



Prairie Drought Surface Hydrology

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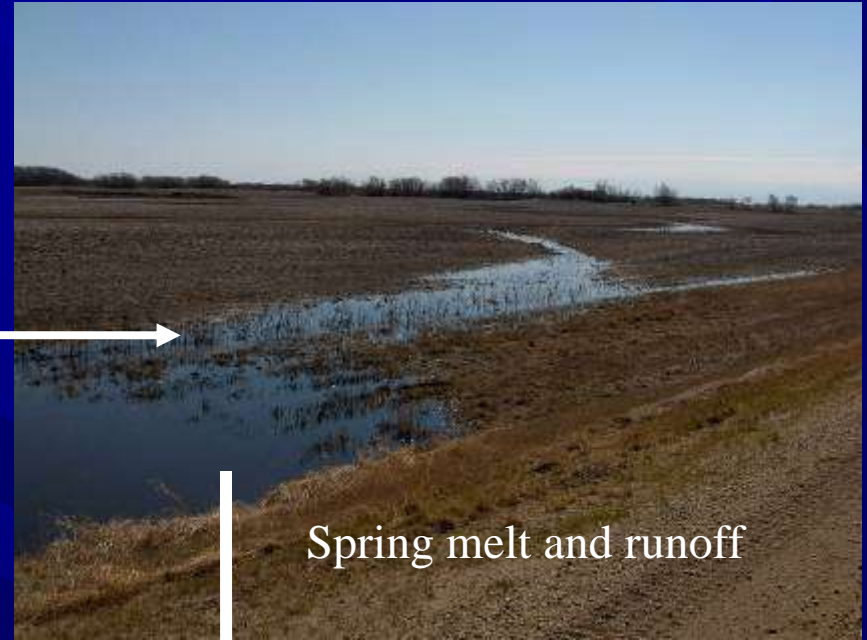


Prairie Runoff Generation

Snow Redistribution to Channels



Spring melt and runoff



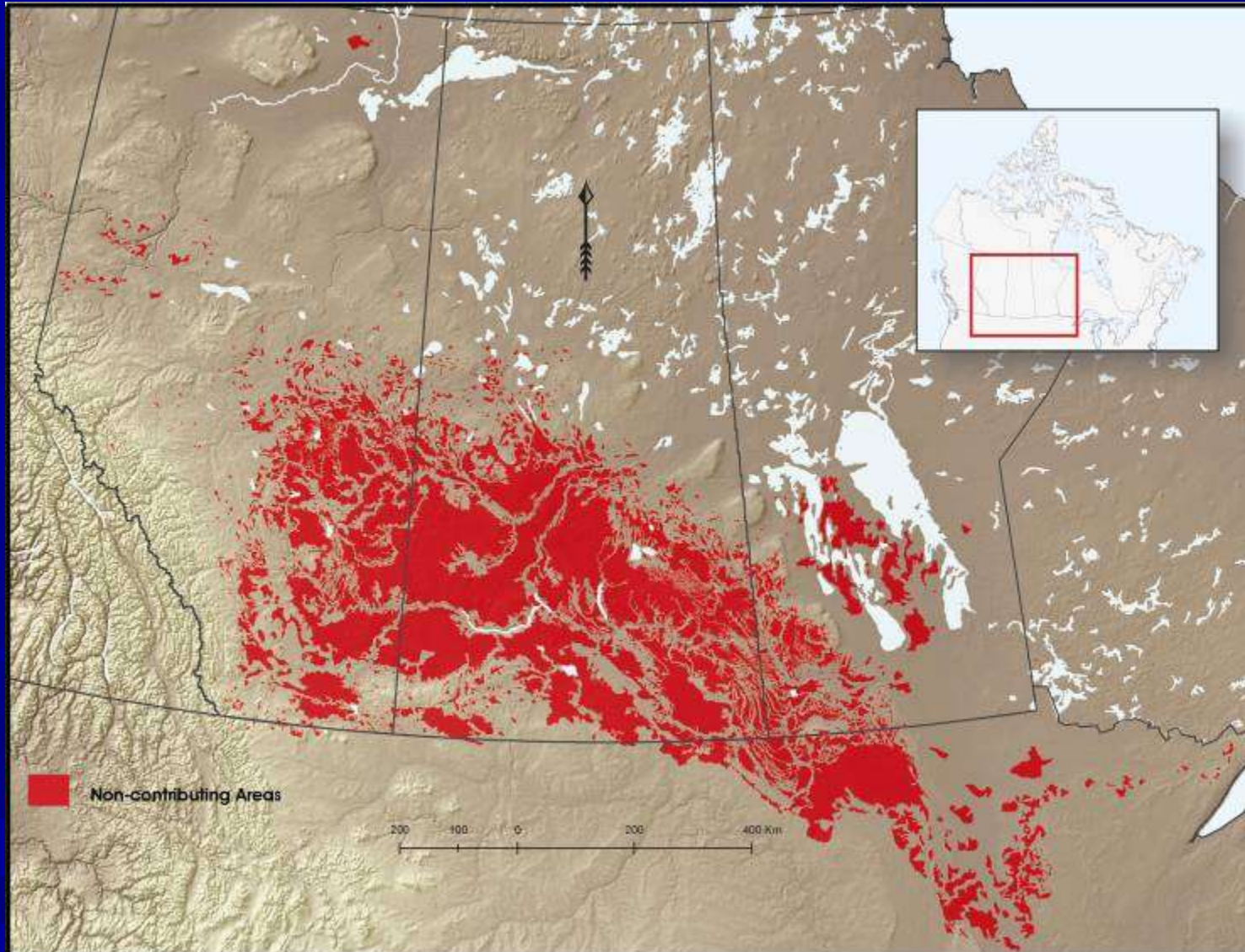
Dry non-contributing areas to runoff



Water Storage in Wetlands



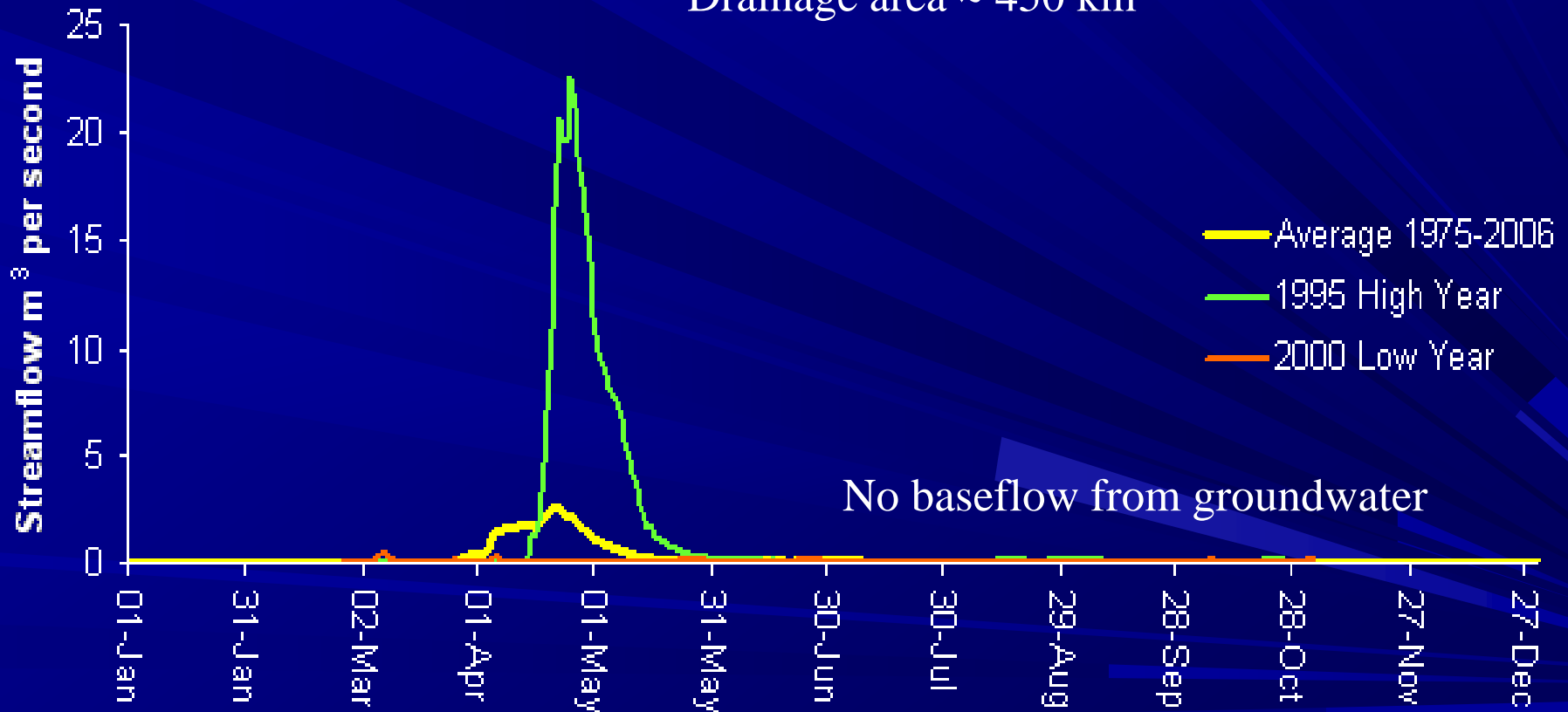
Non-Contributing Areas to Streamflow a Prairie Characteristic



