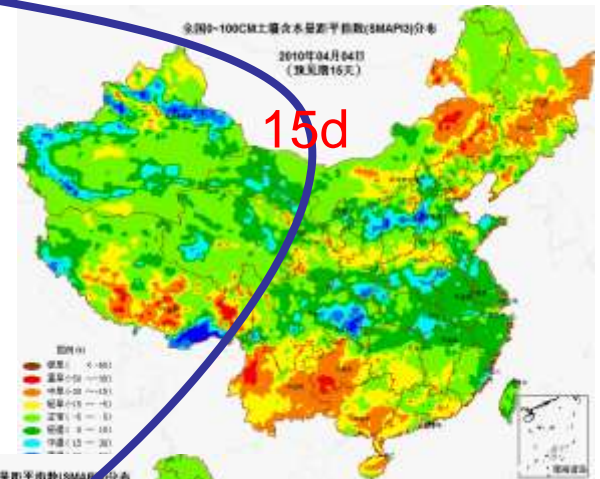
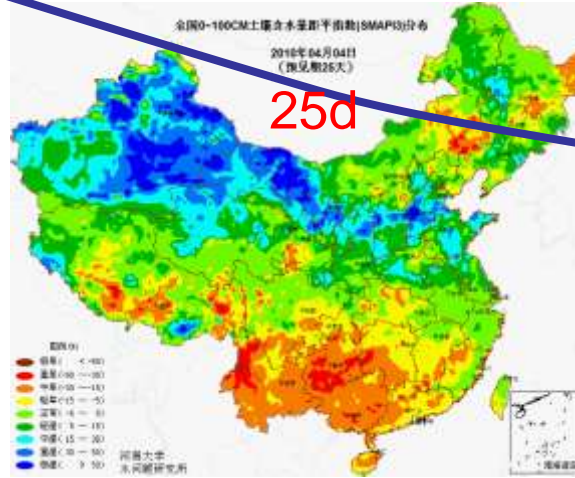
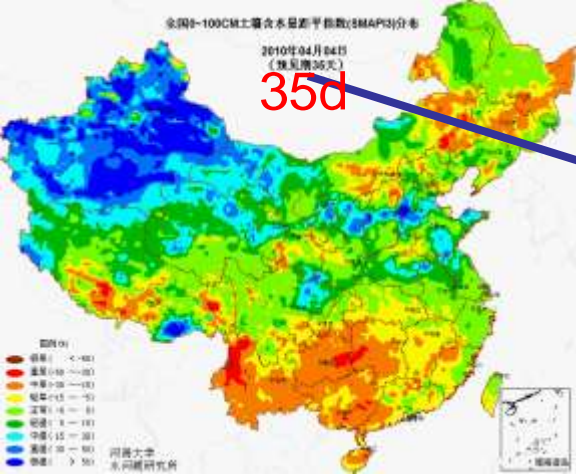




Real-time drought forecasting with a lead time up to 35-d

# Real-time China drought forecast

## Forecast verifying on April 4, 2010 with different lead time



(Drought Monitor,  
China Meteorology  
Administration

**Thanks very much !**  
**Merci beaucoup !**