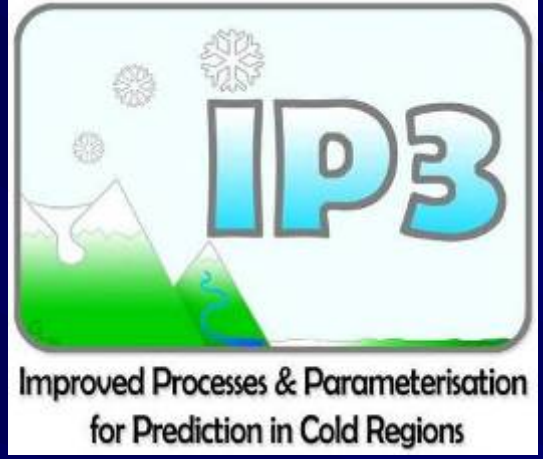

Drought, Climate Variability and Water Resources in Western Canada

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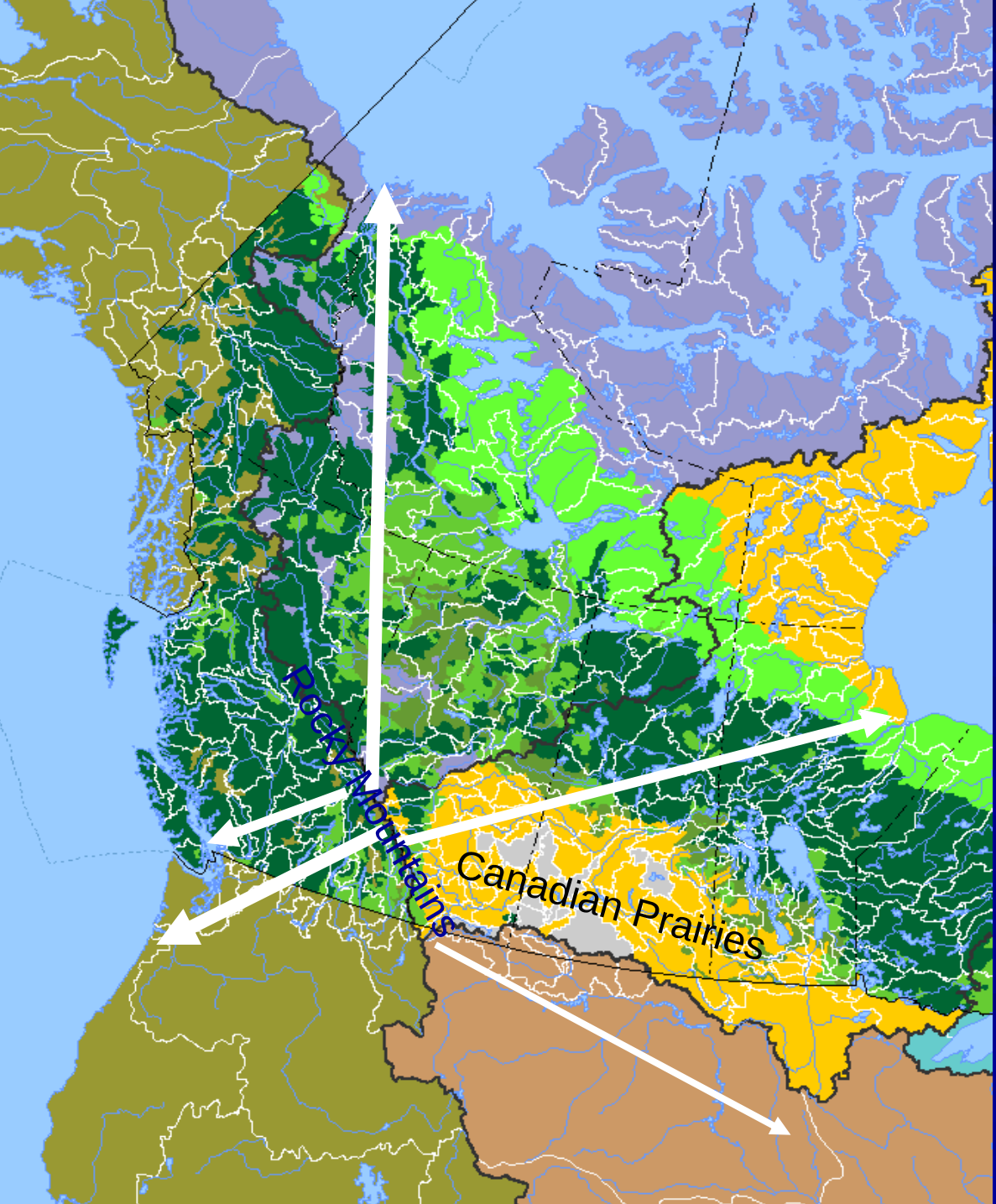
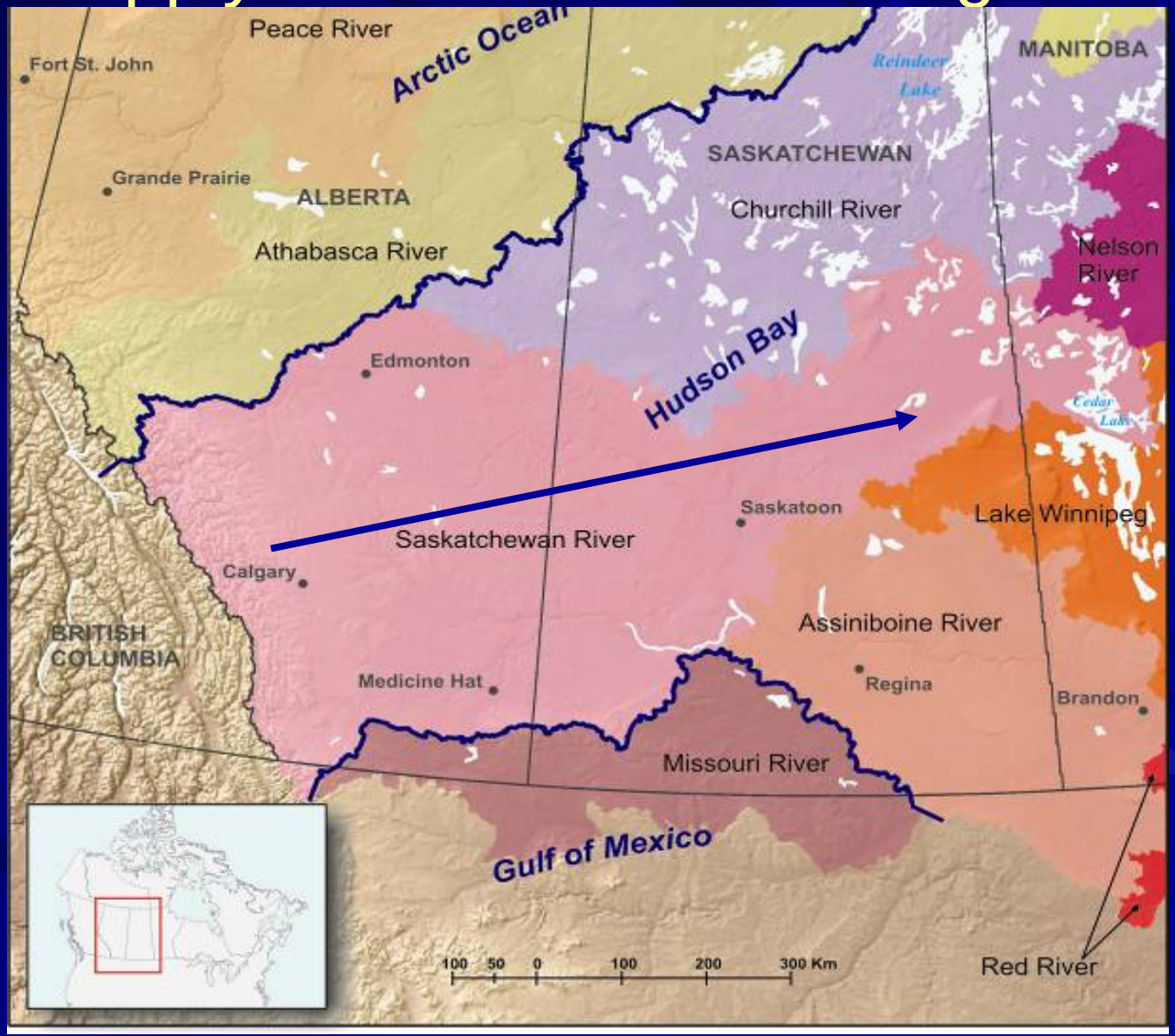


Canadian Rocky Mountains are the Headwaters for much of North America

Canadian Rocky Mountains

Cold alpine and sub-alpine climate

Rivers Draining the Rocky Mountains Supply Prairie Cities and Irrigation

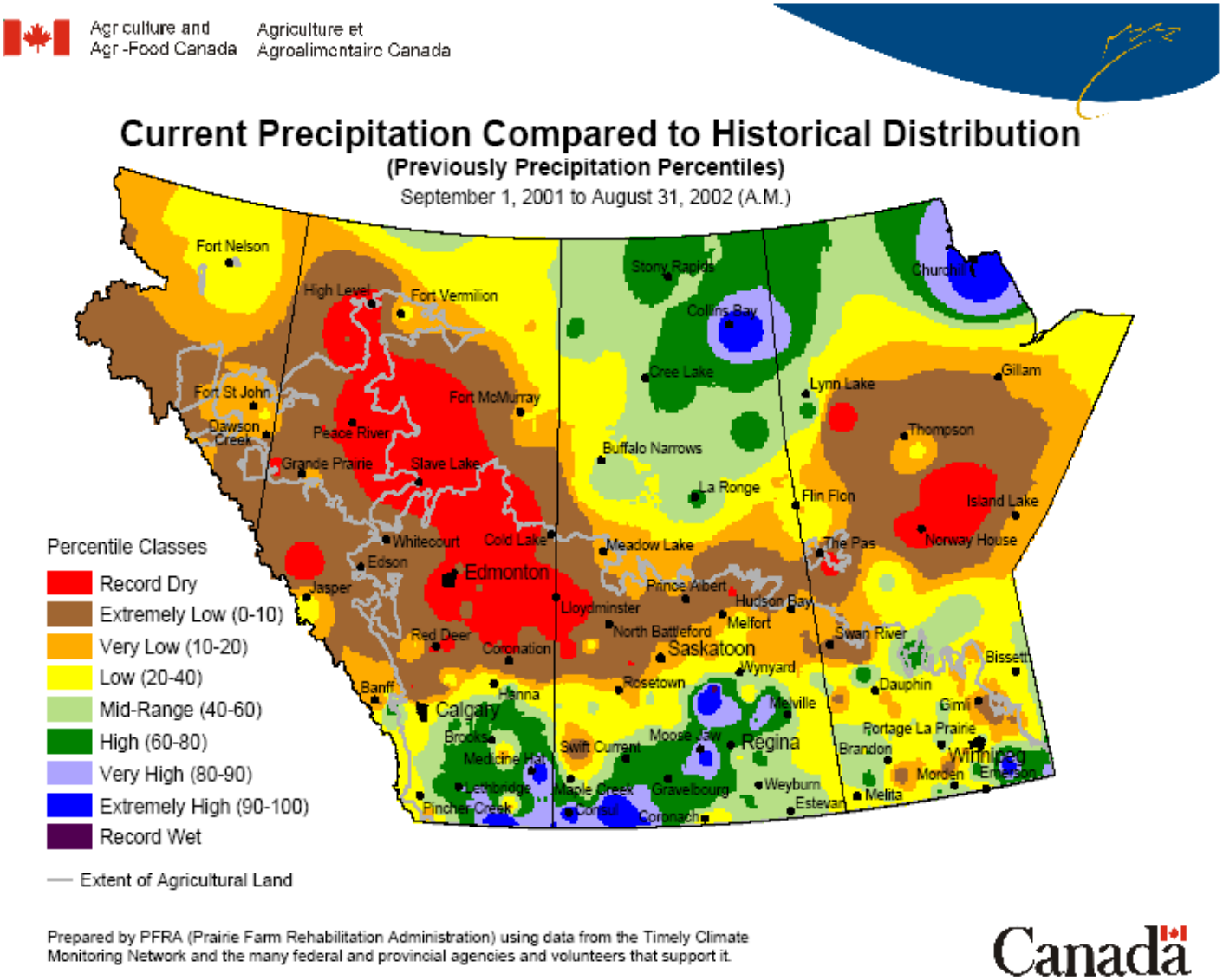


Canadian Prairie Agriculture: mostly dryland grain farming & pasture

Cold, continental, semi-arid climate

- Precipitation on average 350 mm
- Grain Growing
  - 125 mm soil water reserves needed from snowmelt
  - 175 mm spring rainfall needed
  - Roughly 300 kg/ha increased wheat yield for each extra 25 mm of water added