Prairie Hydrology – don't blink

Smith Creek, Saskatchewan

Drainage area ~ 450 km²



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

How to Characterise Hydrological Drought for the Prairies?

- River flows are gauged, but subject to abstraction, storage and do not reflect Prairie hydrological conditions.
- Streamflow network is more representative but is very sparse, and subject to changes in land cover, drainage, abstraction, storage.
- Possibility to model prairie runoff generation and related hydrological processes to create a hydrological drought “surface” for the Prairies using atmospheric driving data and standardised representation of prairie snow redistribution, melt, runoff generation, infiltration and evaporation over small first order prairie basins.

Cold Regions Hydrological Model (CRHM)

Drought Hydrology Simulation

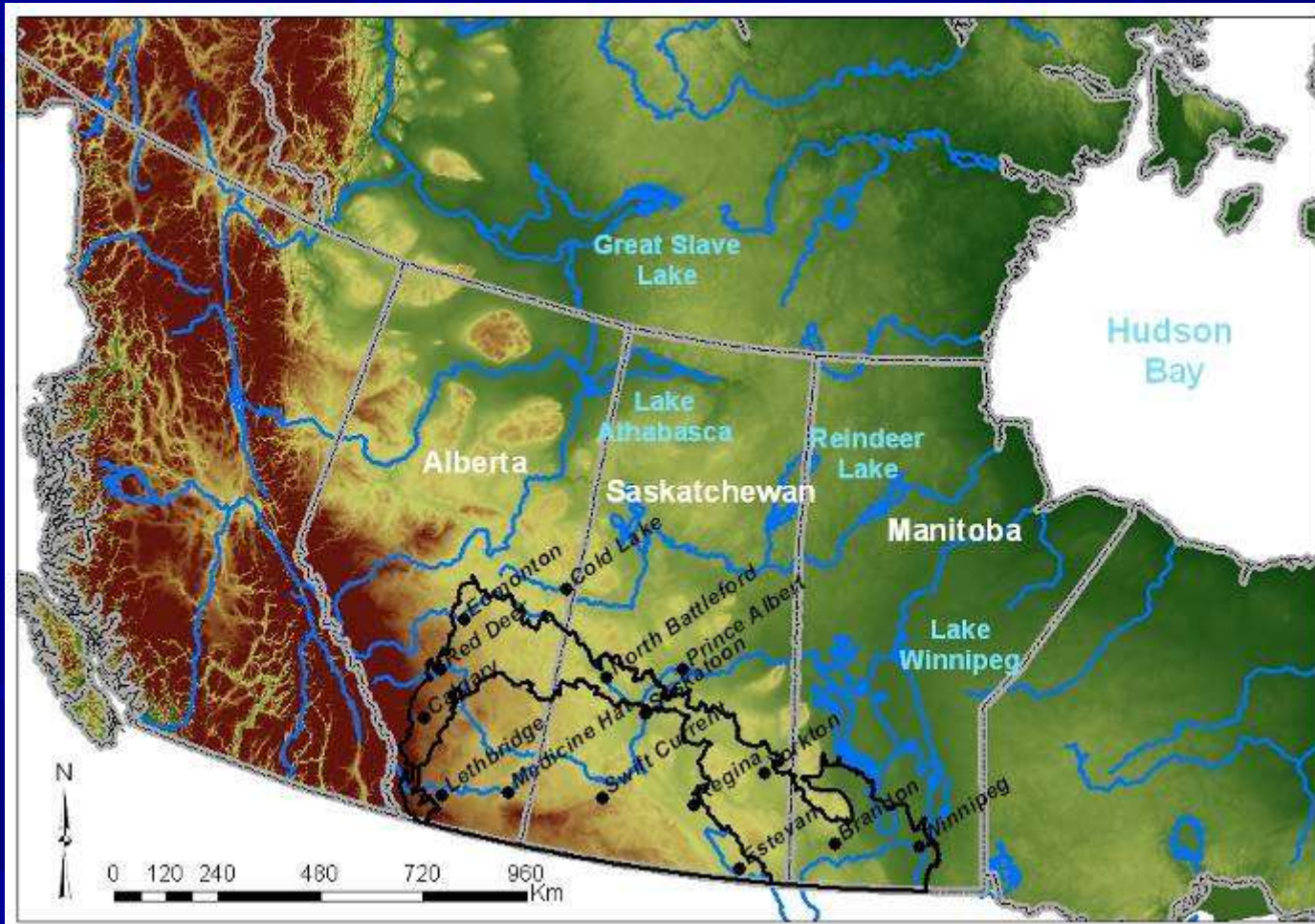
- Model the effects of local drought meteorology on the hydrology of "representative", first-order prairie basins
- Create "virtual" basin models based on real prairie basins
- Allows comparison of basin response to drought conditions and to normal variability
- Requires high resolution driving data over entire Prairies for normal periods and drought periods (1999-2004)
 - Snowfall, rainfall
 - Incoming shortwave radiation, cloudiness or sunshine hours
 - Temperature
 - Humidity
 - Wind speed

Model Setup

- Continuous model simulations using CRHM
 - Each location over 46 year period (1960-2005/06)
 - blowing snow transport, sublimation, snowmelt
 - infiltration into frozen and unfrozen soils
 - ET is calculated by the Penman-Monteith (1965,1981) method
 - soil moisture accounting and runoff to estimate actual evaporation during snow free period
- Vegetation: simple linear growth to max heights (crop/fallow and grass)
 - Stubble left for snow capture; Fallow no growth
 - Specified Julian dates for start, maturity and harvest
- Simulations started on January,1 1960
 - Spin-up year: standardized initial soil moisture conditions at each location : 50% of available water holding capacity (drought year)

