# Model Evaluation During the 1999-2004 Canadian Prairie Drought: A Preliminary Study

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# Motivation

- The 1999-2004 Prairie drought, especially from 2001 to 2002, had major impacts on many sectors of society
- A multi-year research project (DRI, Drought Research Initiative) was carried out to examine this drought from many perspectives (Stewart et al., 2011).
- One component that was lacking is high resolution atmospheric modelling.

# Objective

- In this preliminary project, we focus specifically on the ability of high resolution models to simulate seasonal and shorter time scale precipitation amounts at a few selected locations during the drought.

# Models

- *Weather Research and Forecasting (WRF) Model*
  - Horizontal resolution: 4 km
  - Domain: 1360 x 1016 grid points encompass all of CONUS and portions of Canada and Mexico.
  - 51 stretched vertical levels topped at 50 hPa.
  - WRF-CTRL: Historical simulation, the frequency of output is 1 hour.
  - Period: 2000-2013
- *Fifth-Generation Canadian Regional Climate Model (CRCM5)*
  - Horizontal resolution: 0.44°, 0.22° and 0.11° with respectively.
  - Data frequency: 1 hour
  - Period: 1999-2004
- The model values averaged at 4x4 surrounding grids at each locations were evaluated

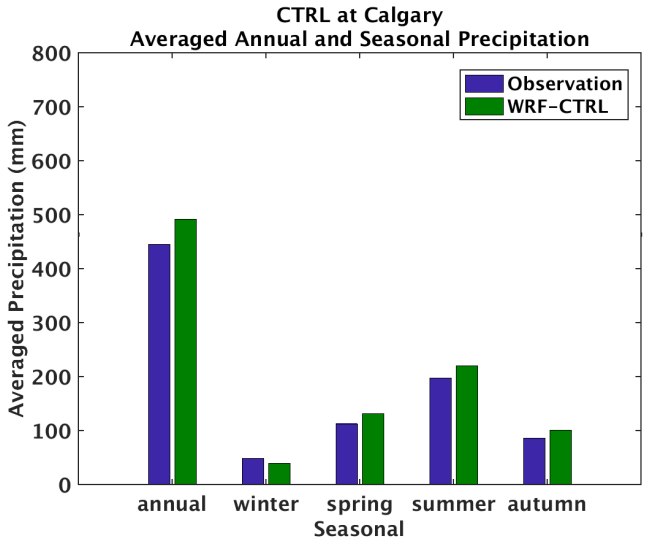
# Locations and Observational Dataset

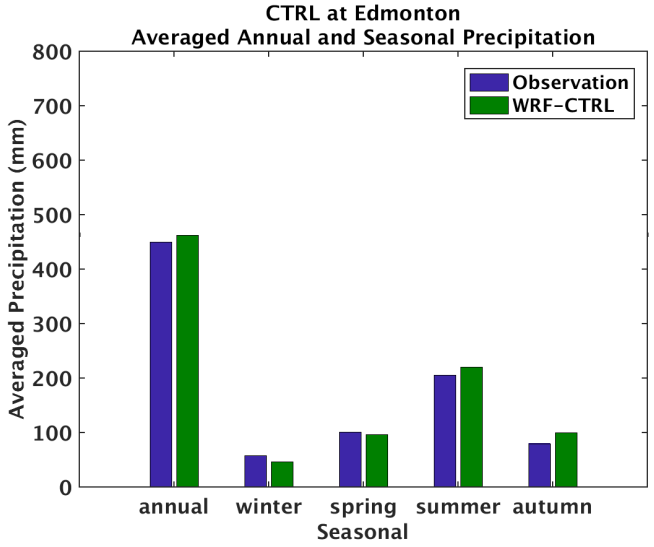
- Locations:
  - Calgary (51°06'50 N, 114°01'13 W)
  - Edmonton (53°19' N, 113°35' W)
  - Saskatoon (52°10' N, 106°43' W)
- Same locations used in Evans et al. (2011) observational study

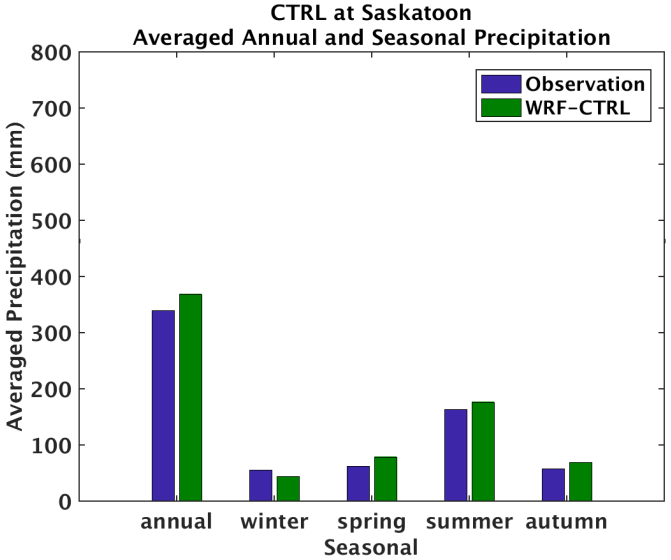
- Observational dataset:
  - Adjusted and Homogenized Canadian Climate Data (AHCCD and AHCCD_daily)

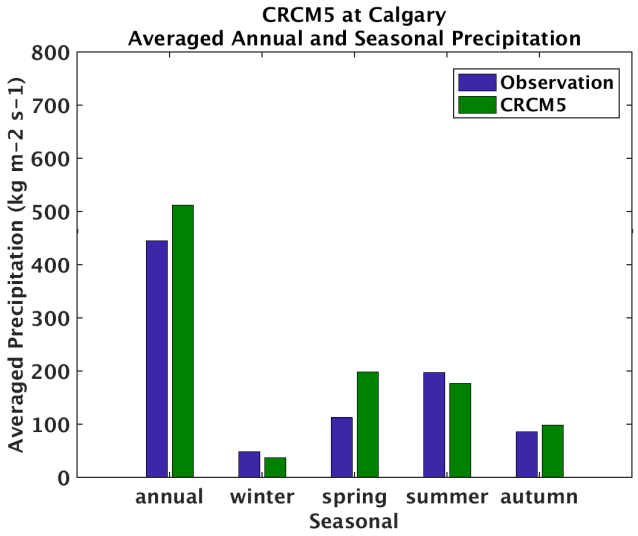
# Averaged annual and seasonal precipitation over 2001-2004 at three locations