Canadian Prairie Drought of 1999-2004
Most Expensive Natural Disaster in Canadian History



- $5.8 billion decline in GDP 2001-2002
- $3.6 billion drop in agricultural production, 2001-2002
- 41,000 jobs lost
- British Columbia & Alberta forest fires
- Saskatchewan dust storms

OBJECTIVE OF DRI – the Drought Research Initiative

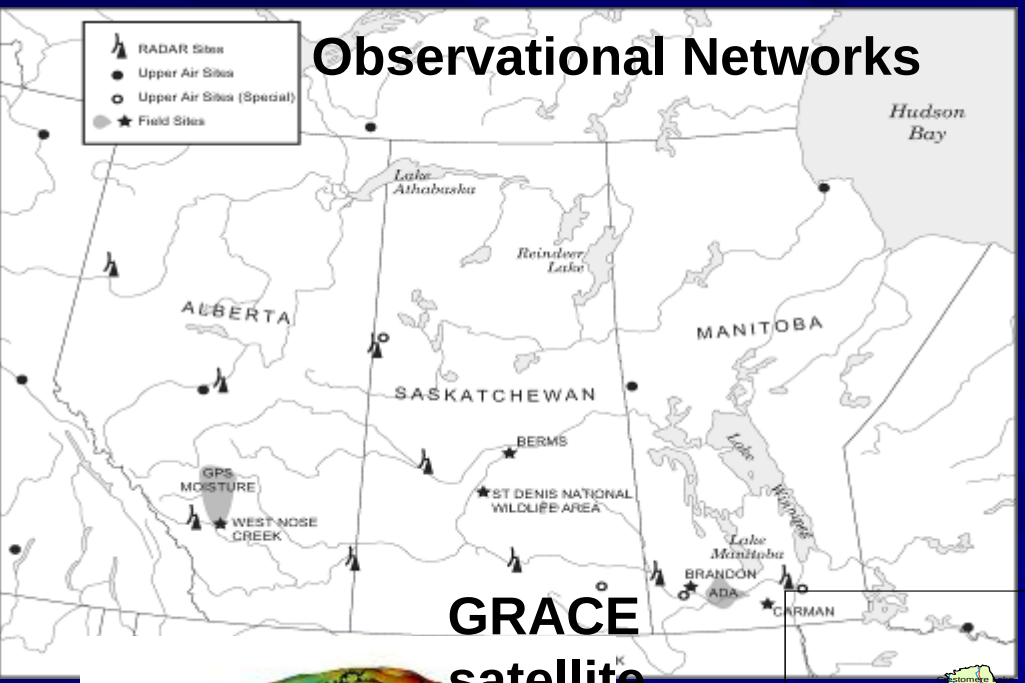
To better understand the physical characteristics of and processes influencing Canadian Prairie droughts, and to contribute to their better prediction, through a focus on the recent severe drought that began in 1999

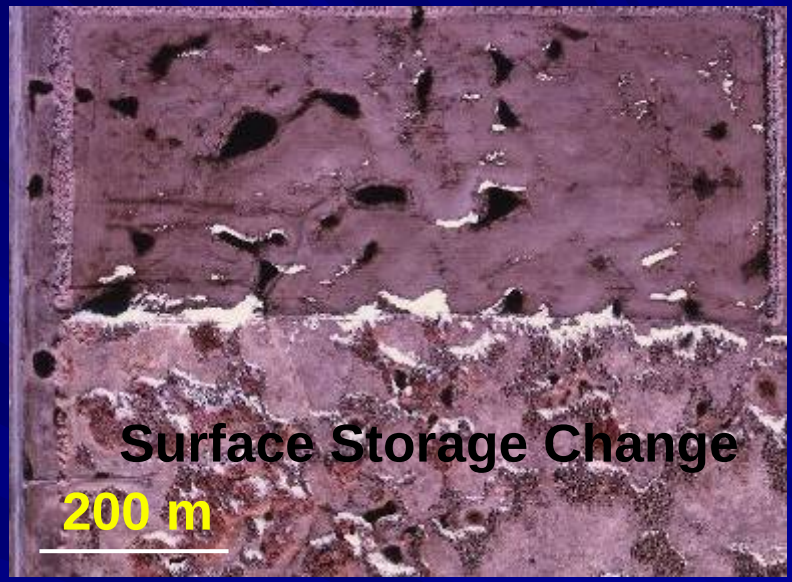
www.drinetwork.ca

DRI THEMES

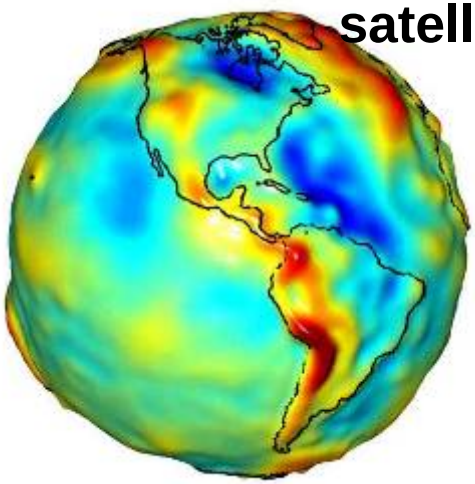
1. Quantify the physical features,
   - flows of water and energy into and out of the region, and
   - storage and redistribution within the region
2. Improve the understanding of processes and feedbacks governing the
   - formation,
   - evolution,
   - cessation and
   - structure of the drought
3. Assess and reduce uncertainties in the prediction of drought
4. Compare the similarities and differences of current drought to previous droughts and those in other regions
5. Apply our progress to address critical issues of importance to society