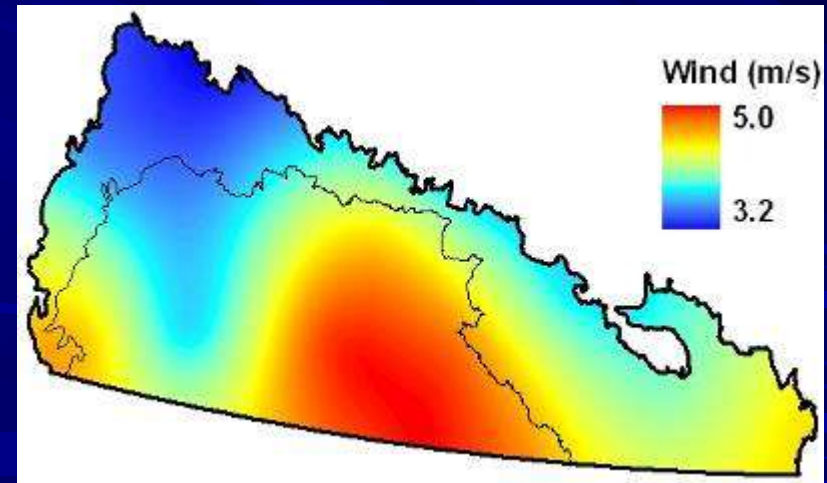
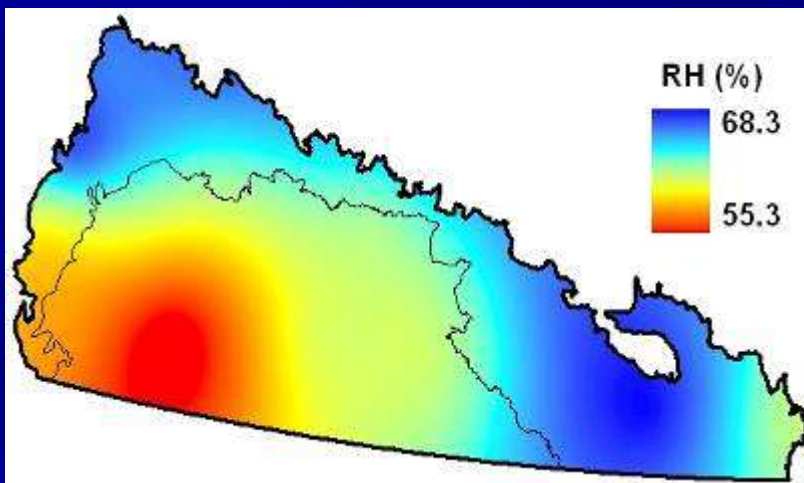
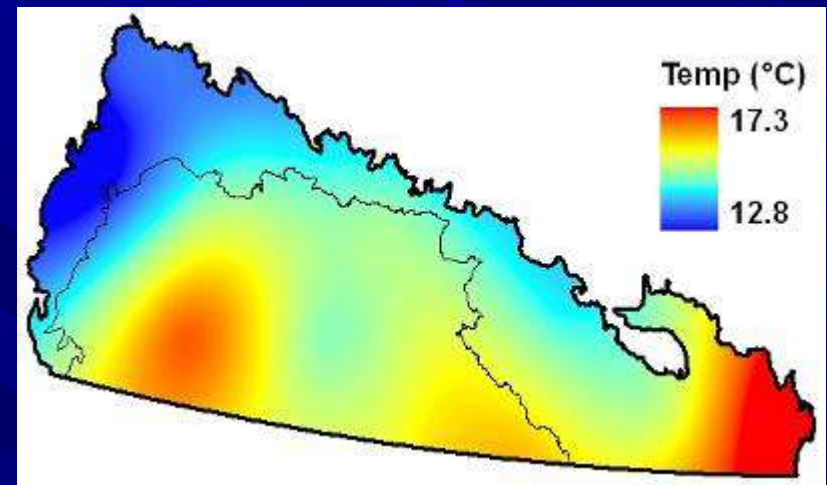
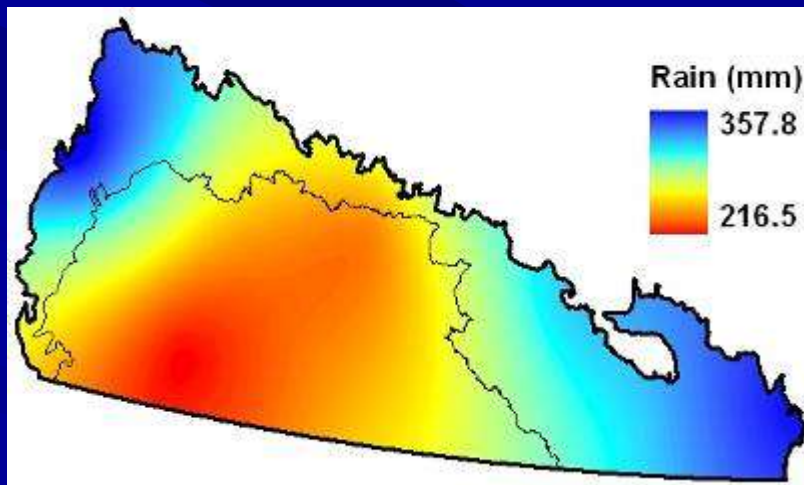
Study Region

Station locations, Prairie ecozone and
Palliser Triangle boundaries



Growing Season Climate Normals ('71-'00)

- If Capt. Palliser only had GIS!



Evapotranspiration

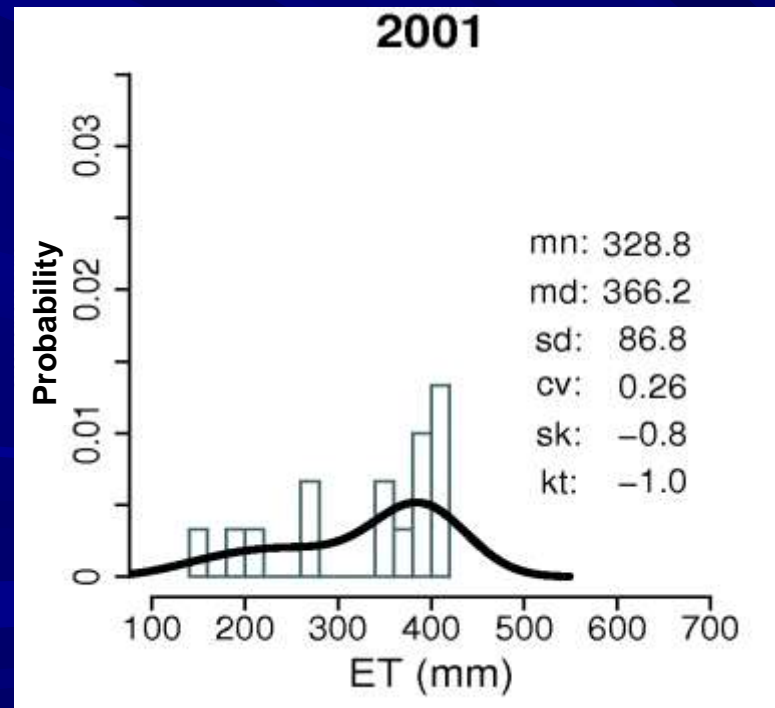
- Indicator of plant productivity, ecosystem function
- Impaired by drought and cold weather
 - Lower in cold or dry conditions
 - Higher in warm and/or wet conditions
- Controlled not only by summer meteorology, but by vegetation type, length of winter, snowmelt infiltration, runoff, soil texture, soil moisture status
- Excellent indicator of the impact of drought on surface hydrology

Examining Distributions (Probability Density)

- Better than histograms for visualizing distributions
 - Smoother and does not rely on end points of bins
 - Reveal underlying features of the distribution
- Simply the probability of a variable to occur
 - Assume the distribution can be described by the Gaussian (normal) kernel estimator which considers the standard deviation

Example showing histogram and probability density on same plot

Area under curve equal to 1

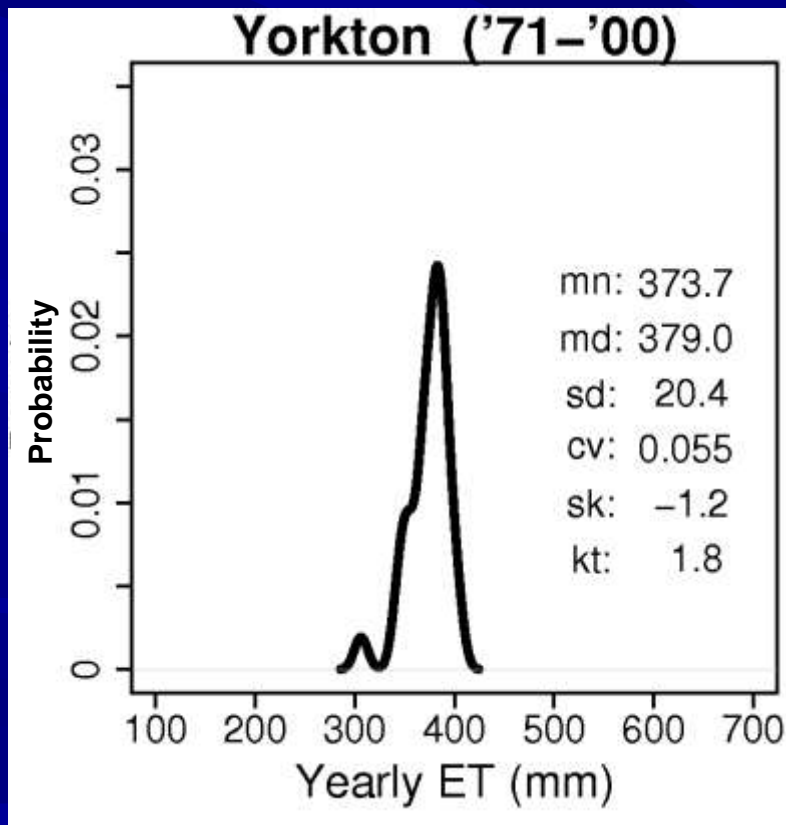


Growing Season ET: ('71-'00)

