

Applications of a Climate Moisture Index for assessing impacts of the 2001-2002 drought on aspen forests in the Prairie Provinces

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Two major methods for measuring “drought”

1. “Relative indicators”

Provide a measure of moisture relative to the long-term mean and variability at a given location

e.g., Standardized Precipitation Index, Palmer Indices

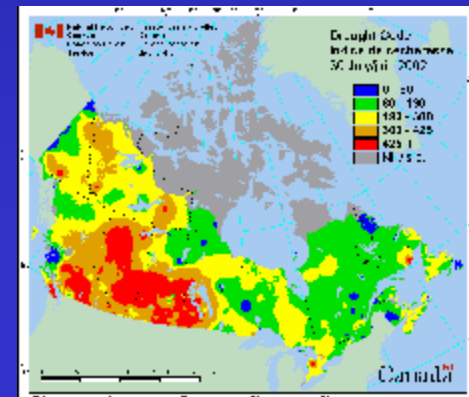
2. “Absolute indicators”

Provide a measure of moisture conditions as they affect biophysical processes such as fire (fuel moisture), vegetation (soil moisture) & stream flow (water runoff)

e.g., Canadian Fire Weather Index System for assessing forest fire risk

Climate Moisture Index

for assessing forest-climate relationships



Climate Moisture Index (CMI)

A simple index for assessing moisture regimes in remote forested regions where long-term climate data are typically limited to temperature and precipitation

$$\text{CMI} = P - \text{PET}$$

(units in cm/year)

P is mean annual precipitation
(includes water input as both rain and snow)

PET is annual potential evapotranspiration
(loss of water vapour from well-vegetated landscape)

Methods for estimating PET:

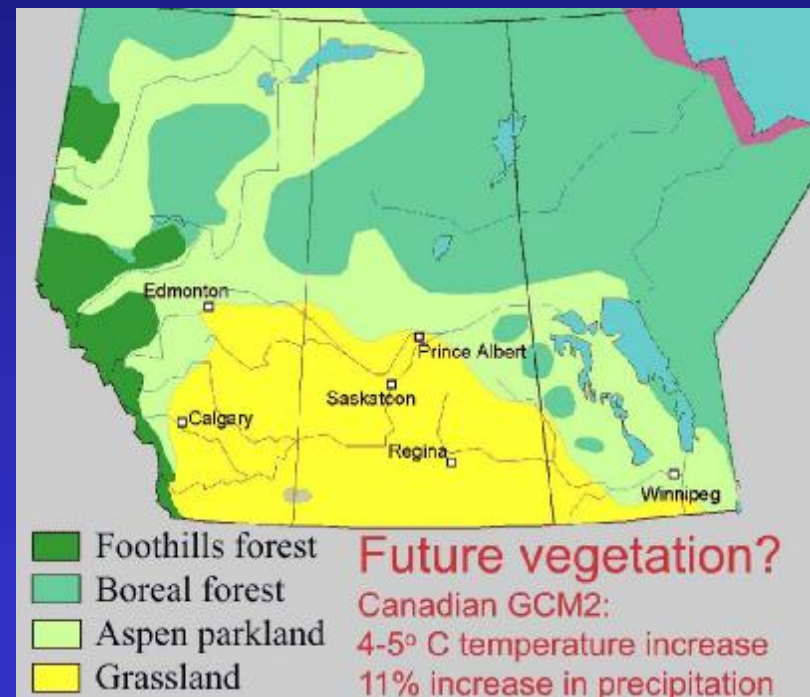
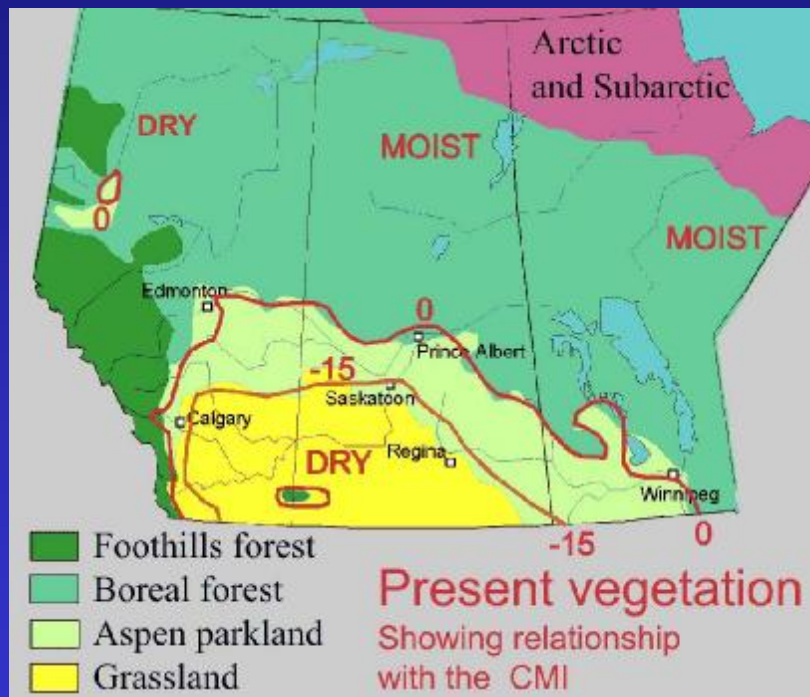
1. Jensen-Haise (mean monthly solar radiation, temperature, and elevation)
2. Simplified Penman-Monteith (maximum and minimum temperature, elevation)