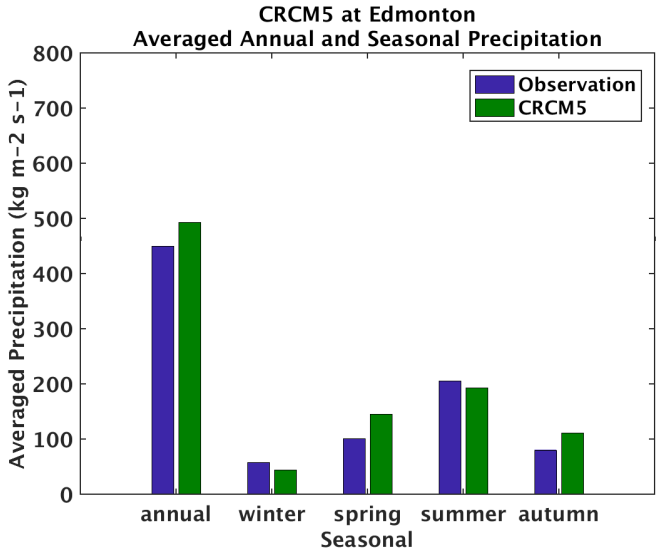
Winter-DJF; Spring-MAM; Summer-JJA; Autumn-SON