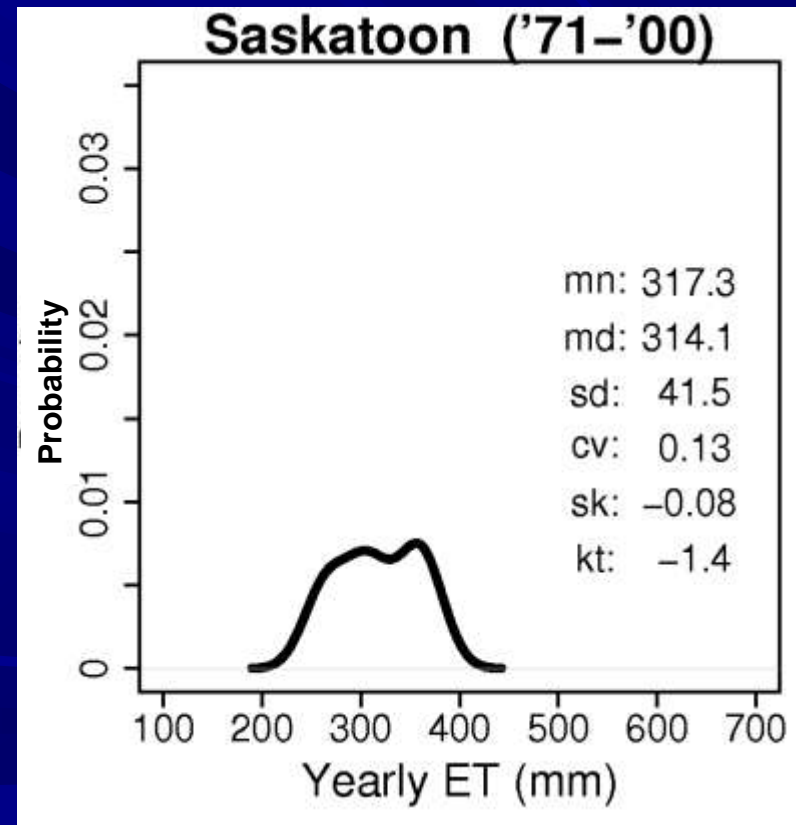
■ Climate exerts strong influence on distributions

- Outside Palliser: narrow, variance smaller, suggests drought resilience
- Within Palliser: wider, variance larger, drought prone

Outside Palliser



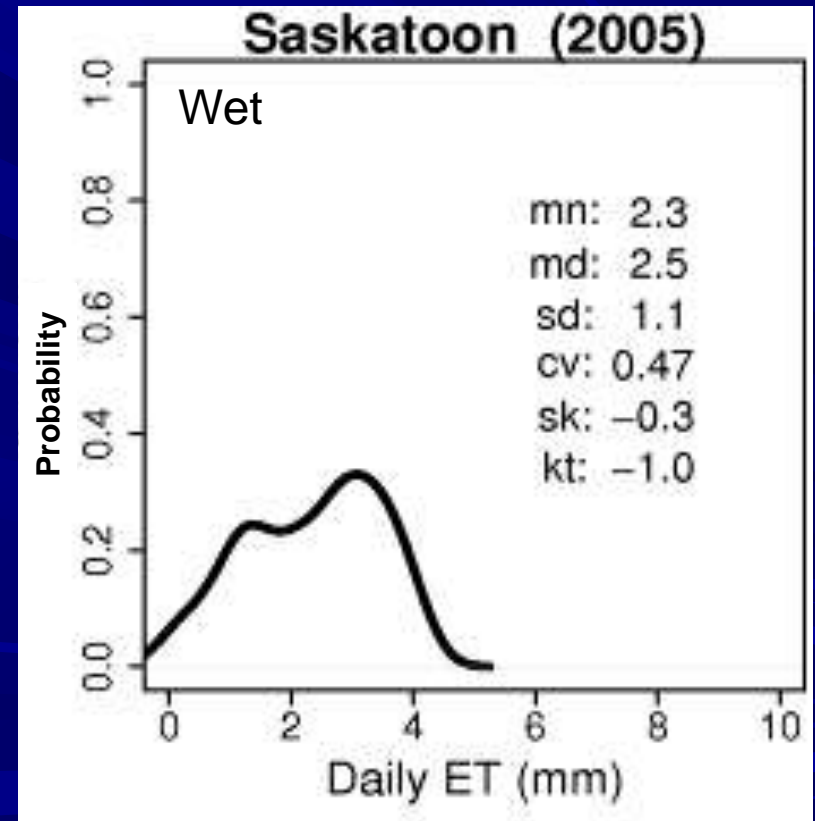
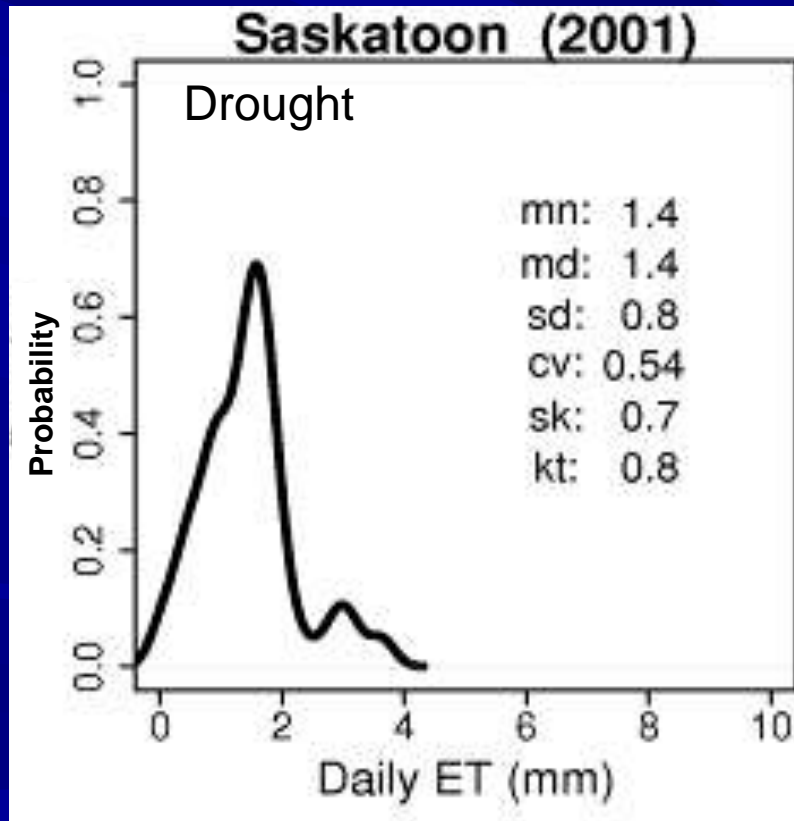
Within Palliser