1. QUANTIFY THE DROUGHT



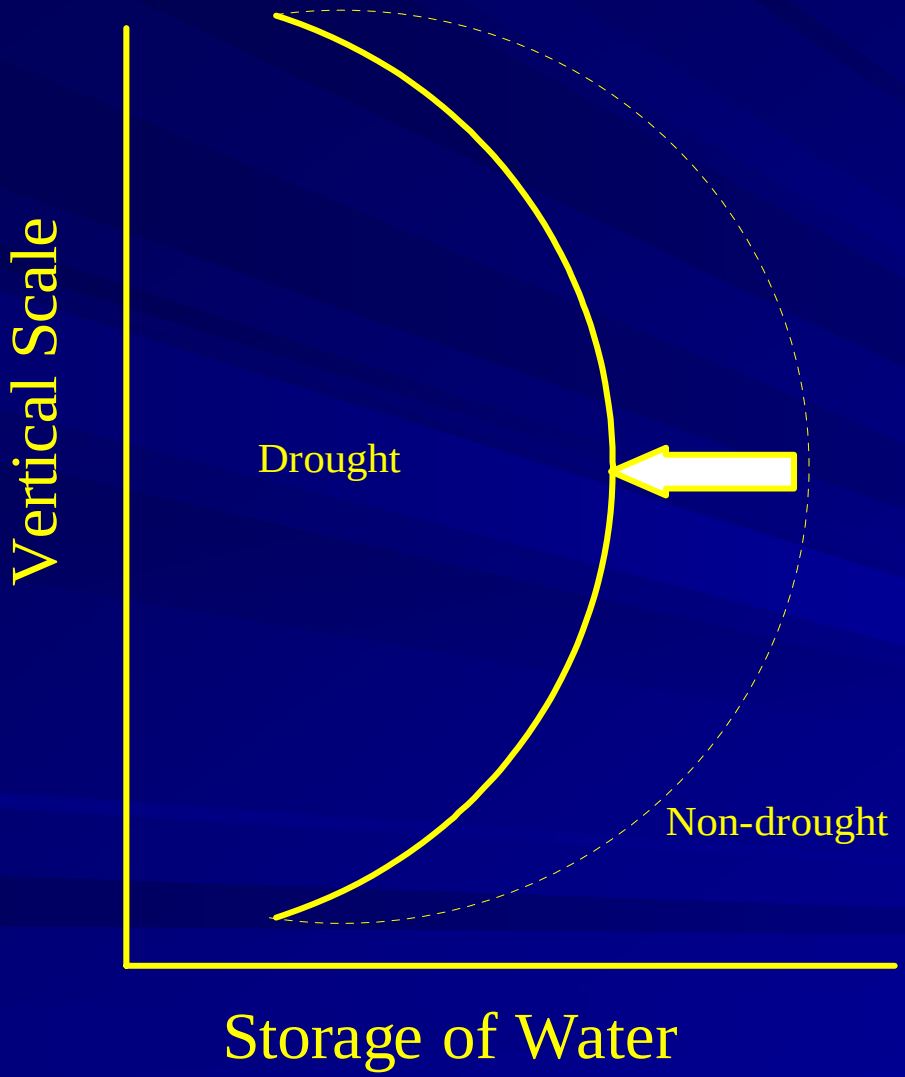


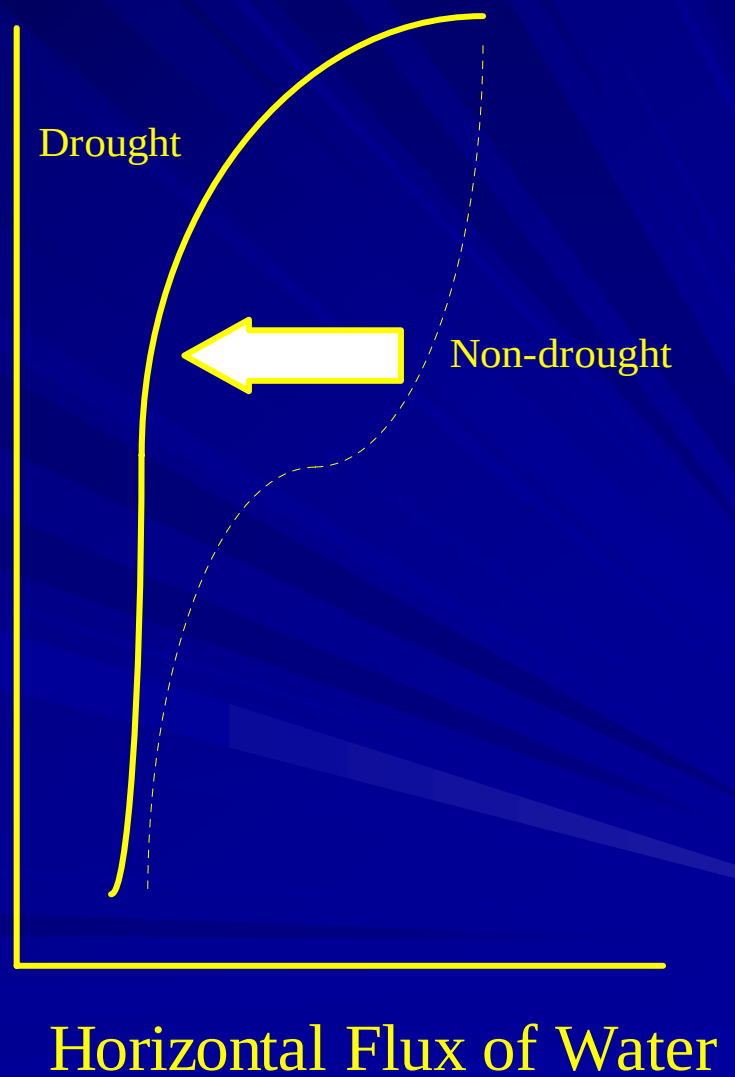
GRACE satellite



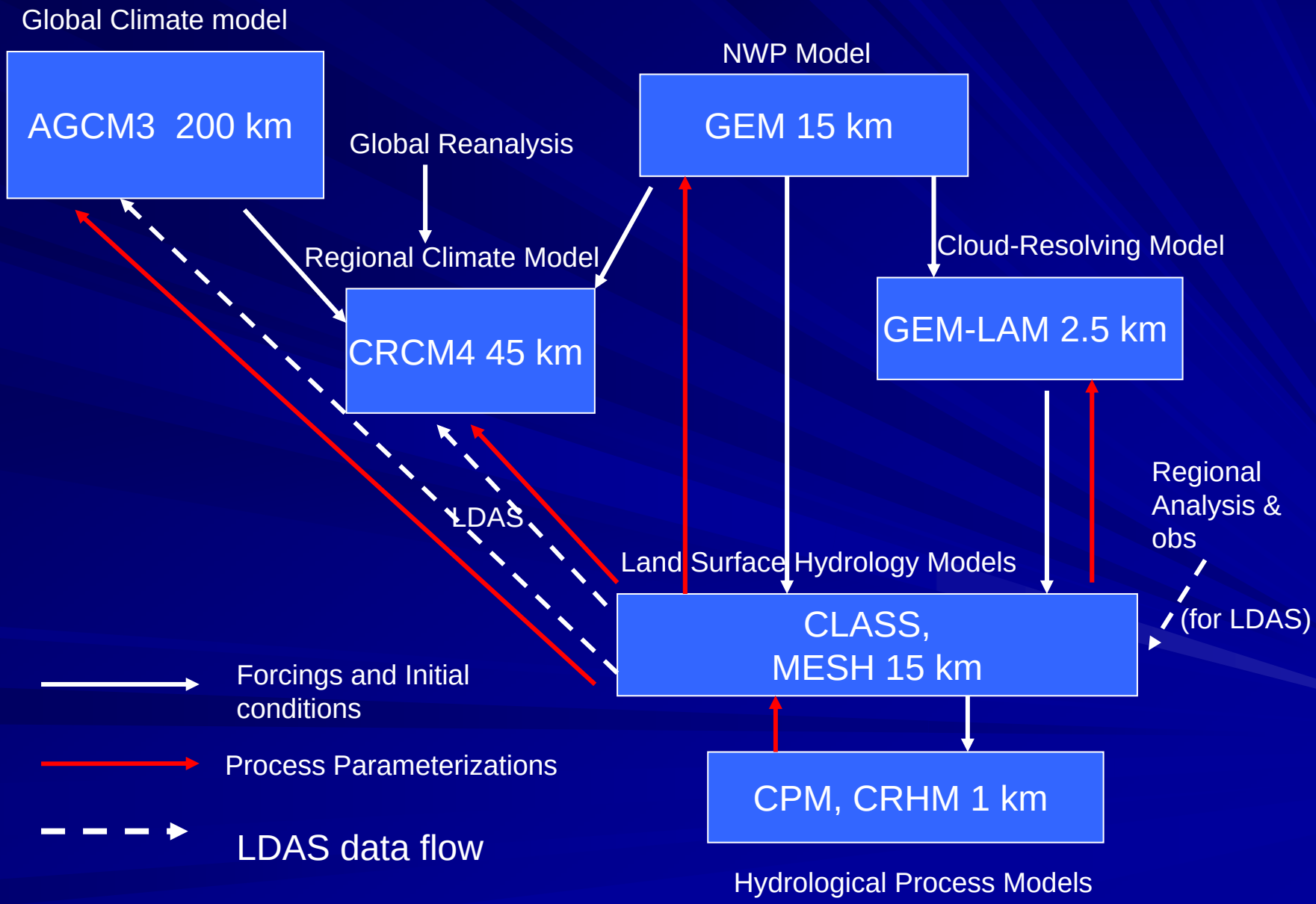
Wells in South Saskatchewan

2. UNDERSTAND THE DROUGHT



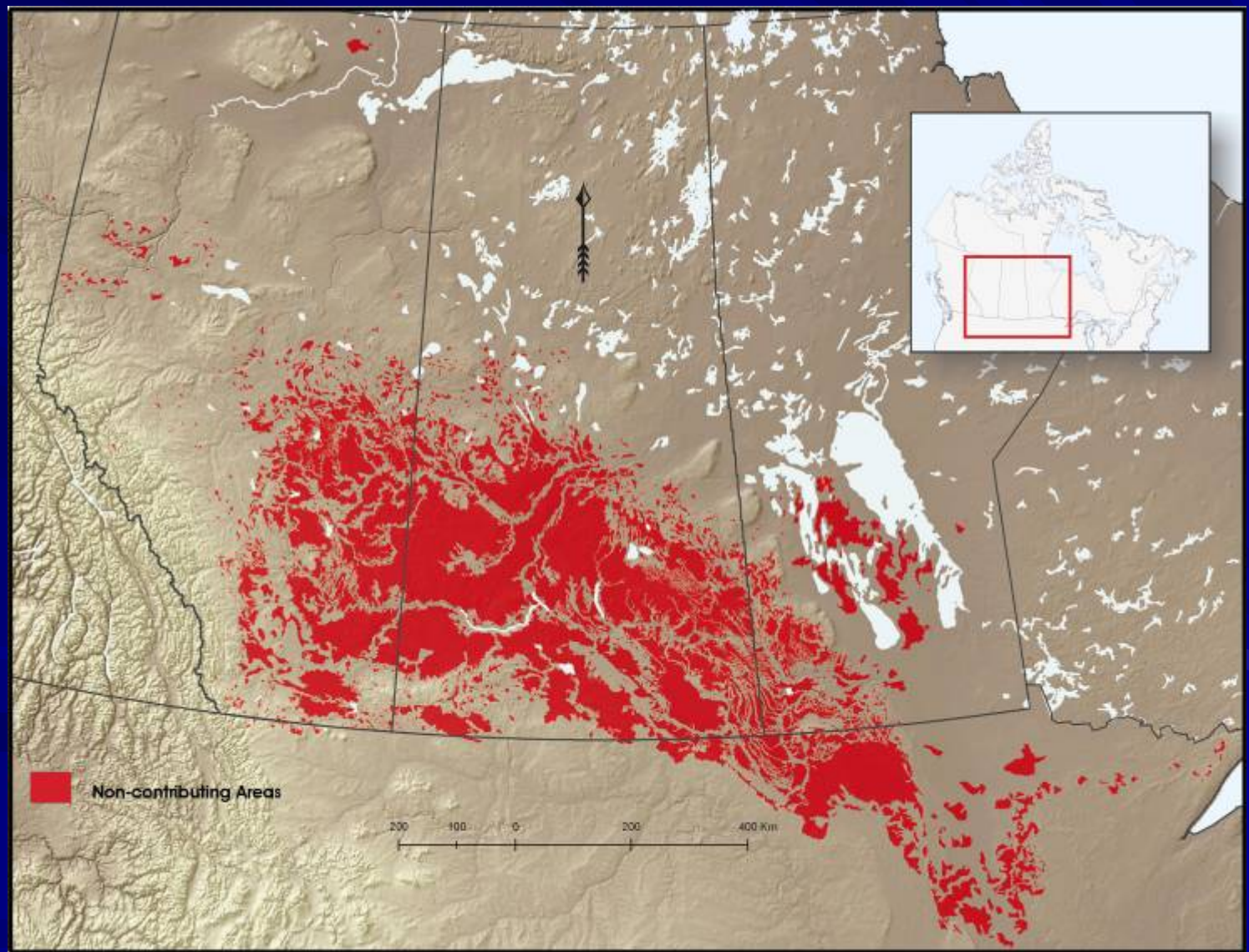


3. SIMULATE AND PREDICT THE DROUGHT

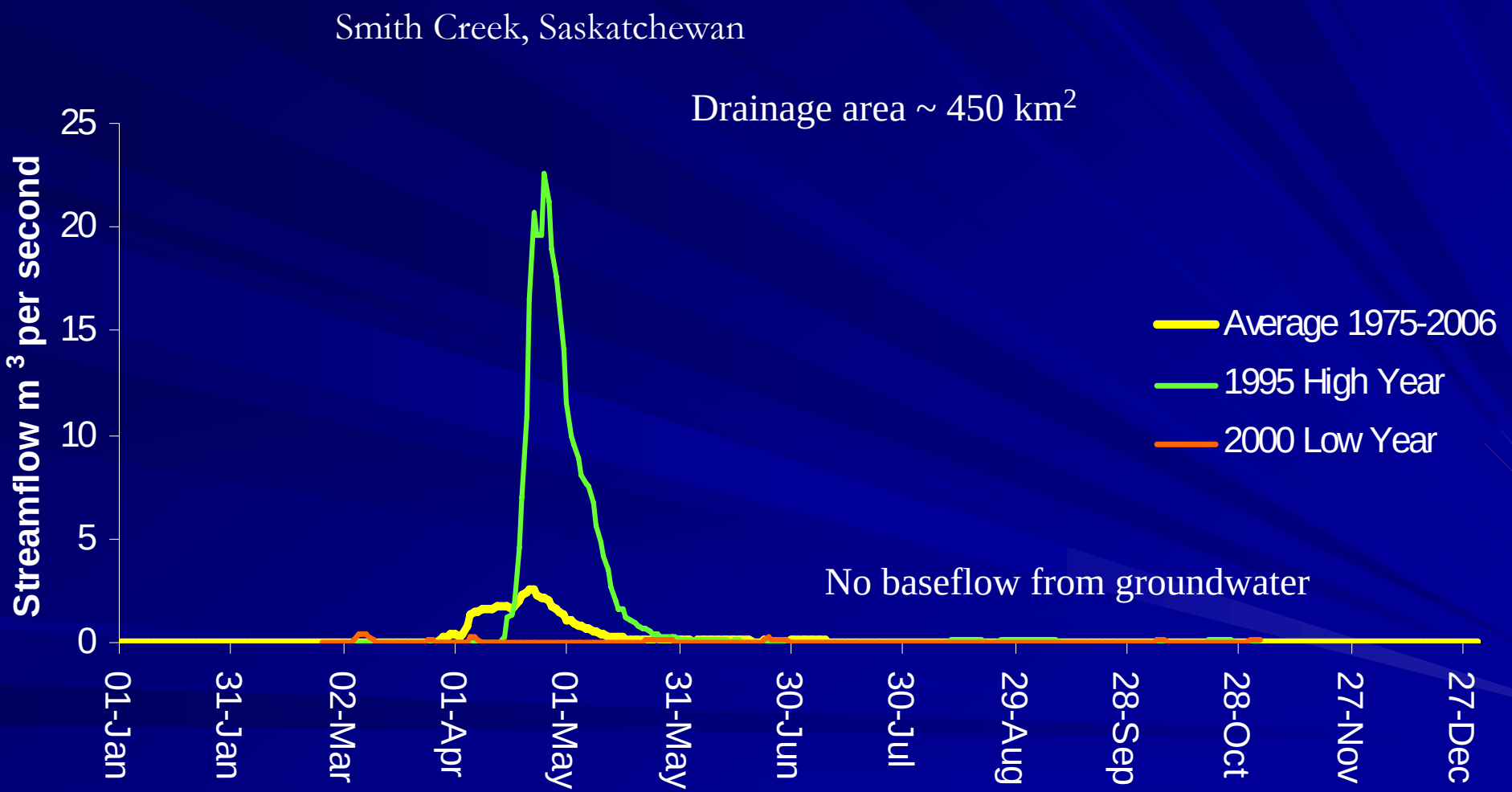


Canadian Prairie Runoff Generation

Runoff Non-Contributing Areas to Streamflow a Prairie Characteristic



Prairie Streamflow – very seasonal



Hydrological drought can be viewed as the absence of prairie runoff……

Sparse Prairie Streamflow Network for Drought Analysis