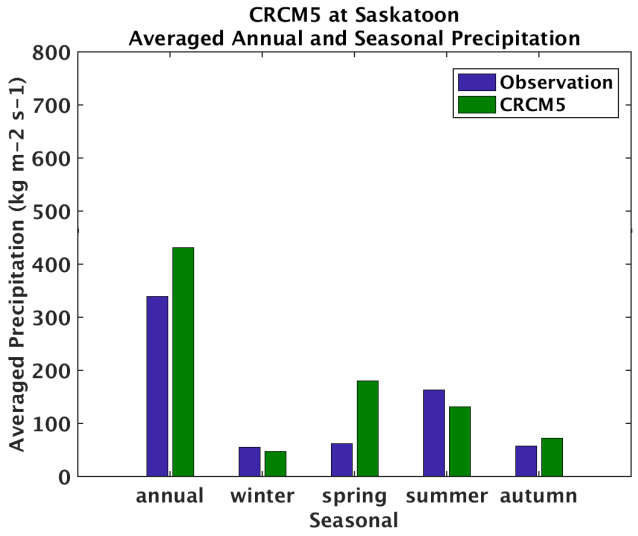


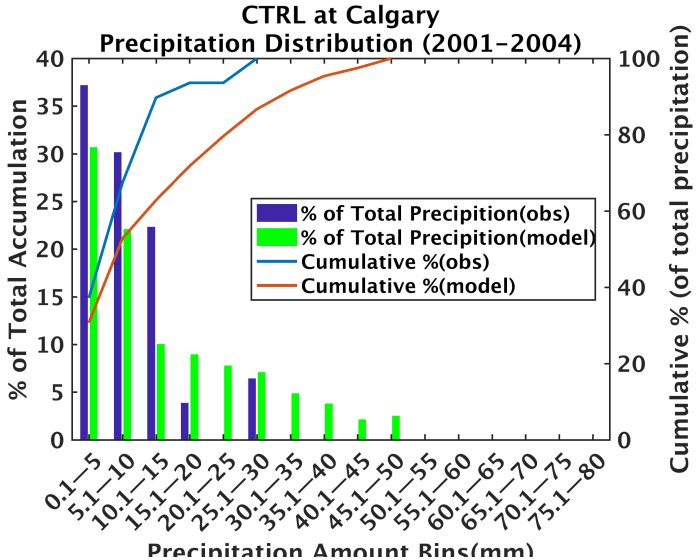



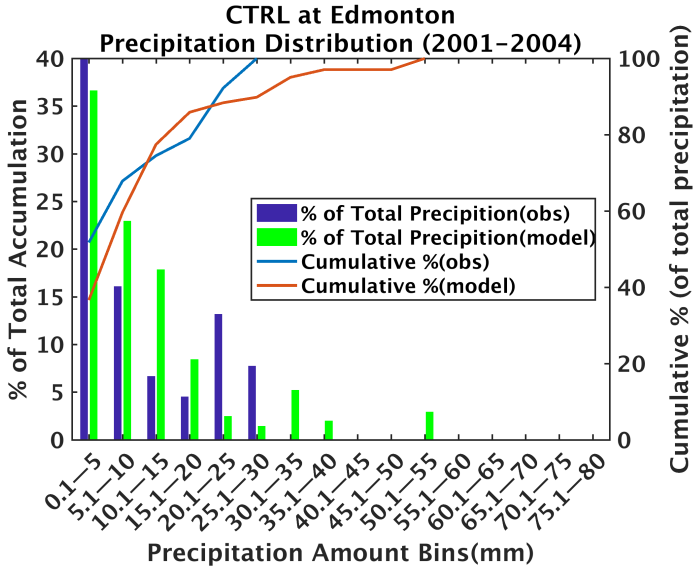



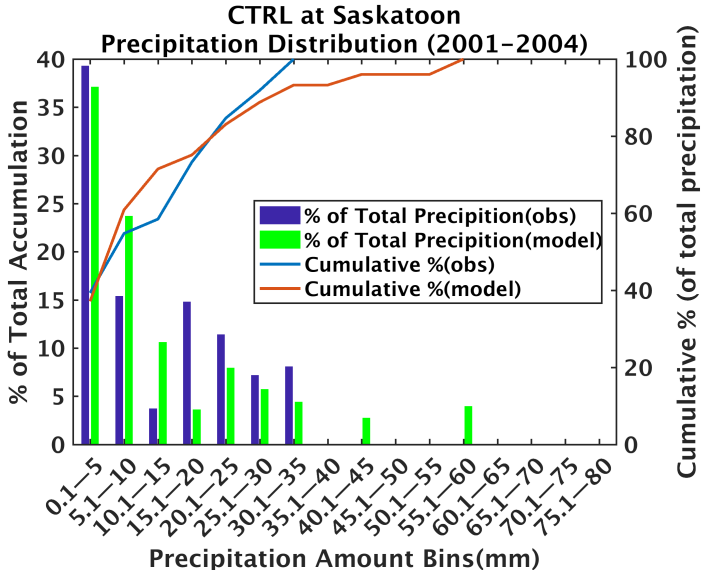



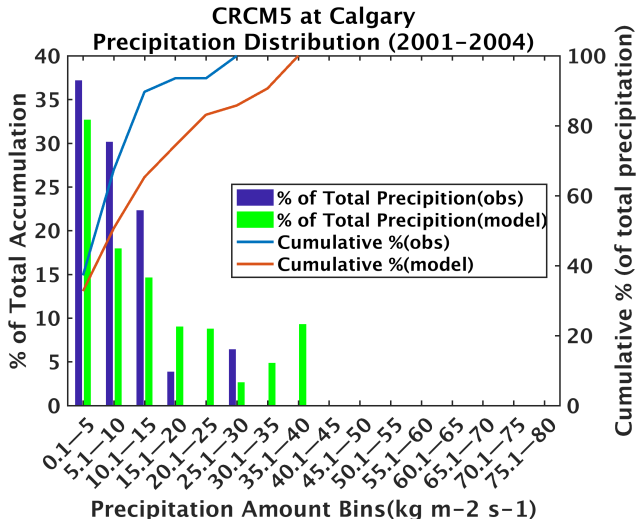



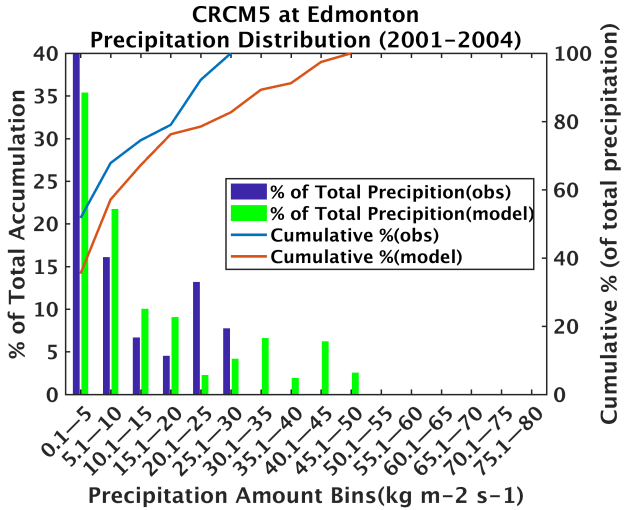
# Daily Precipitation Distributions During 2001-2004

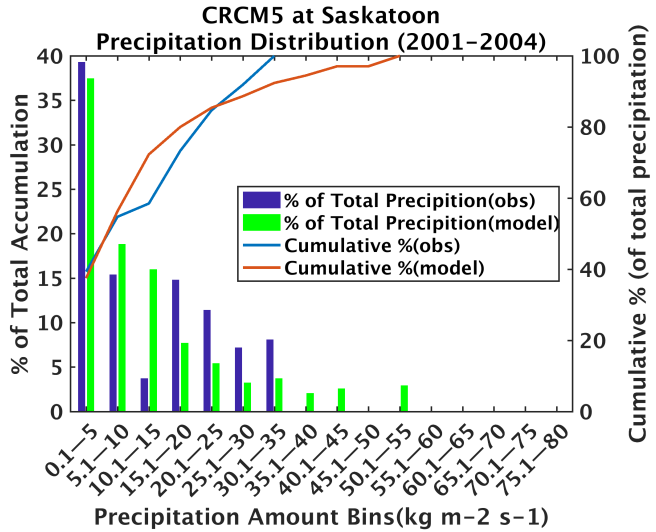


# Summer days with precipitation as a fraction of the 92 total summer season days

| WRF-CTRL | | | | |
|---|---|---|---|---|
| | Summer 2001 | (% of days) | Summer 2002 | (% of days) |
| | obs | model | obs | model |
| Calgary | 56.5 | 46.7 | 45.7 | 43.5 |
| Edmonton | 52.2 | 56.5 | 53.3 | 43.5 |
| Saskatoon | 38.0 | 38.0 | 44.6 | 46.7 |

| CRCM5 | | | | |
|---|---|---|---|---|
| | Summer 2001 | (% of days) | Summer 2002 | (% of days) |
| | obs | model | obs | model |
| Calgary | 56.5 | 34.8 | 45.7 | 33.7 |
| Edmonton | 52.2 | 46.7 | 53.3 | 47.8 |
| Saskatoon | 38.0 | 35.9 | 44.6 | 35.9 |

# Summary

This preliminary study has led to several initial points:

- Model simulations showed the same pattern as observations
- Model simulations, in comparison with observations:
  - Both model simulations produced more annual precipitation, especially CRCM5
  - WRF-CTRL generally showed slightly more seasonal precipitation
  - CRCM5 generated more precipitation in spring in particular
- Daily precipitation distributions during the drought period:
  - Models over-predicted large precipitation events
  - Models under-predicted smaller amount (< 5 mm) events
- WRF-CTRL produced precipitation on a similar number of days as observed but CRCM5 generally produced precipitation on fewer days.
- Overall and in general, WRF better simulated the precipitation than did CRCM5

Note that is just a preliminary project and it needs to be re-done over a larger domain

# Drought Evolution

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3. Agriculture and Agri-Food Canada

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# Motivation and Objective

Motivation:

- Spatial and temporal features of drought are critical but not well known
- Several studies suggest more frequent and more severe droughts in future (especially high emission scenarios) but what does this mean?
    For example, don't know: rapid onset, spatial extents, persistence, propagation, termination

Objective: To examine the temporal and spatial evolution of drought with

focus on onset, magnitude, strength and frequency

# Main Dataset

SPEI: Standardized Precipitation Evapotranspiration Index

Initially utilize SPEI dataset (Tam et al., 2018):

- 29 CMIP5 models from 1900-2100
- 3 RCP scenarios (2.6, 4.5, 8.5)
- Canada wide
- 1, 3, 12 month duration

In this study, we use observed CANGRD(Canadian Gridded) SPEI dataset

# Study Steps

1. Replicate study of past droughts by Bonsal et al. (2011)* and compare results

    - a few example follow

2. As appropriate, examine future droughts in the same manner

3. Compare past and future conditions

* Bonsal, Wheaton, Meinert and Siemens, 2011: Characterizing the surface features of the 1999-2005 Canadian Prairie drought in relation to previous severe twentieth century droughts, Atmos.-Ocean,49, 320-338.