Daily ET During Drought and Wet Periods

■ Influence of climate at a point

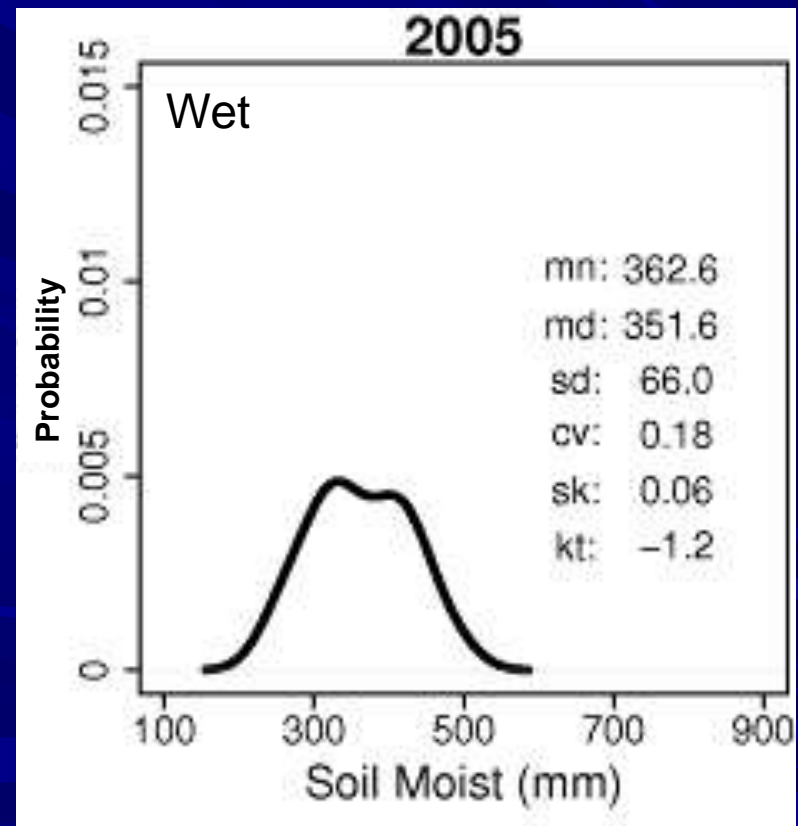
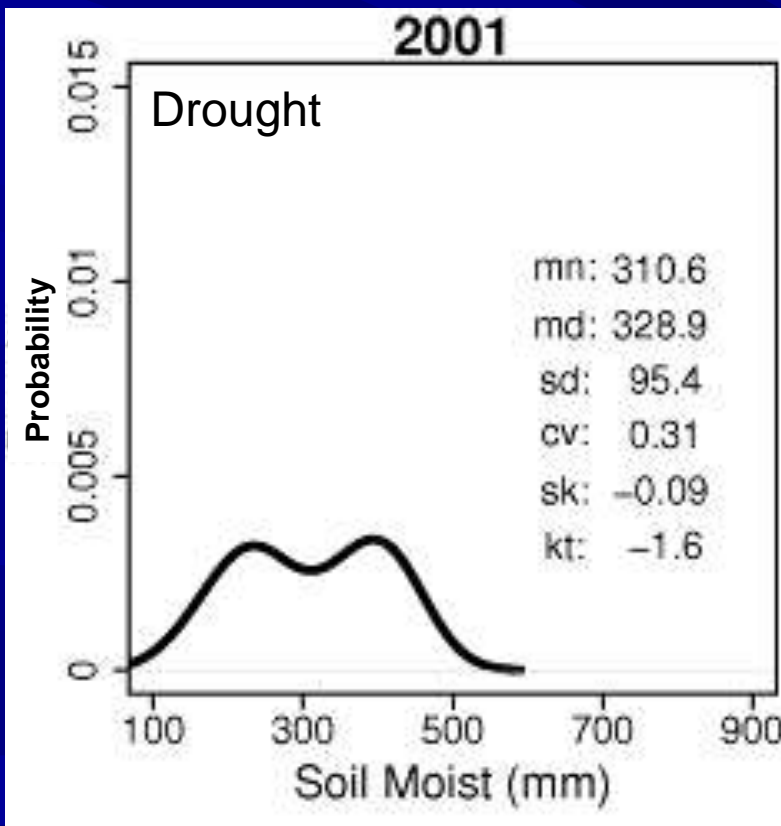
- Drought period: ET low, distribution narrow, variance small
- Wetter period: ET higher, distribution wider, variability larger



Spatial Variation of Soil Moisture Among Stations (Drought vs Wet)

■ All 15 stations considered

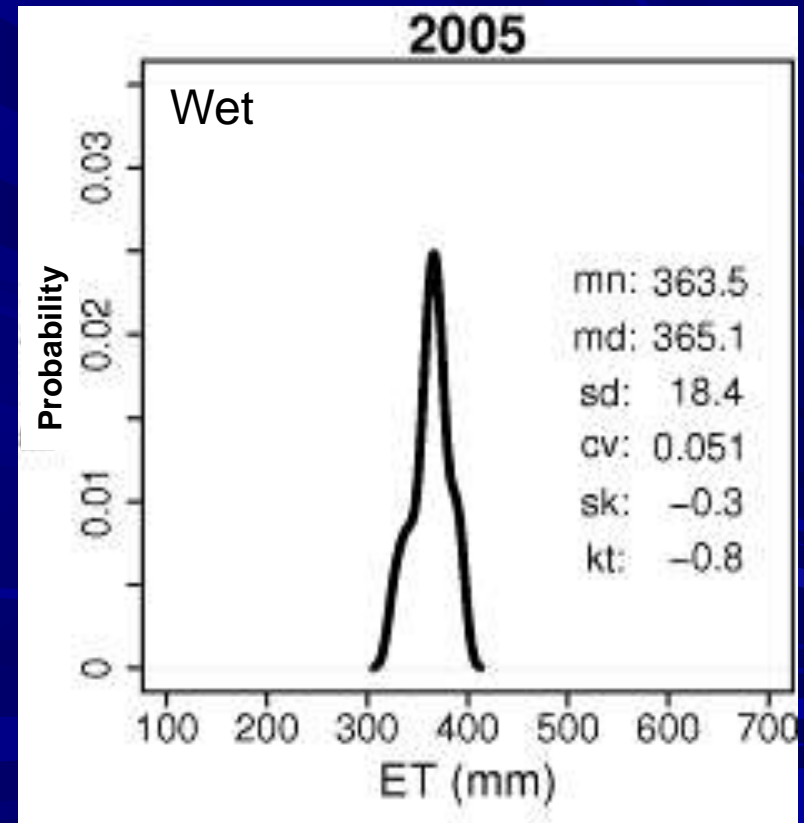
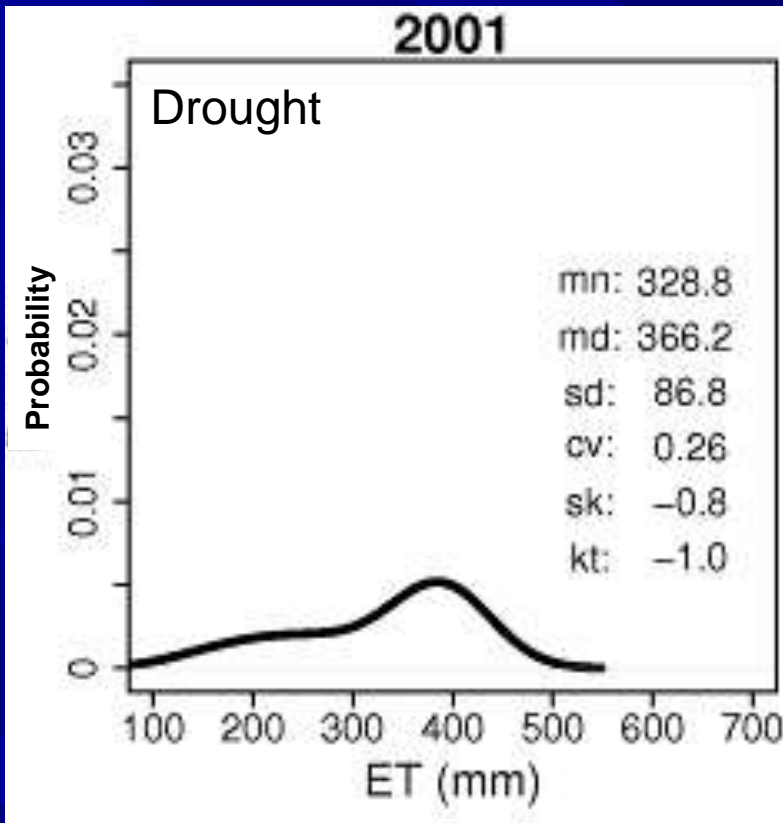
- Mean for normal period 332 mm
- Drought period: distribution wide, variance large, median > mean
- Wetter period: shift in lower values, variance smaller, median < mean



Spatial Variation of ET Among Stations (Drought vs Wet)