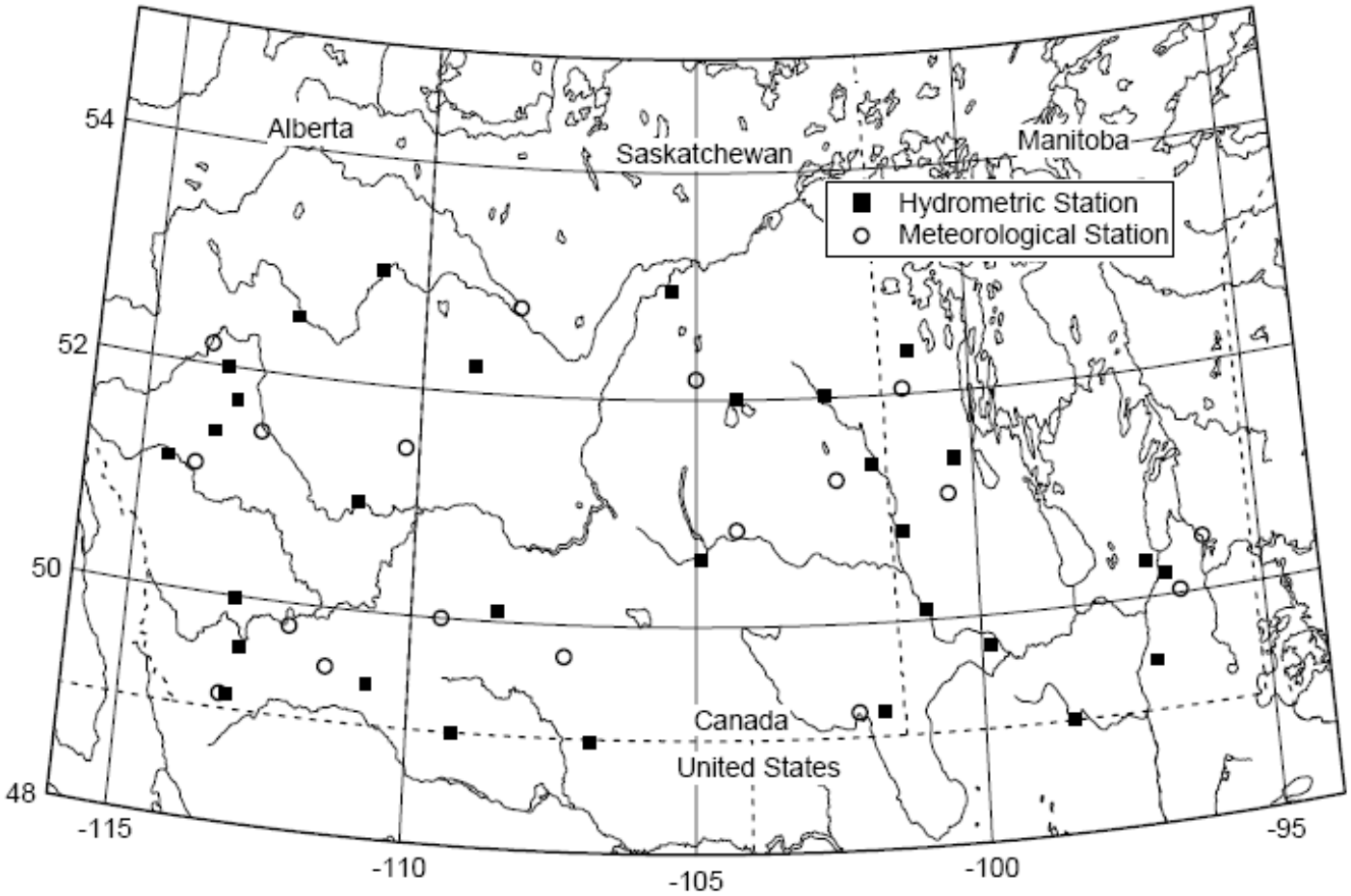


Fig. 1 Location of the hydrometric and meteorological stations used for trend analysis in the Canadian provinces of Alberta, Saskatchewan and Manitoba.

Burn et al., 2008

Inadequate coverage to characterise prairie runoff

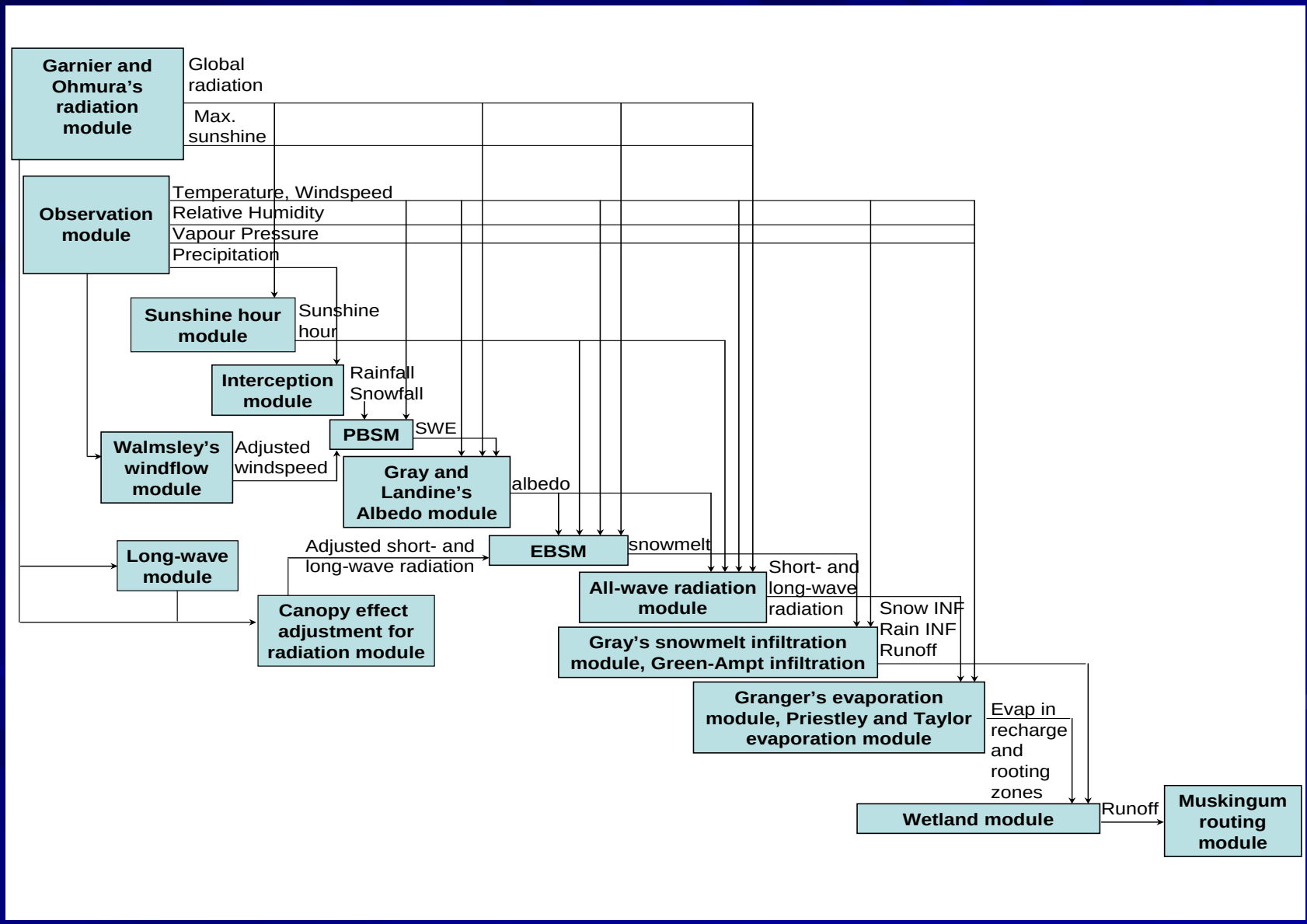
How to Characterise Hydrological Drought for the Prairies?

- River flows reflect Rocky Mountain, but not Prairie hydrological conditions.
- Streamflow network is very sparse.
- Modelling required to create a hydrological drought “surface” for the Prairies over small first order basins.