# Drought Classification

SPI: Standardized Precipitation Index
PDSI: Palmer Drought Severity Index

Bonsal et al. (2011)

TABLE 1. Classifications based on the PDSI (Palmer, 1965) and SPI (McKee et al., 1993).

| Classification | | PDSI | SPI |
|---|---|---|---|
| Drought | Exceptional | ≤–5.0 | ≤–2.5 |
| | Extreme | > –5.0 to –4.0 | > –2.5 to –2.0 |
| | Severe | > –4.0 to –3.0 | > –2.0 to –1.5 |
| | Moderate | > –3.0 to –2.0 | > –1.5 to –1.0 |
| | Mild | > –2.0 to –1.0 | > –1.0 to –0.5 |
| Near Normal | | > –1.0 to 1.0 | > –0.5 to 0.5 |
| Wet | Mild | 1.0 to <2.0 | 0.5 to <1.0 |
| | Moderate | 2.0 to <3.0 | 1.0 to <1.5 |
| | Severe | 3.0 to <4.0 | 1.5 to <2.0 |
| | Extreme | 4.0 to <5.0 | 2.0 to <2.5 |
| | Exceptional | ≥ 5.0 | ≥ 2.5 |

# Drought Stages

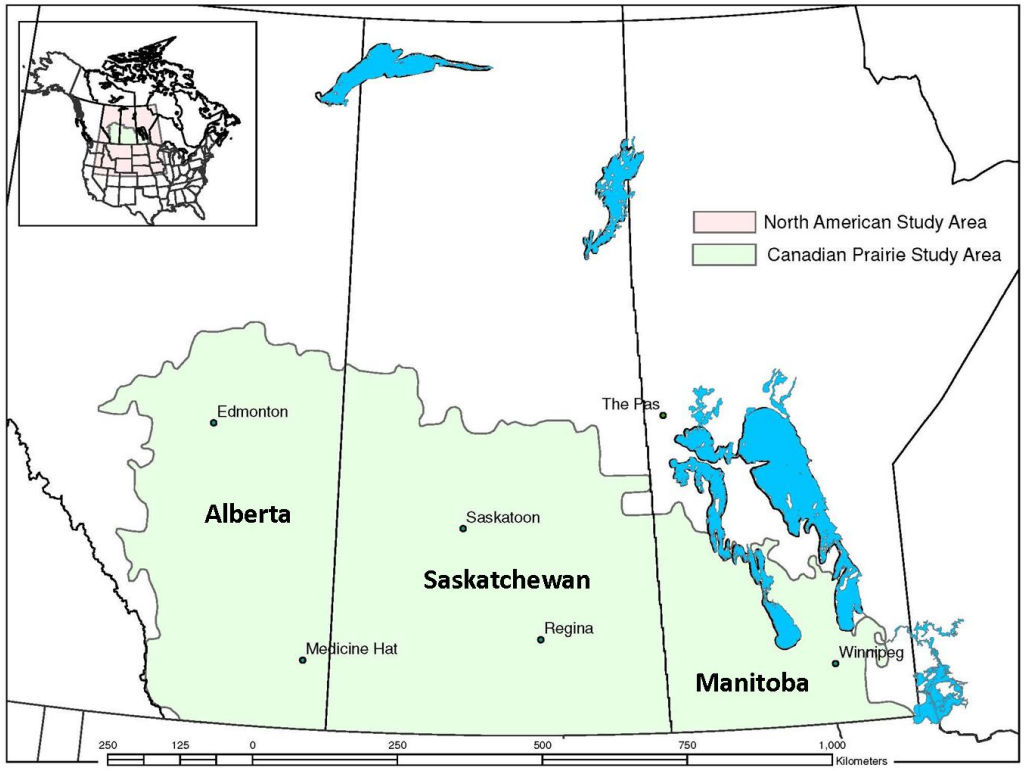
Based on fraction of area under severe drought

TABLE 3. Drought stages used in this investigation.

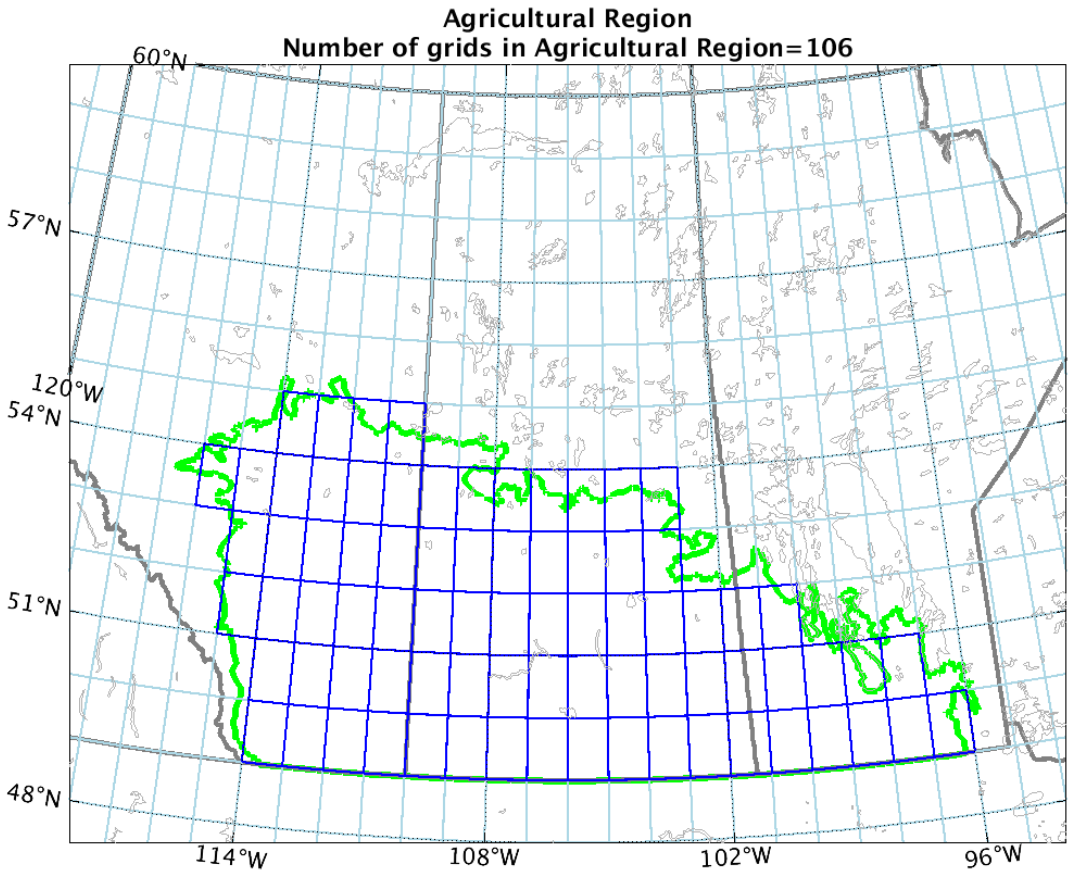
| Stage | Description | Area in Severe Drought or Worse |
|---|---|---|
| 1) Onset | Initiation or emergence (i.e., early signs of drought) | 10% |
| 2) Growth | Spreading and deepening of drought | 10% to 50% |
| 3) Persistence | Period with extensive drought conditions | >50% |
| 4) Peak | Maximum extension and severity of drought | Peak Value |
| 5) Retreat | Decrease of drought area with possible secondary peaks | 50% to 10% |
| 6) Termination | End of drought with return to near-normal conditions | 10% to 0% |