■ All 15 stations considered

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



Summary and Conclusions

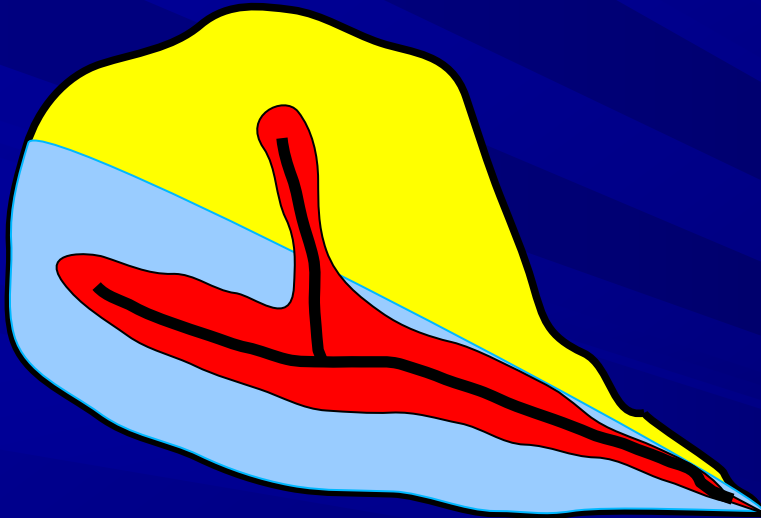
- Only looked at 15 sites, behaviour at other locations is unknown
- Distributions vary both temporally and spatially
- Mean is not only measure of spatial distribution, width of distribution is also important (i.e. variability around the mean)
- Differences in distribution of actual ET between drought and wet periods provides a stronger indicator of drought than soil moisture alone

CRHM Surface Water Drought Modelling

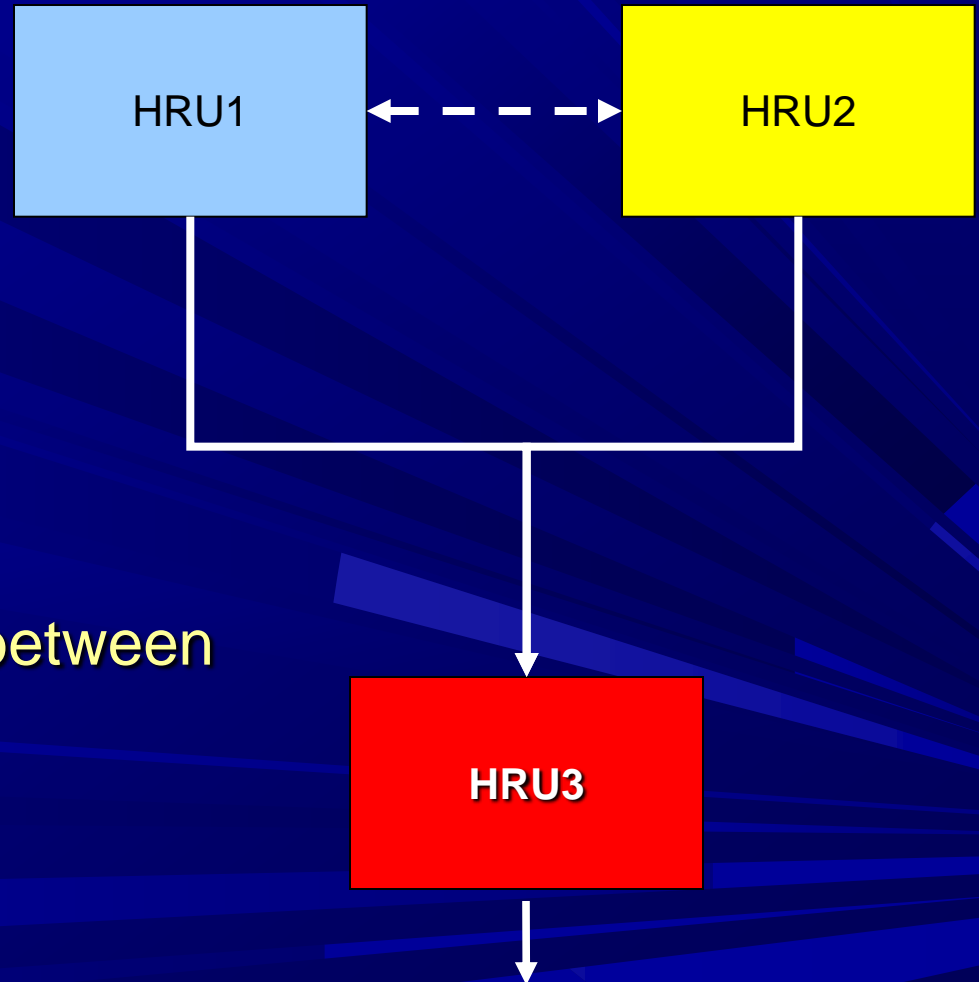
- CRHM was used to create 2 “virtual” models of typical prairie basins
- Models were run over climate normal period (1961-1990)
- Output(s) during drought period were compared to normal period and spatially interpolated