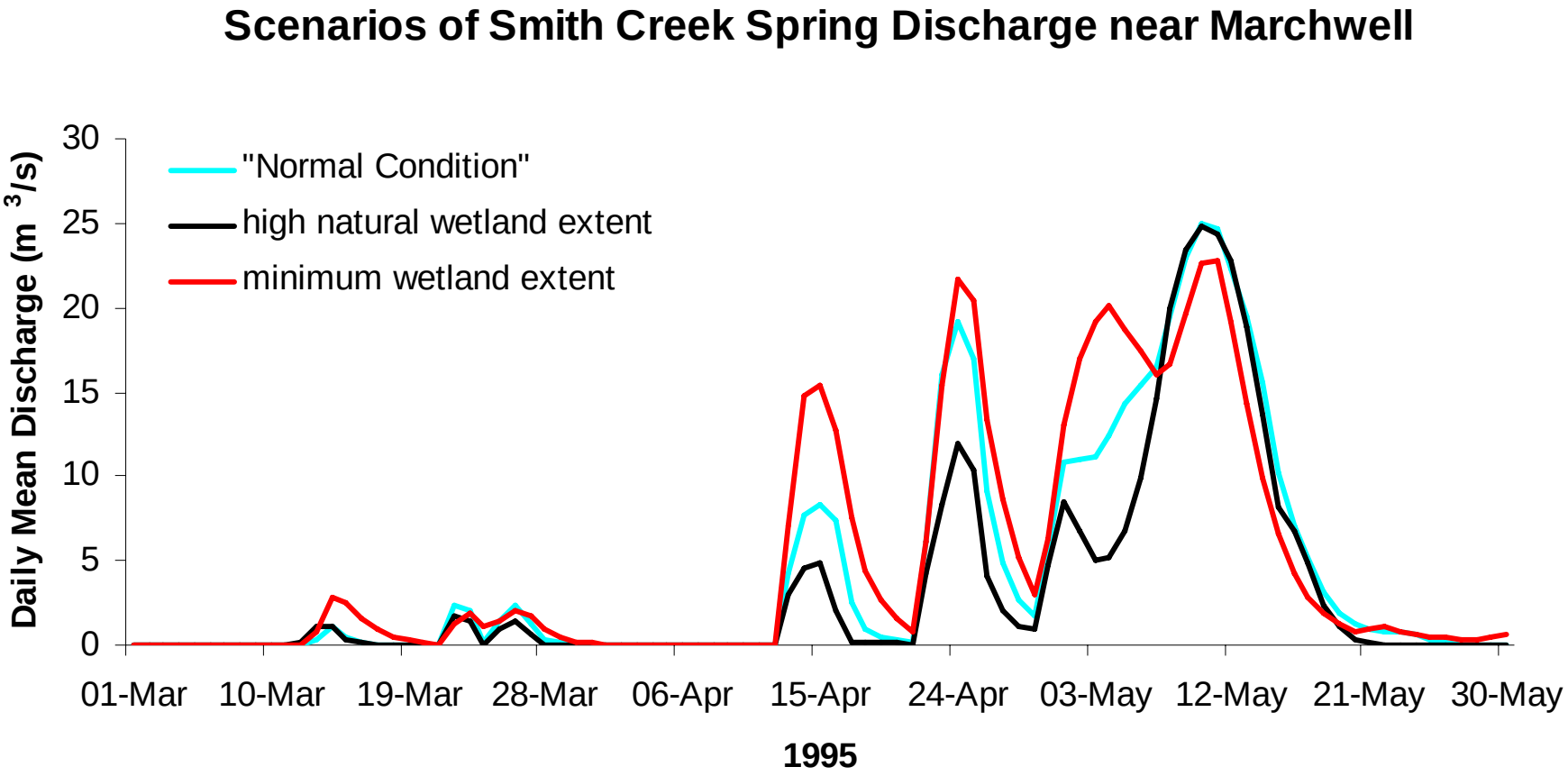
Cold Regions Hydrological Model (CRHM) Drought Hydrology Simulation

- Create “virtual” representative basin models, which can produce simple exceedence probability drought indices
- Allows comparison of basin response to drought conditions and to historical variability
- Requires high resolution driving data over entire Prairies for normal (1961-1990), non-drought (1962-1987) and drought periods (1999-2004)
  - Snowfall, rainfall
  - Temperature
  - Humidity
  - Wind speed

CRHM Prairie Module Structure

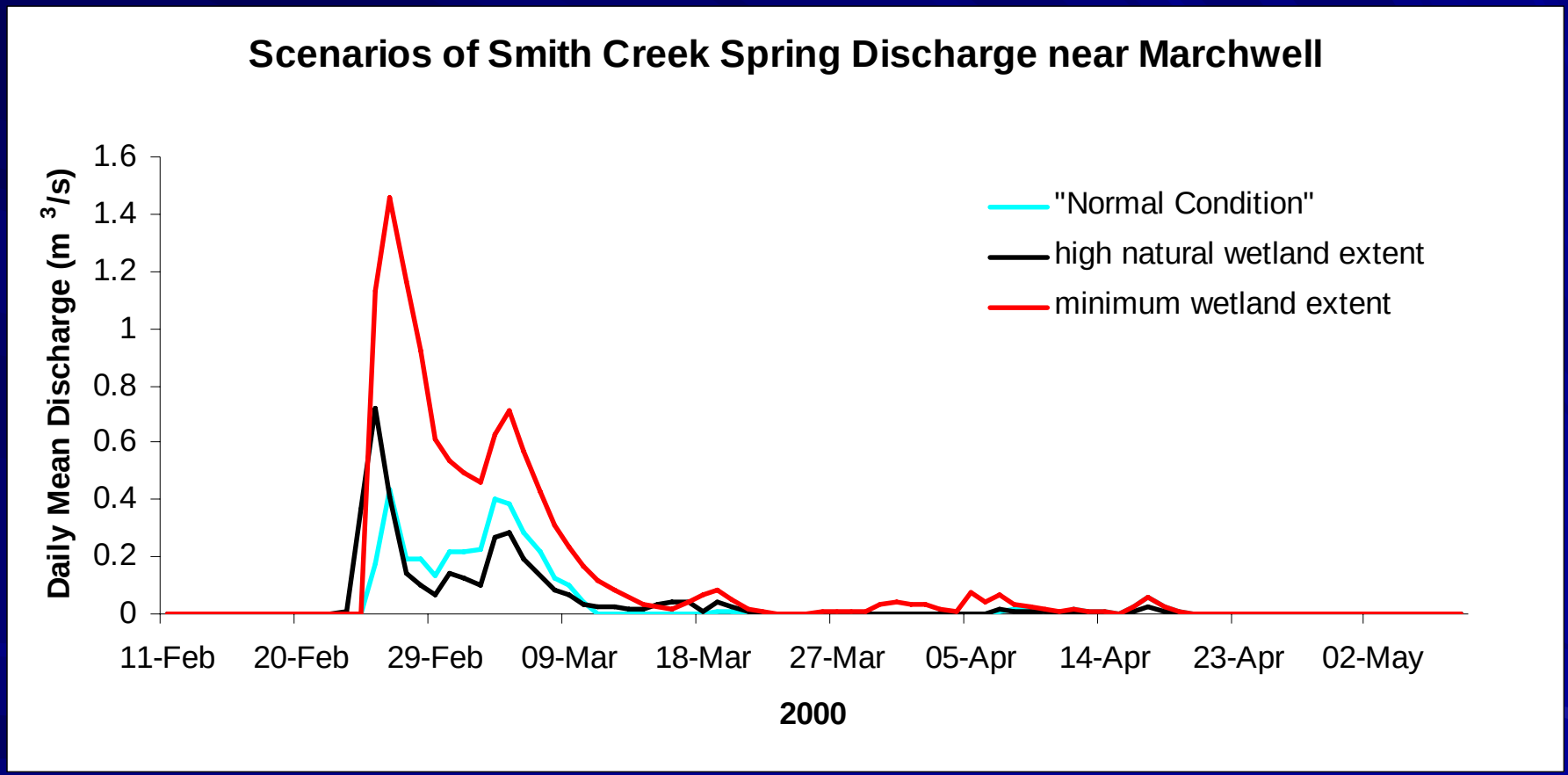


Impact of Wetland Change on Streamflow in a Wet Year



1995 Flood: Record High Discharge Volume

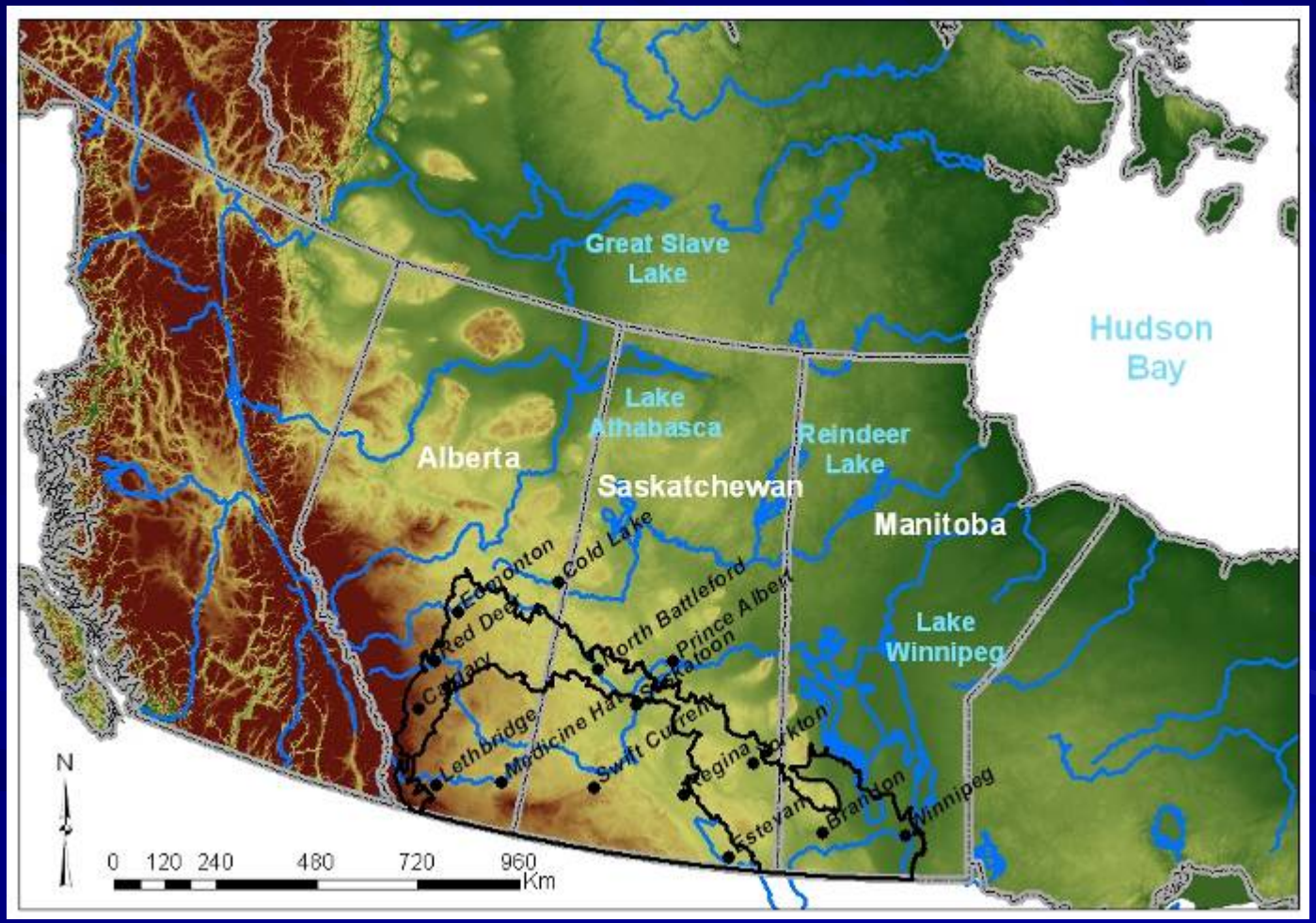
Impact of Wetland Change on Streamflow in a Drought Year