Bonsal et al. (2011)

# Agricultural Region and SPEI grids

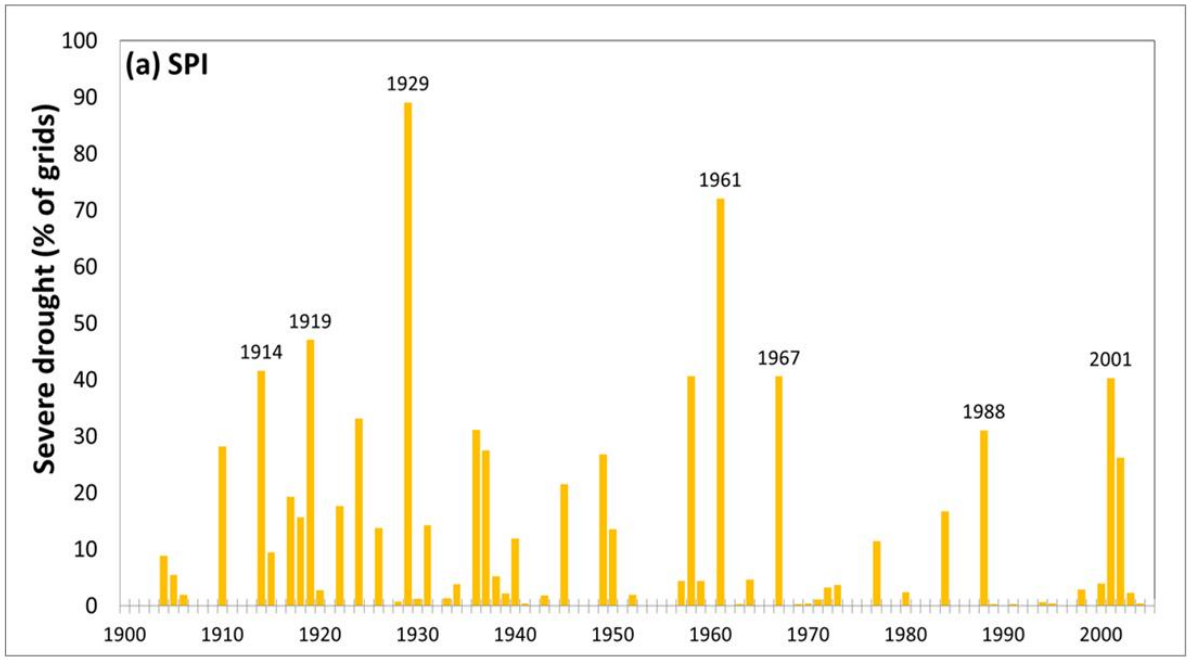


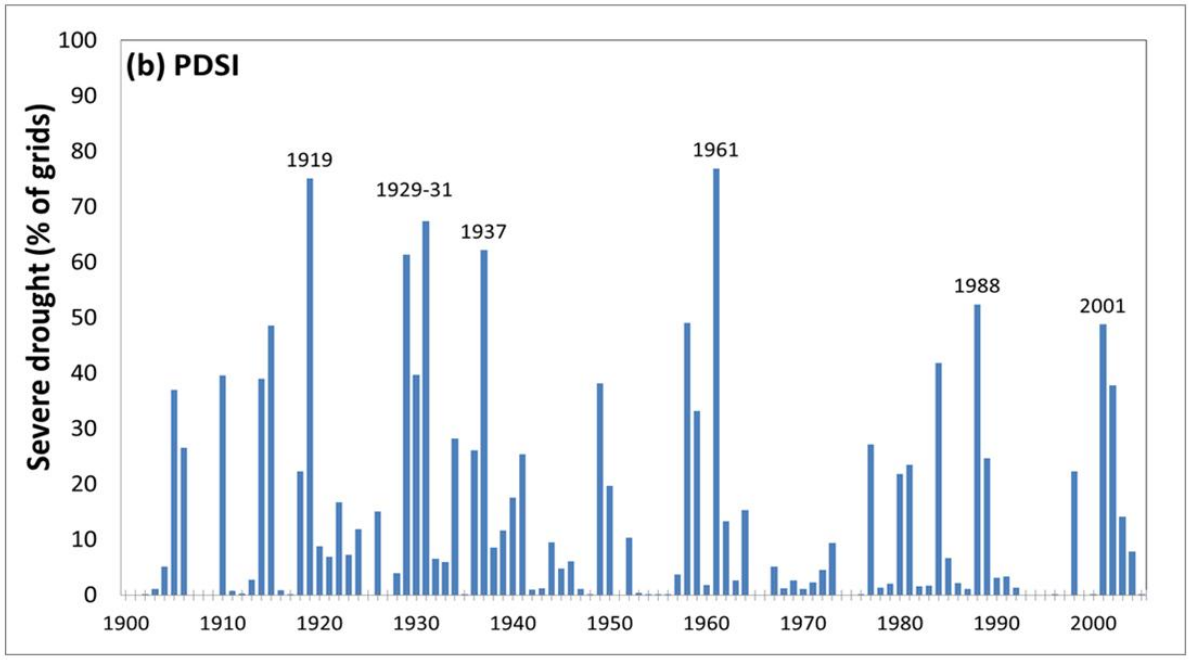

Bonsal et al. (2011)



# % of Grids in Severe or Worse Over Agricultural Region from 1901 to 2005

12 month running values associated with the agricultural year(September to August)
< -1.5 for SPI 12 month running values
< -3.0 for PDSI 12 month running values
<-1.5 for SPEI 12 month running values