CRHM model of small upland prairie stream basin

Small stream basin

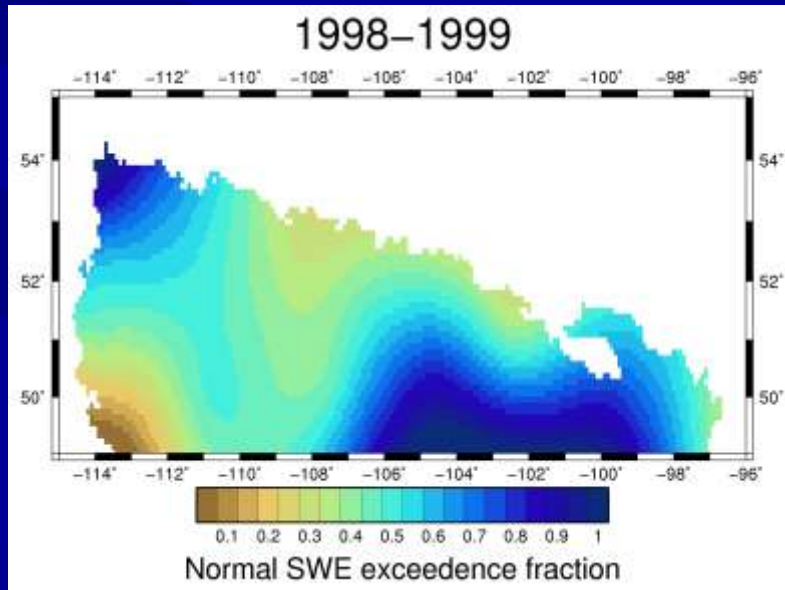


CRHM model

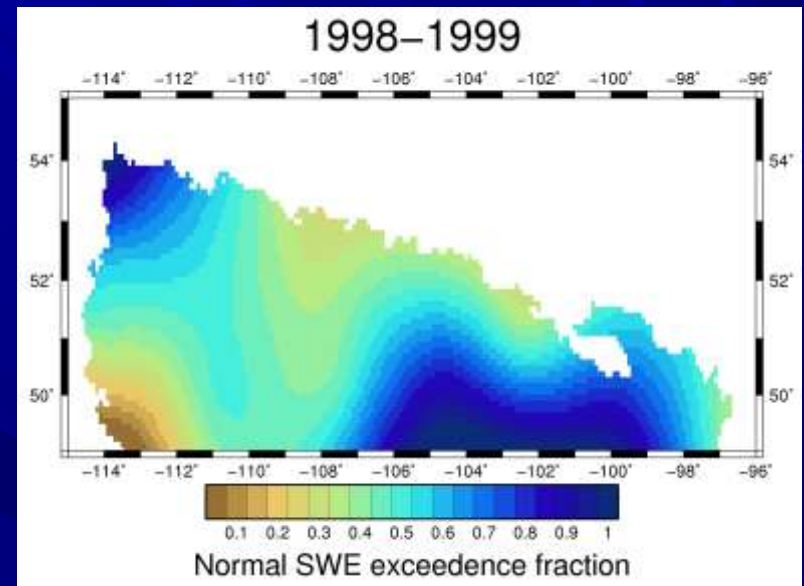


- HRUs 1 and 2 alternate between stubble and fallow
- HRU3 is grassed

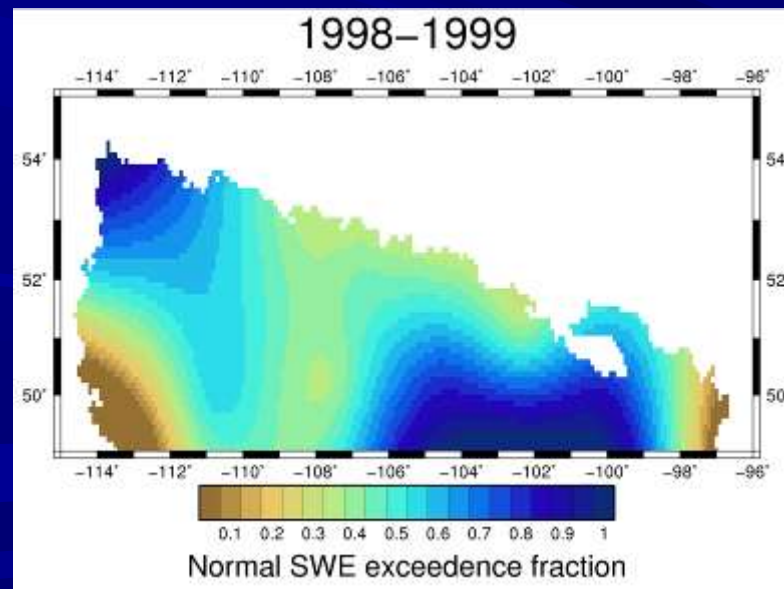
Fallow



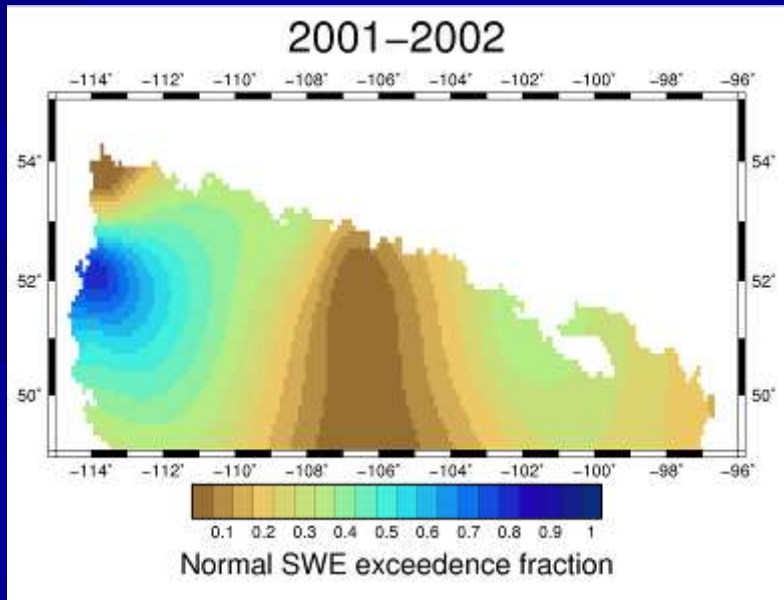
Stubble



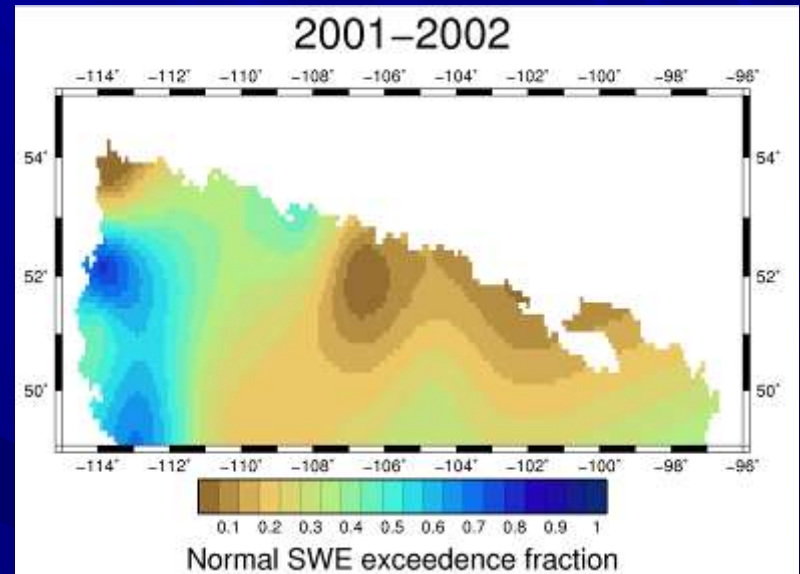
Grass



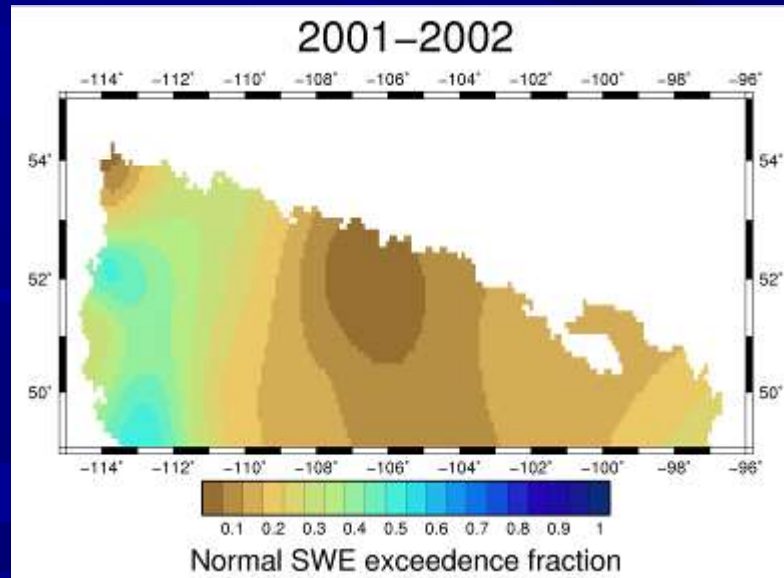
Fallow



Stubble

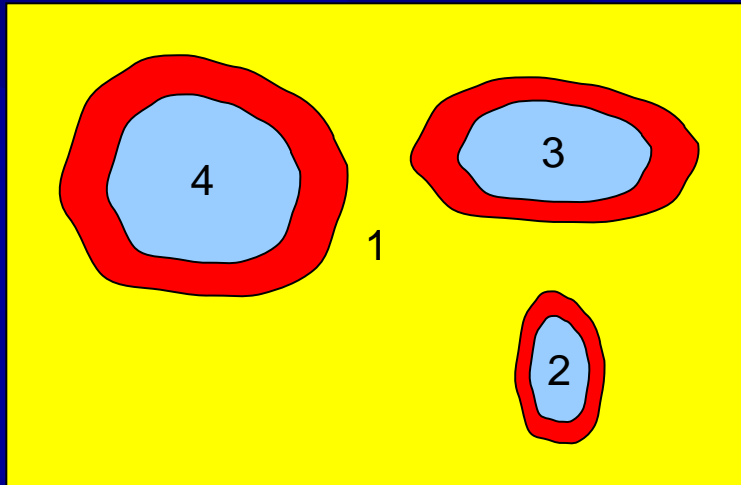


Grass

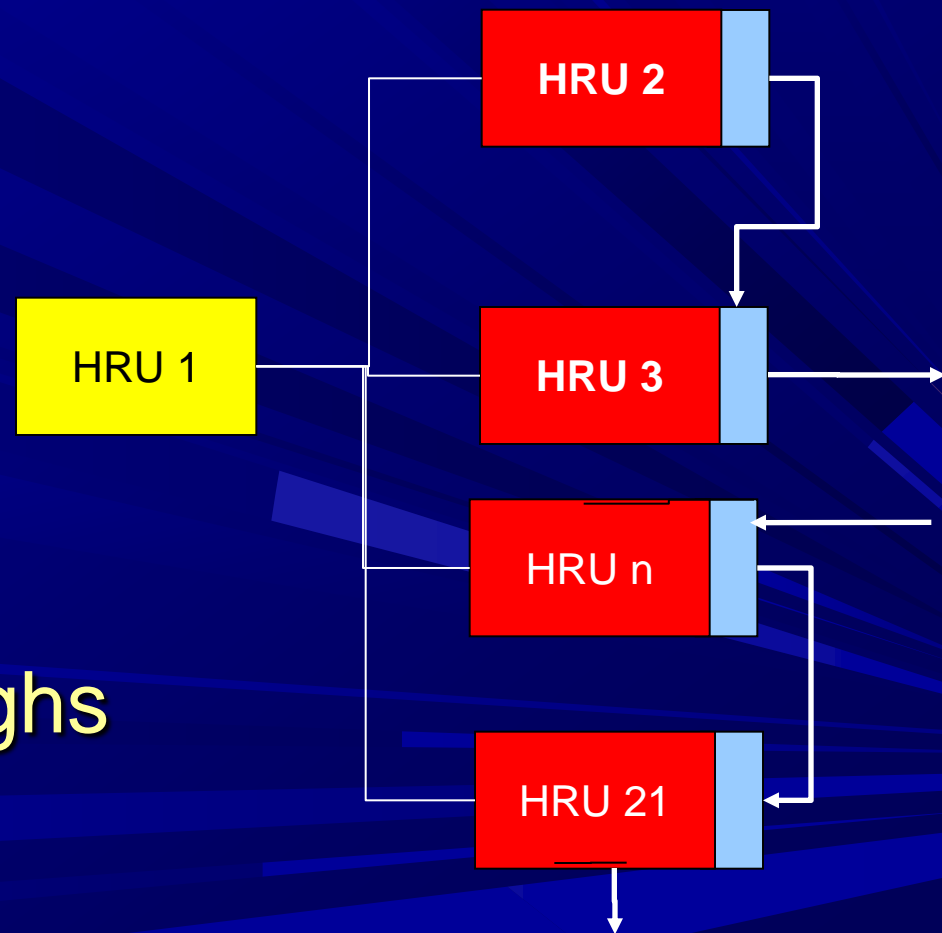


CRHM model of small prairie wetland basin

Small wetland complex



CRHM model



- HRU 1 is cropped
- HRUs 2-21 are sloughs