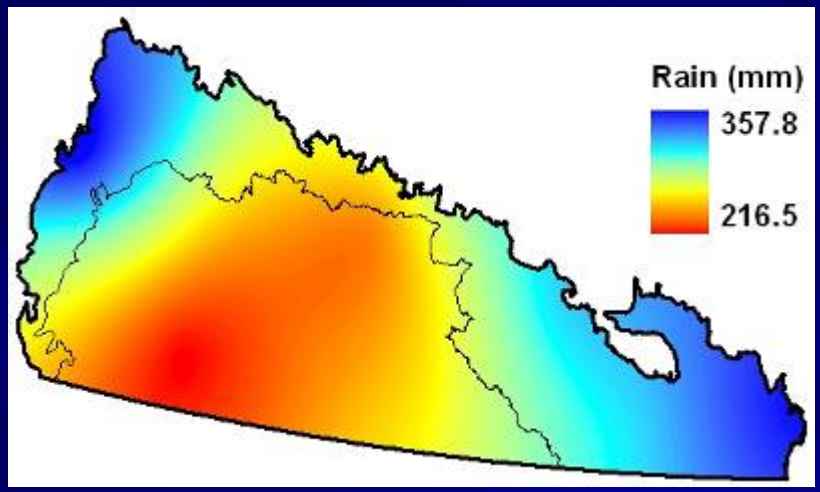
2000 Drought: Lowest Discharge Volume on Record

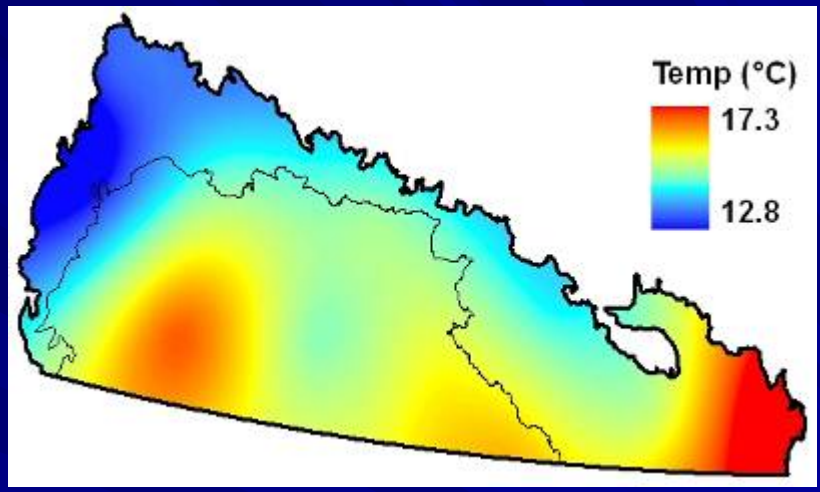
Drought Hydrology Simulations

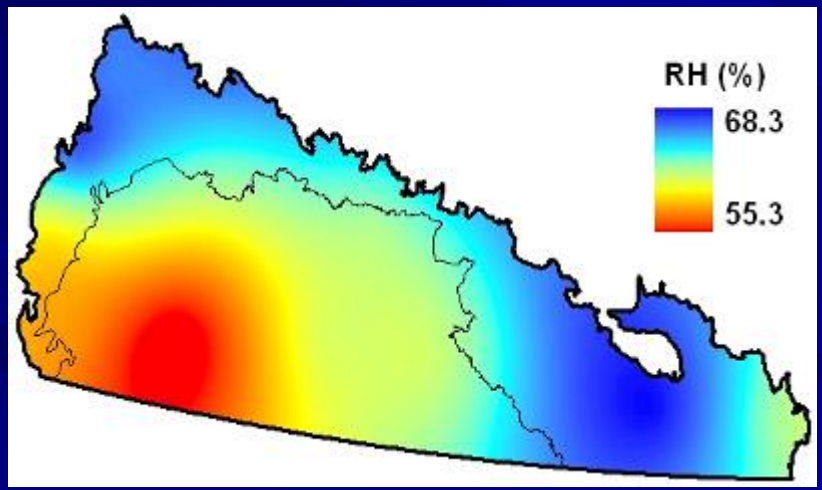
Station locations & Prairie ecozone

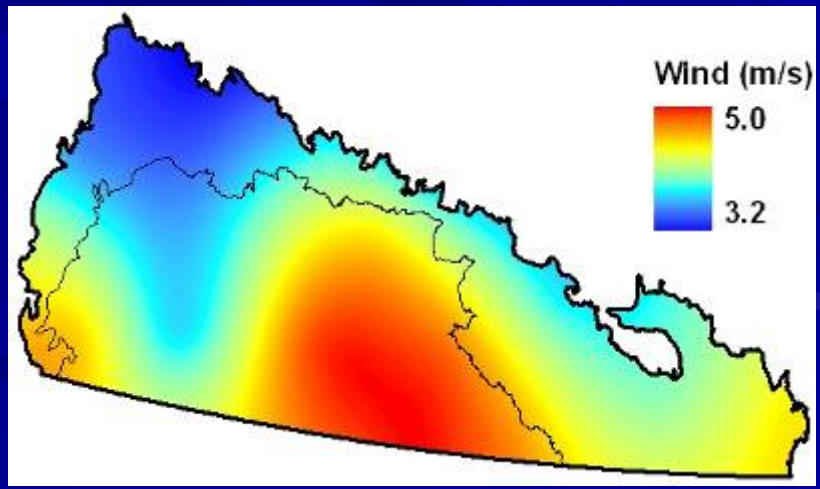


Summer Growing Season Climate Normals (1971-2000)









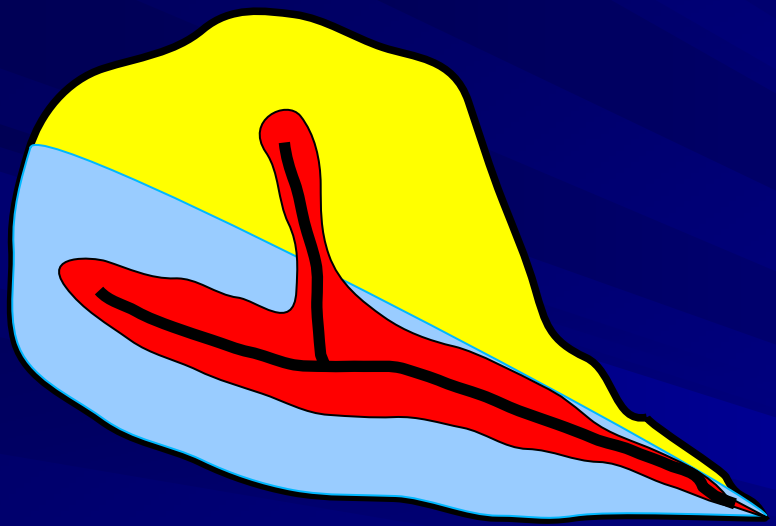
Dry southwestern zone is suited for pasture rather than dryland farming

CRHM Surface Water Drought Modelling

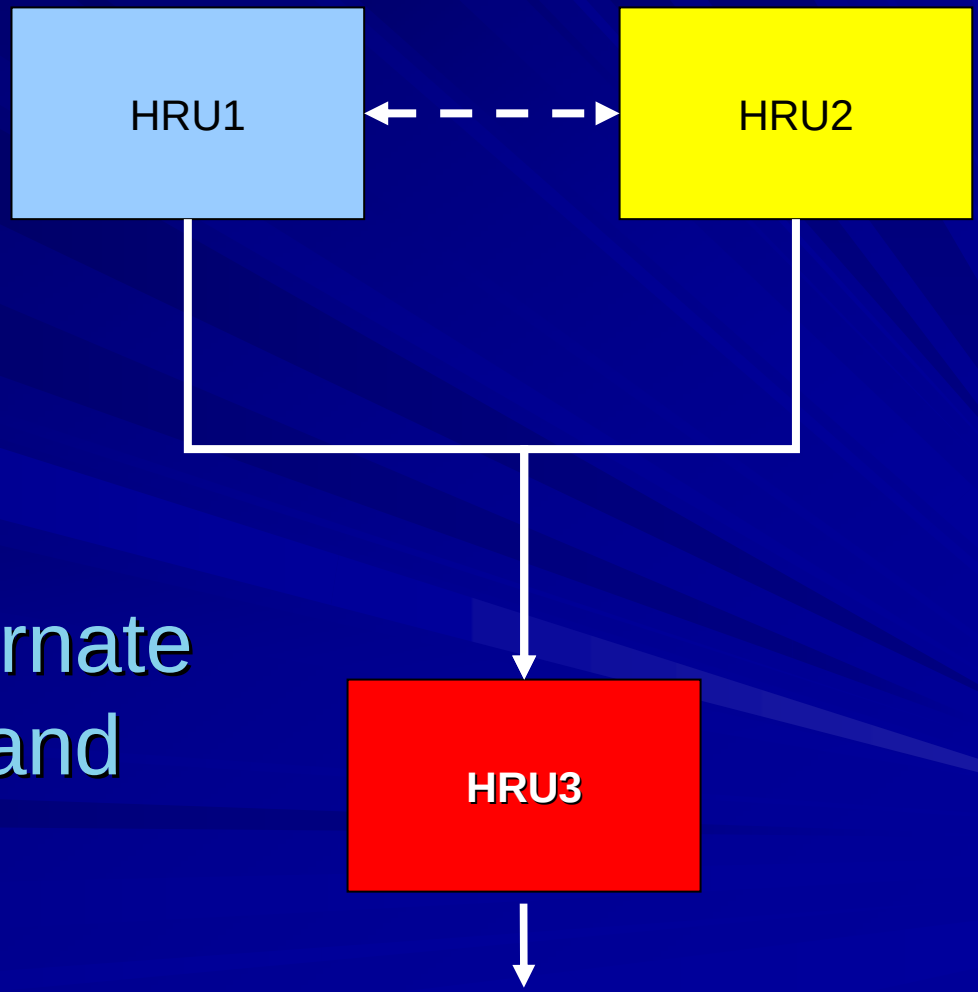
- CRHM was used to create “virtual” model of typical prairie upland basin
- Model was run over climate normal period (1961-1990)
- Output during drought period was compared to normal period and spatially interpolated