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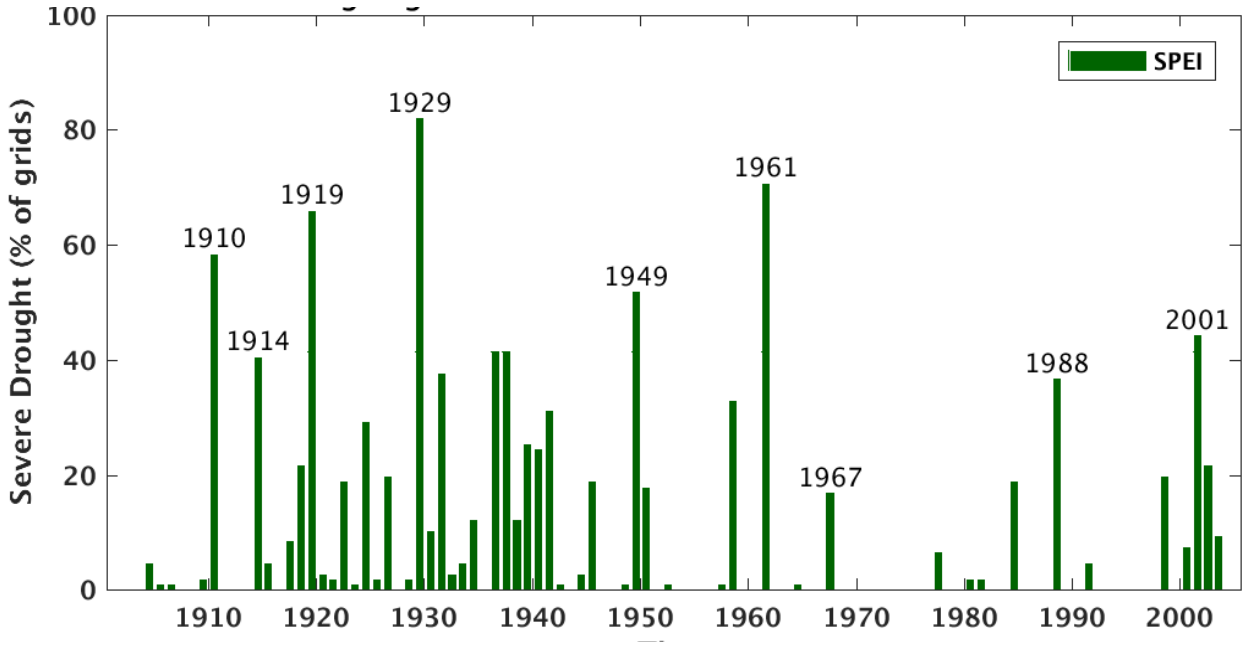
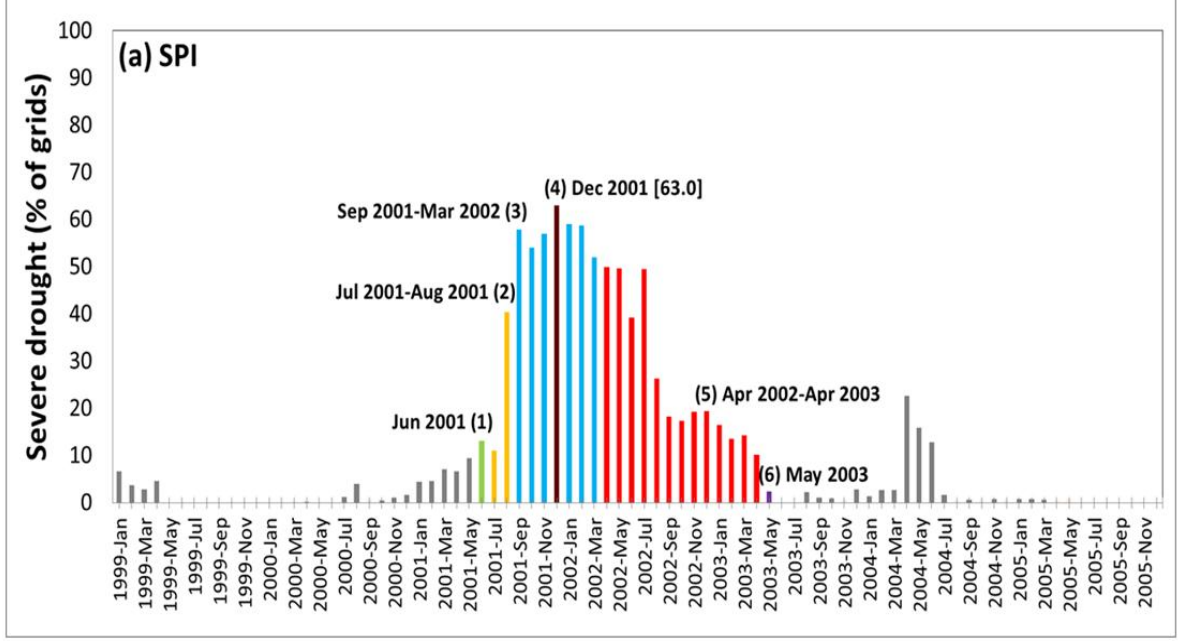
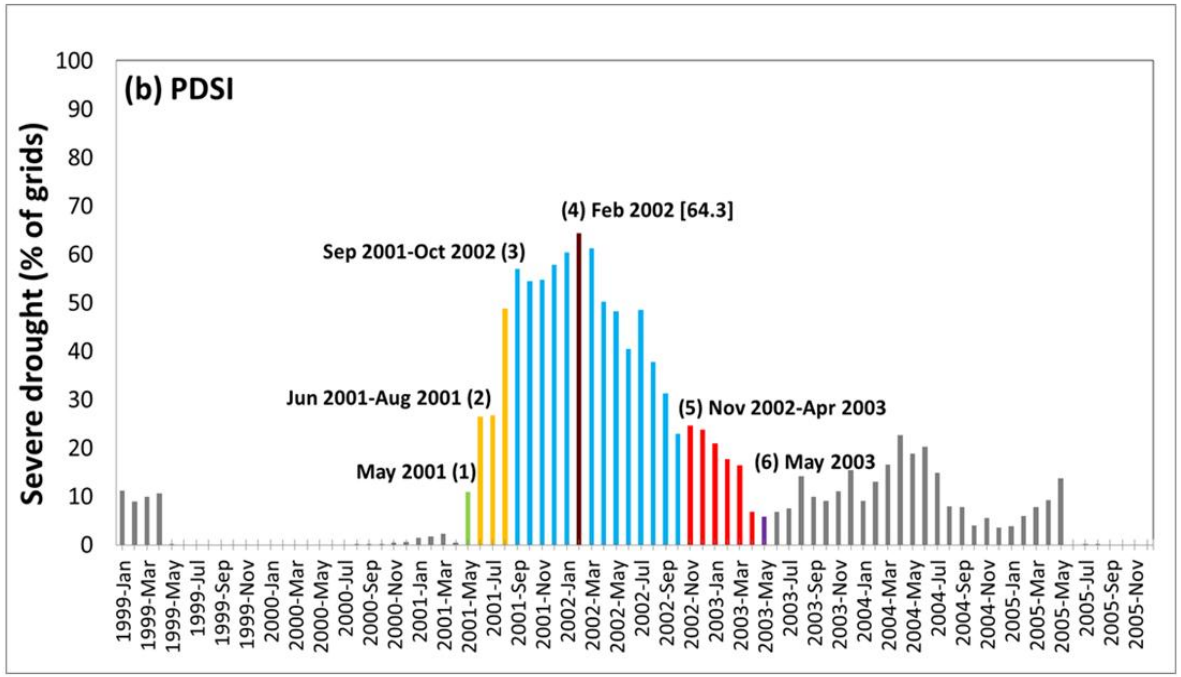