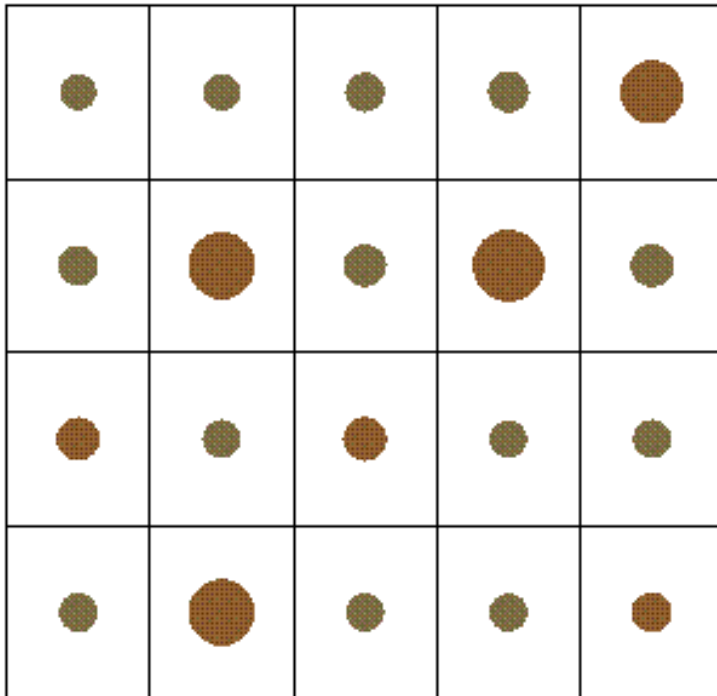
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Full

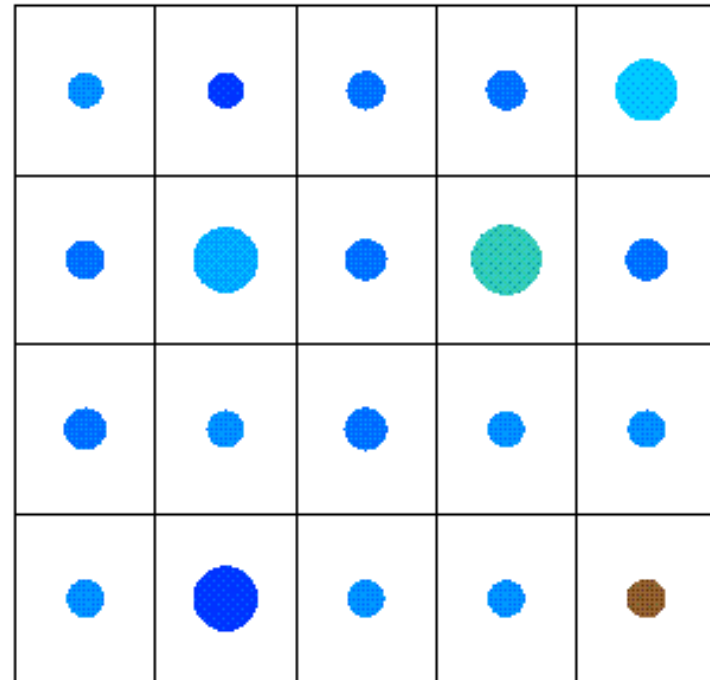
1-May-1999

Lethbridge



1-May-1999

Brandon



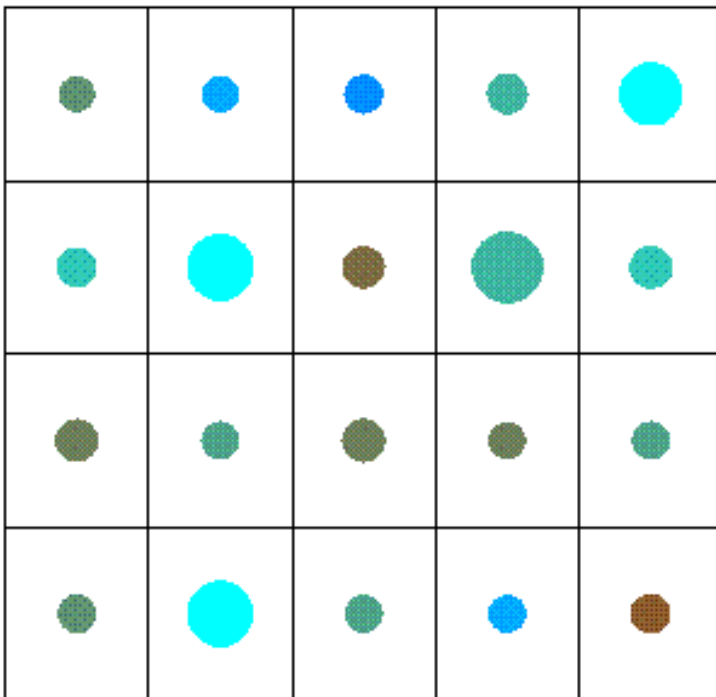
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Full

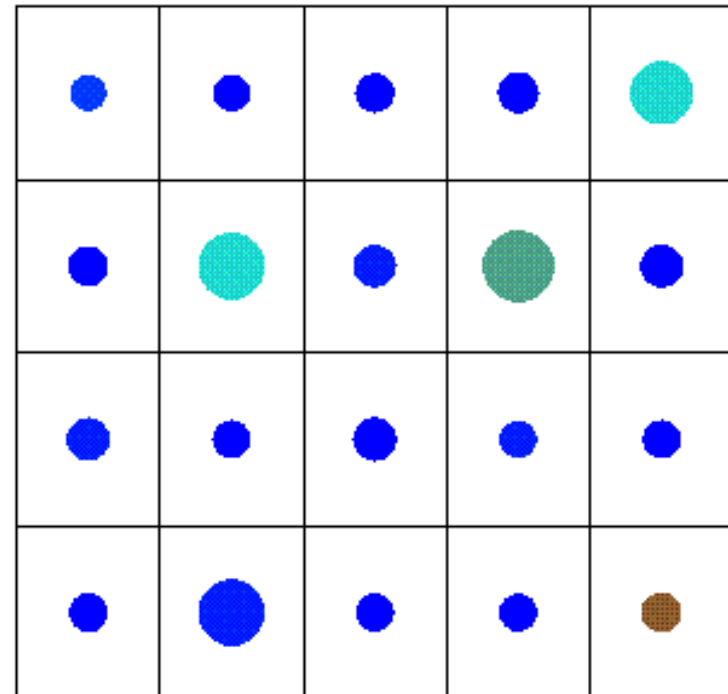
1-May-2002

Lethbridge



1-May-2002

Brandon



Conclusions

- Redistribution of snow leads to longer drought recovery time for grass coulees than fallow fields or stubble fields
- Wetland complexes have substantial memory of drought conditions that must be overcome for recovery and of wet conditions that sustain water storage during droughts.