CRHM model of small upland prairie stream basin

Small stream basin

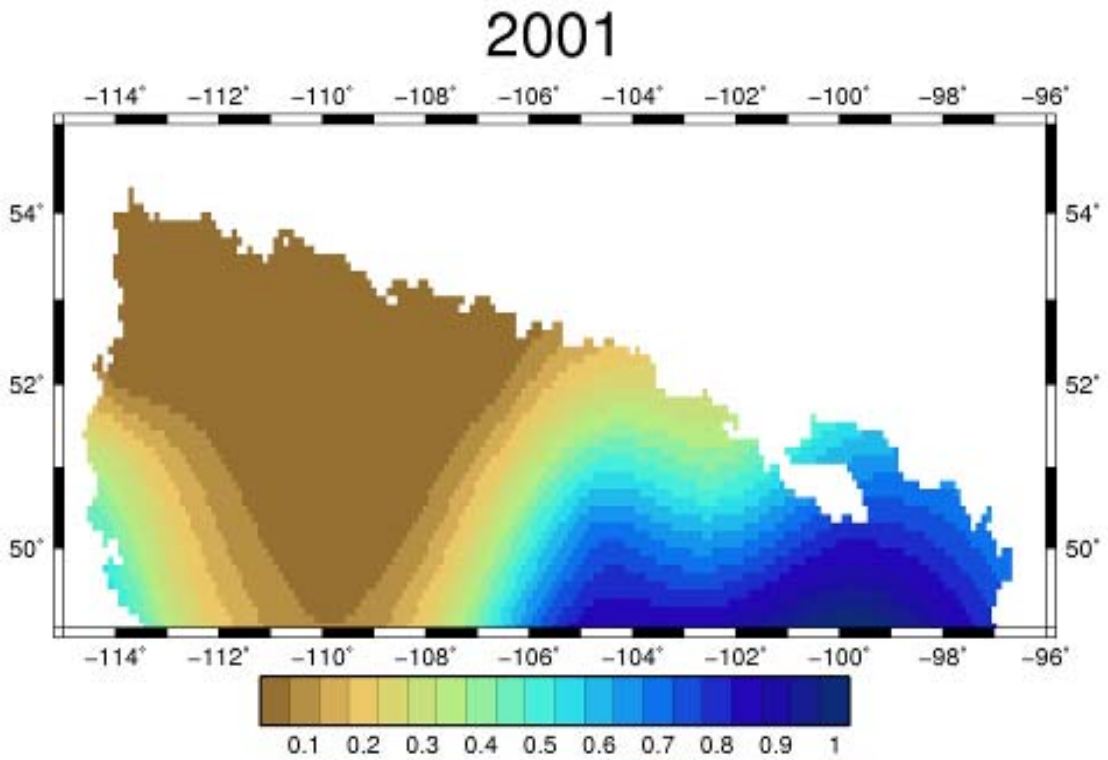


CRHM model

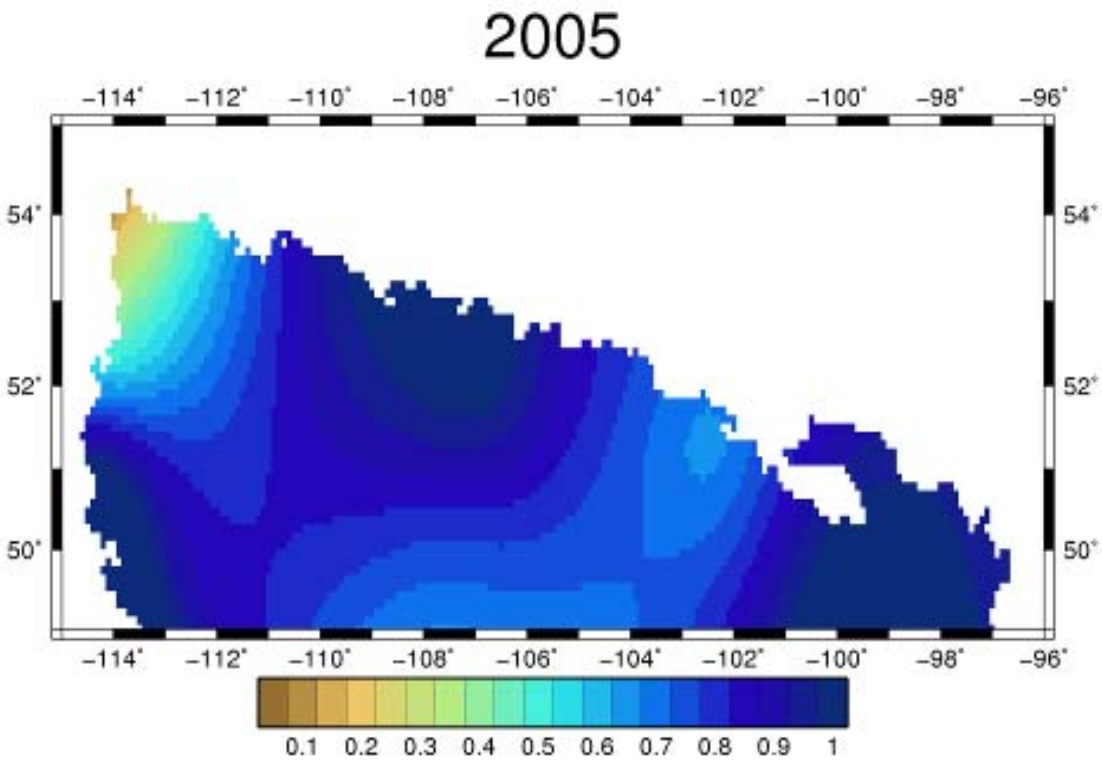


- HRUs 1 and 2 alternate between cropped and fallow
- HRU3 is grassed

Prairie Spring Discharge 2001 Drought

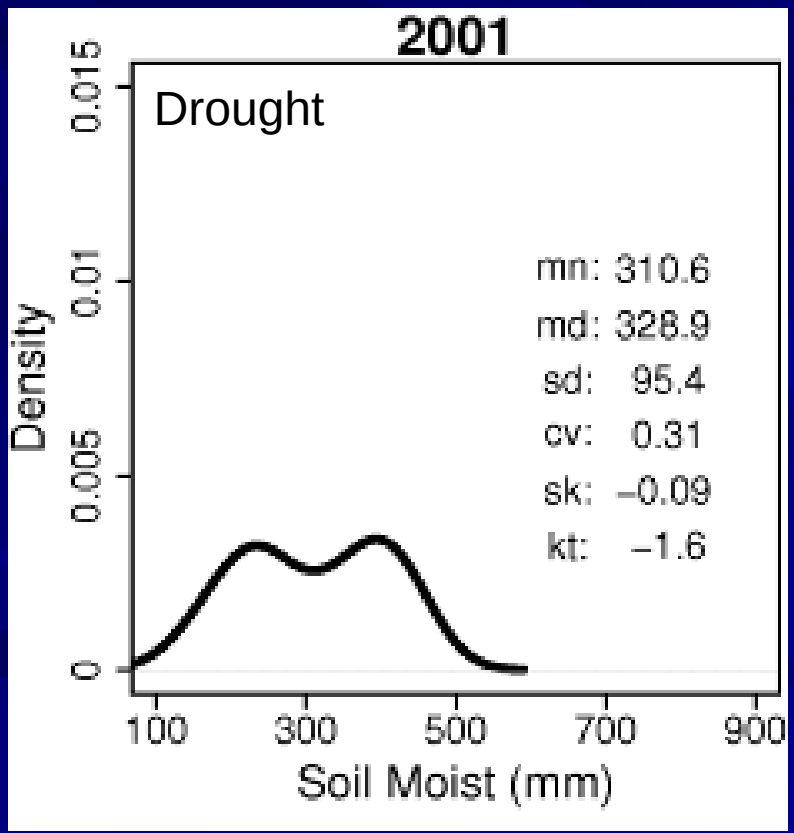


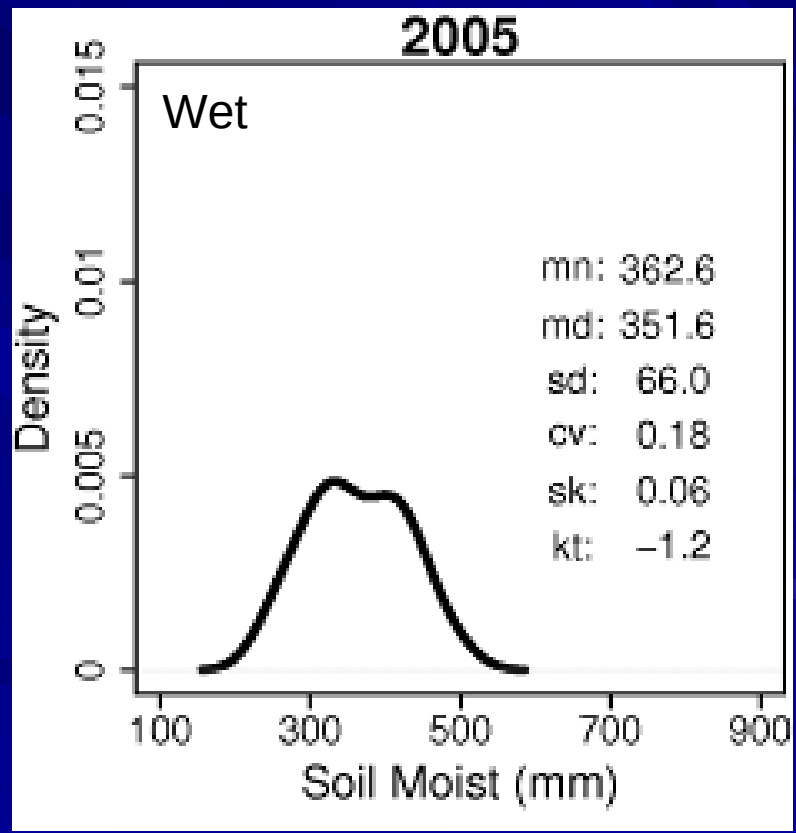
Prairie Spring Discharge 2005 Wet Year



Spatial Variation of Prairie Soil Moisture (Drought vs Wet)

- Mean for normal period 332 mm
- Drought period: distribution wide, variance large, median > mean
- Wetter period: distribution loses low soil moisture, variance smaller, median < mean