SPEI

# % of Grids for 1999-2005 Event in Severe Drought

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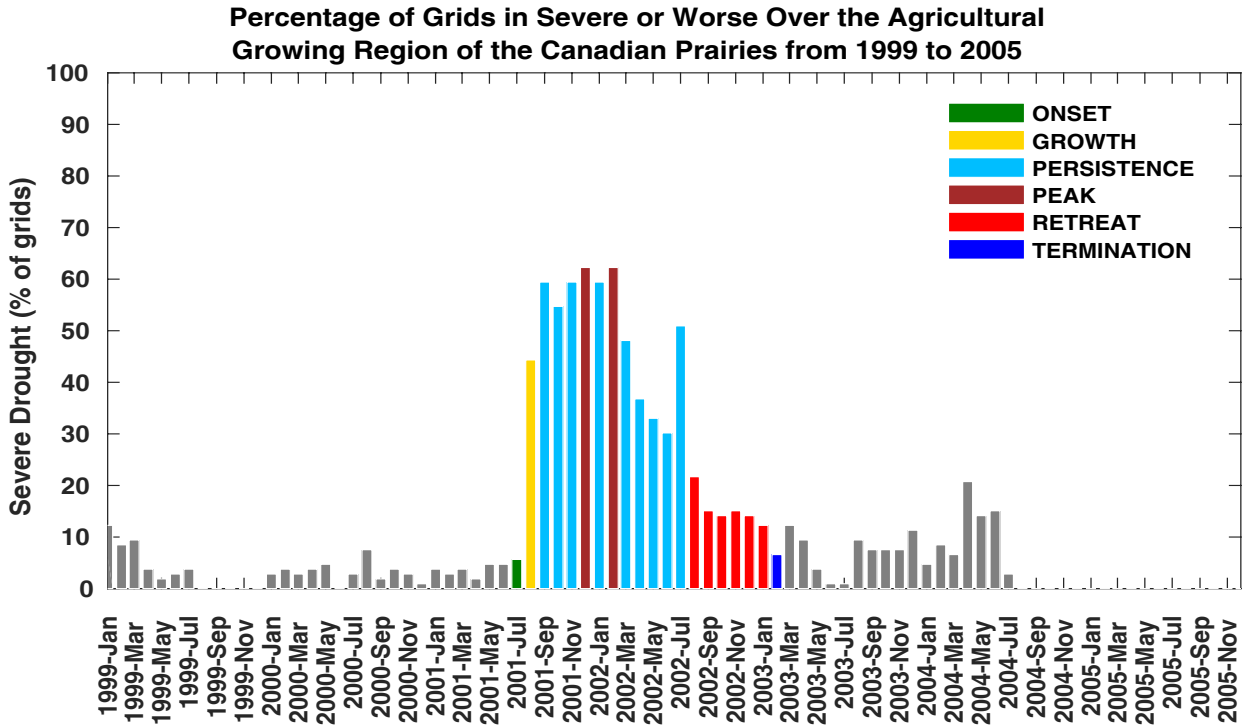
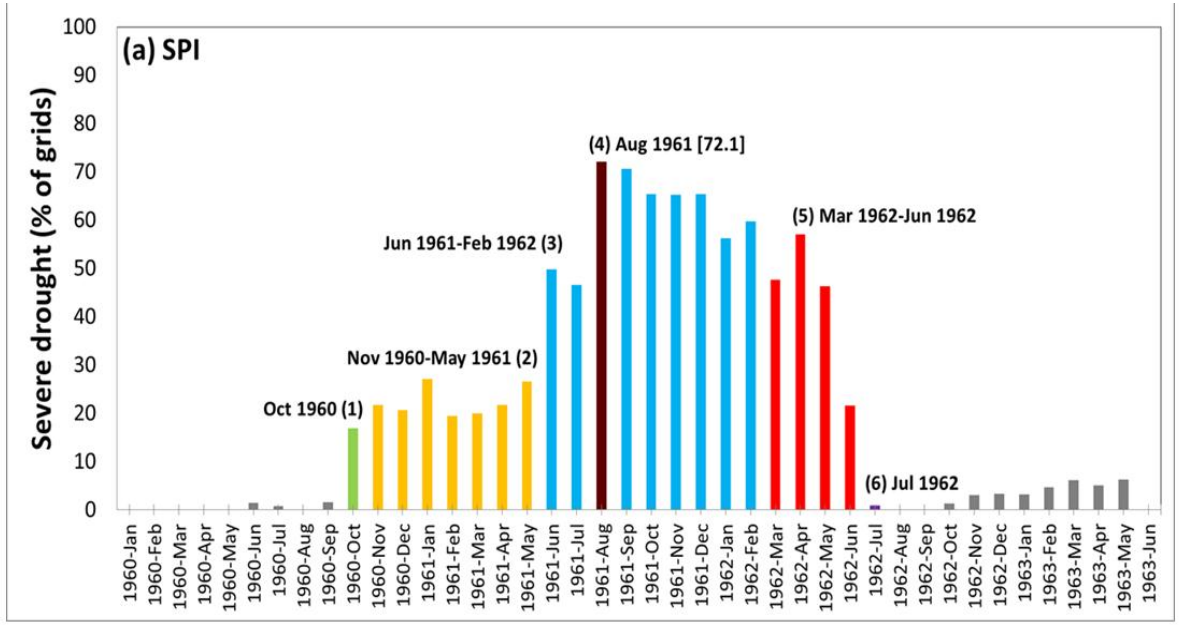
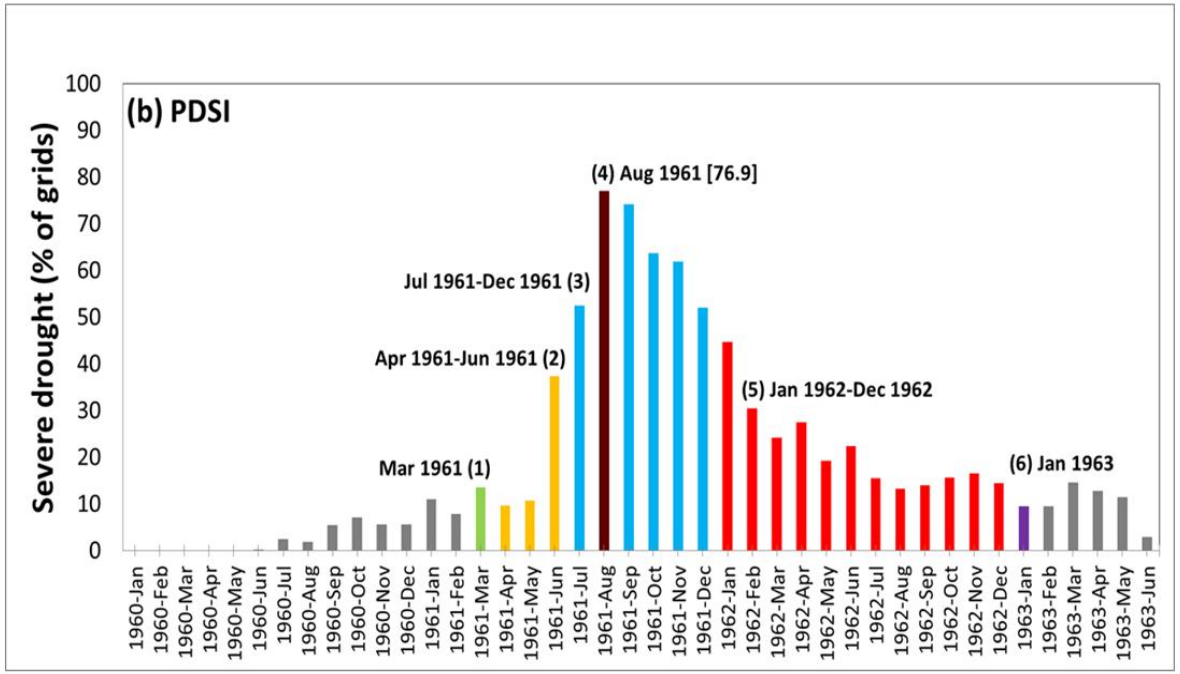



SPEI

# % of Grids For 1960-1962 Event in Severe Drought

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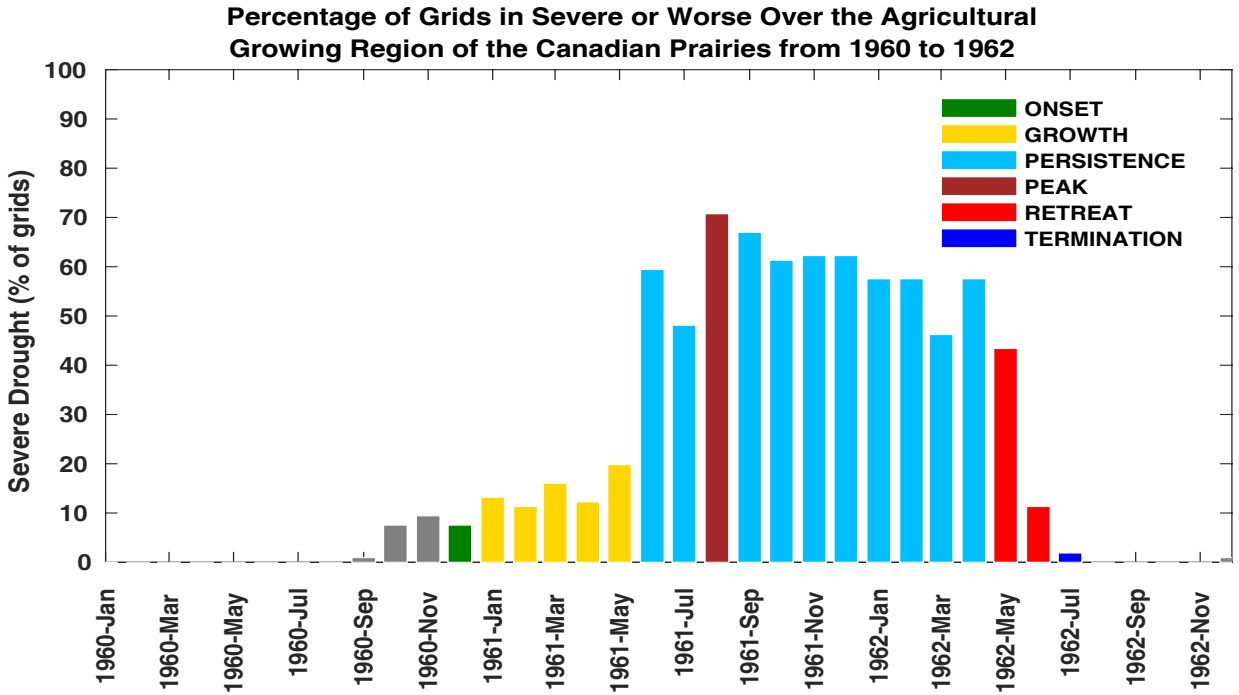


SPEI

# Quick Comments

- SPEI shows similar patterns as SPI
- Some slight differences exist
- SPEI appears to sometimes give longer durations

Note: this is only preliminary

# Issues and Next

- Which models to choose? Suggestions for proceeding?
- Initial focus on Prairies (‘classic droughts’), other regions?

    But drought typically means something different elsewhere

        ‘Dry’ in N.S. may good for wheat

        10 days in Ontario can affect crops (higher temporal resolution)

        Etc.