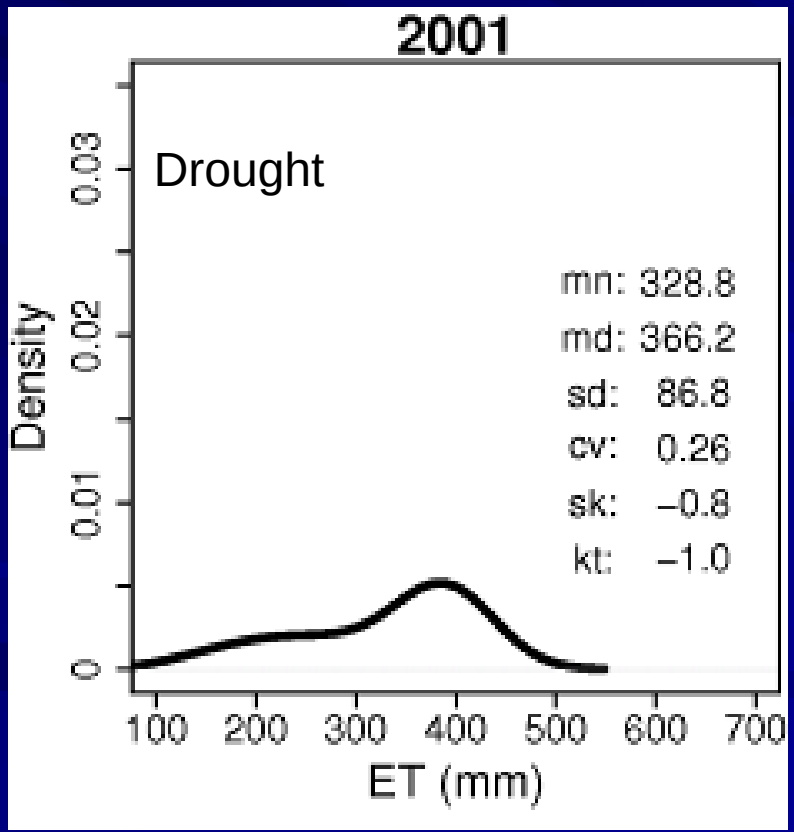


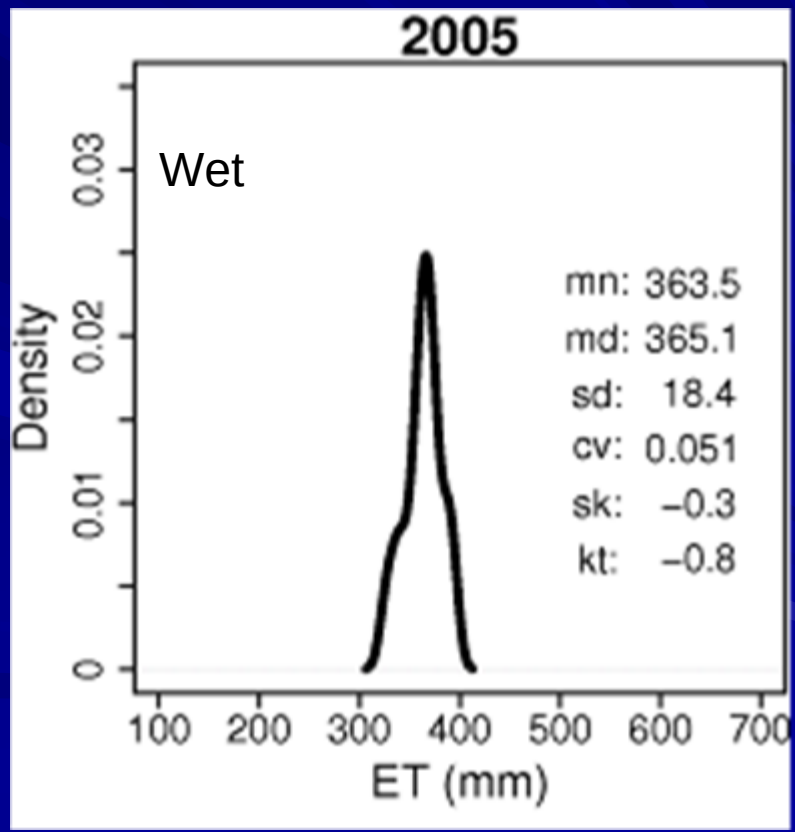


Probability density of soil moisture

Spatial Variation of Evapotranspiration (Drought vs Wet)

- Mean for normal period 352 mm
- Drought period: distribution wide, variance large, median >> mean
- Wetter period: distribution symmetric, variance greatly reduced





Probability density of evapotranspiration

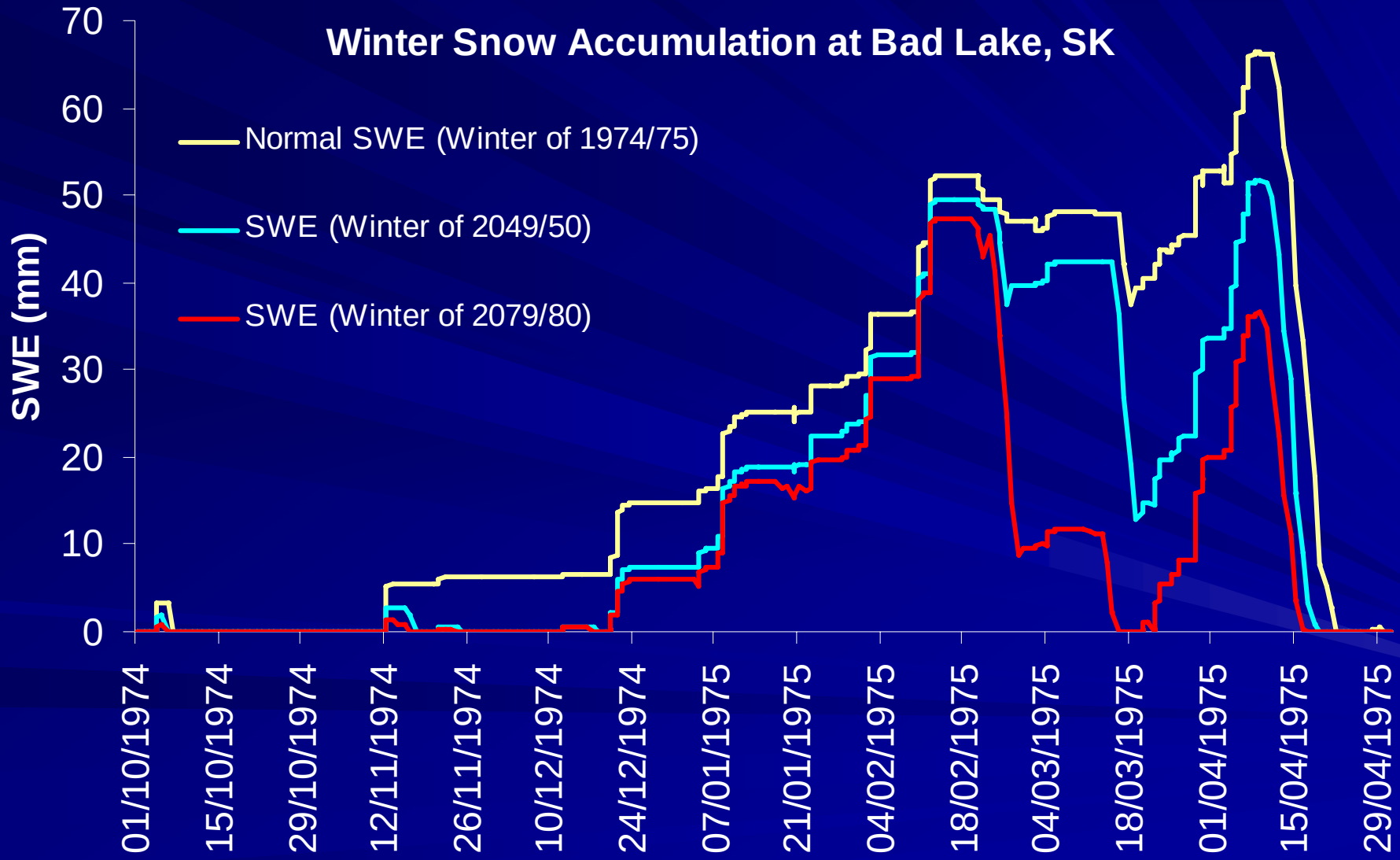
Climate Change Impacts

- Virtual basin model also useful for estimating climate change impacts on Prairie hydrology
- Climate warming has a strong effect on cold season hydrological processes.

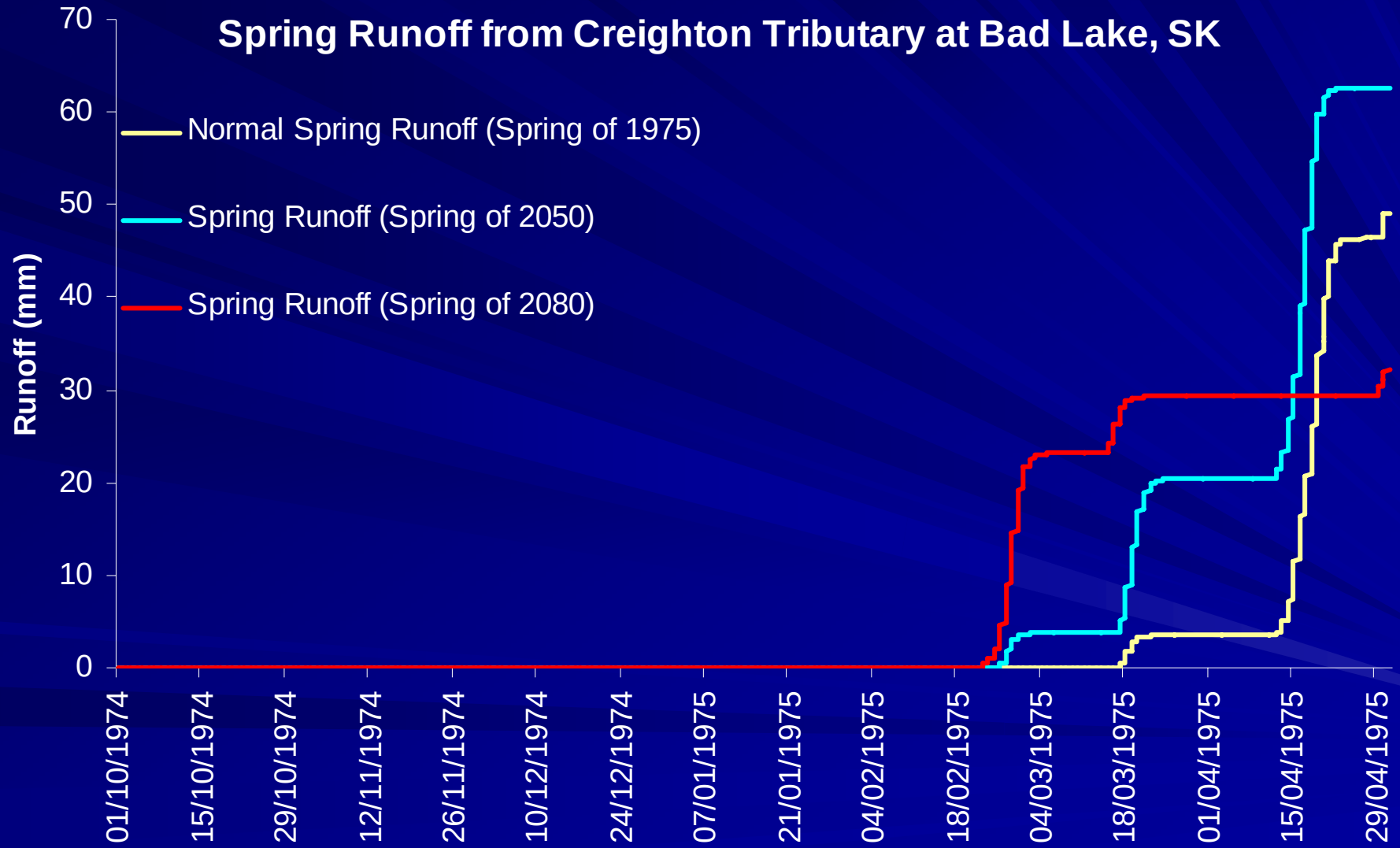
Prairie Streamflow & Climate Change
First more, then less

- Three most reliable climate change scenarios suggest increases in annual prairie winter temperature and precipitation from the 1961-1990 average:
  - 2050 +2.6 ºC and +11%
  - 2080 +4.7 ºC and +15.5%
- Using these scenarios in the virtual upland basin results in a 24% rise in 2050 spring runoff, but a 37% drop by 2080, compared to conditions in the mid 1970s.

Prairie Climate Change – Winter Snow



Prairie Climate Change – Spring Runoff



Conclusions

- Prairie streamflow is inherently unreliable in drought,
  - Hydrological droughts migrate across the Prairies.
  - Drought increases the variability of soil moisture, evapotranspiration and snowpack
- Future climate change likely to first increase then decrease spring snowmelt runoff from prairie drainages.
  - Flooding
  - Shortages
- If droughts also increase, this means greater use will need to be made of mountain-derived river water supplies for agriculture

Thanks!

- The gracious invitation of ISACS-3 and financial support of National Natural Science Foundation of China made this presentation possible.