From Hogg (1994) Can. J. For. Res. 24: 1835-1845
and Hogg (1997) Agric. For. Meteorol. 84: 115-122.



Application of the Climate Moisture Index:

Analysis of climatic factors affecting forest distribution under present and projected future climate (Hogg and Hurdle 1995)



From Hogg, E.H. and P.A. Hurdle. 1995. The aspen parkland in western Canada: A dry-climate analogue for the future boreal forest? *Water, Air and Soil Pollution* 82: 391-400.

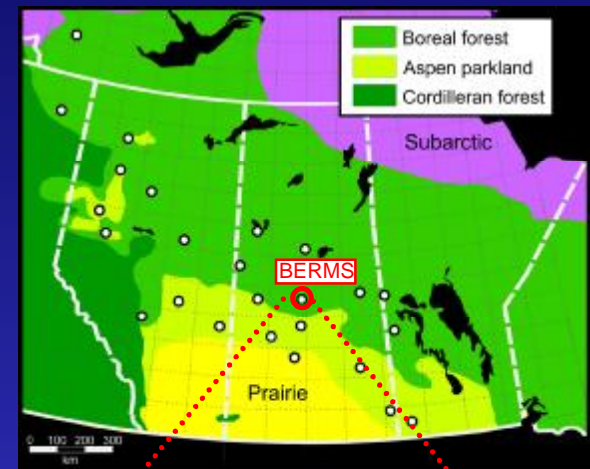
Applications of the CMI (continued):

Studies of drought impacts on forest growth & dieback

CIPHA:

Climate Impacts on Productivity & Health of aspen

- Started in 2000 by Hogg, Brandt and Kochtubajda in response to concerns about aspen dieback
- Annual monitoring of aspen forest health in 25 study areas (75 stands)
- Includes tree-ring analysis of past growth



Aspen tree-rings



BERMS Old Aspen site
Prince Albert National Park

Results:

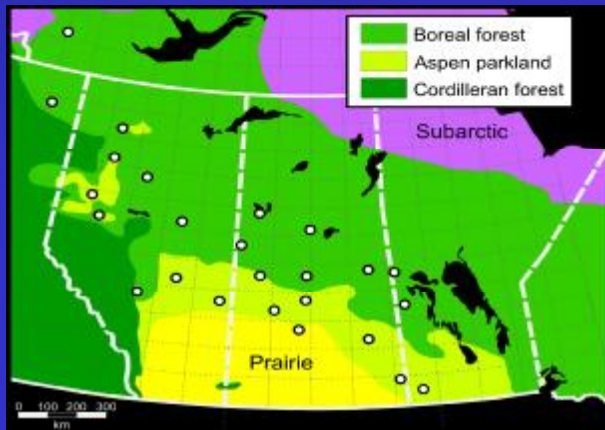
CIPHA tree-ring analysis

total of 432 aspen trees sampled

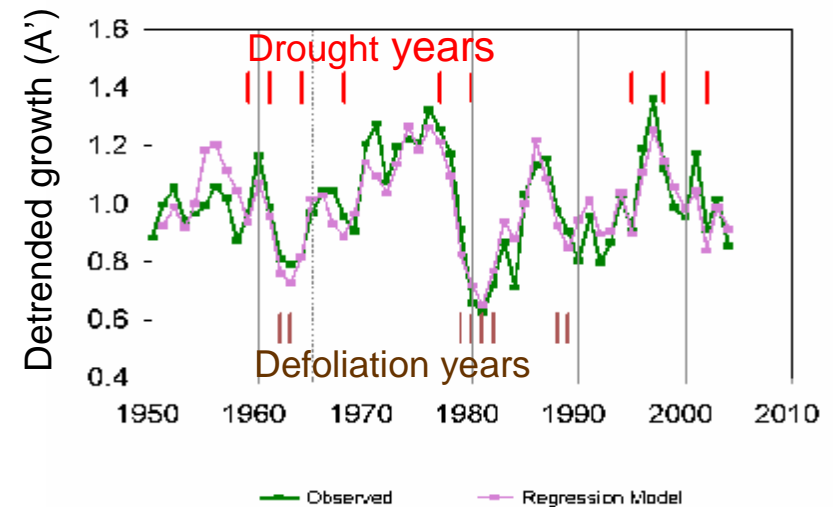
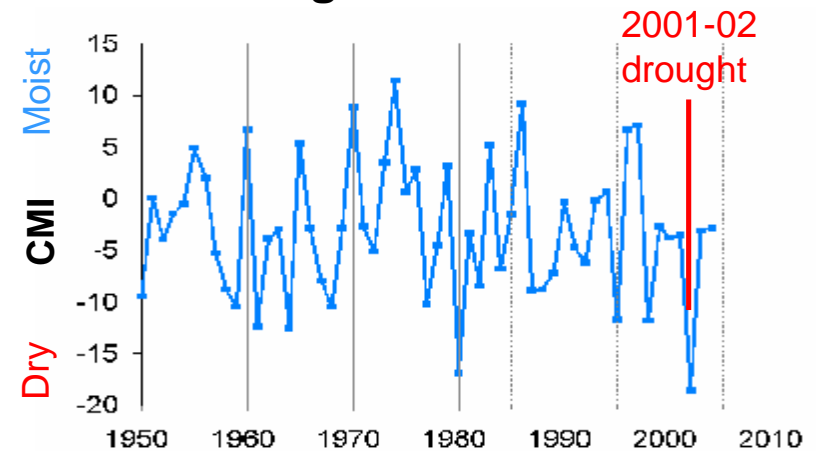


Main factors affecting aspen growth:

- **Climate Moisture Index (CMI)**
for 1 August-31 July (“tree water year”)
- **Insect defoliation (D)**
mainly forest tent caterpillar



Interannual variation in the regional CMI



$$\text{Regression: } A' = 1.169 + 0.0111 \text{ CMI} + 0.0099 \text{ CMI}_{-1} + 0.0071 \text{ CMI}_{-2} + 0.0058 \text{ CMI}_{-3} + 0.0055 \text{ CMI}_{-4} - 0.0119 \text{ D}, r^2 = 0.697$$

From Hogg et al. 2005, Can. J. For. Res.
(results updated to 2004)

Impacts of the 2001-2002 drought

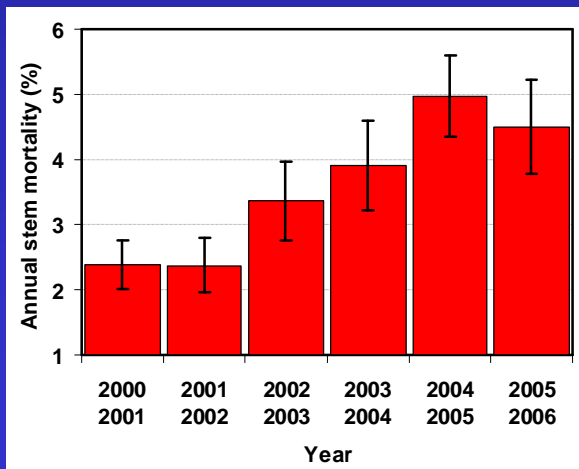
- Severe aspen mortality in the parklands of Sask. & Alberta (resembling fire in some areas!)
- Conifers and urban trees also affected
- Aspen mortality in CIPHA plots increased in the 4 years following the drought
- Spatial variation in mortality best correlated with drought severity (minimum CMI)



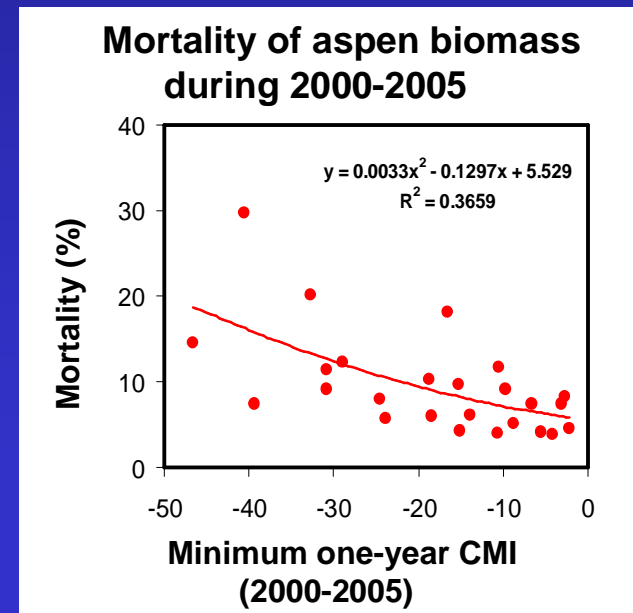
Drought-damaged aspen foliage August 2002



← Aspen dieback at Batoche, Sask. May 2003



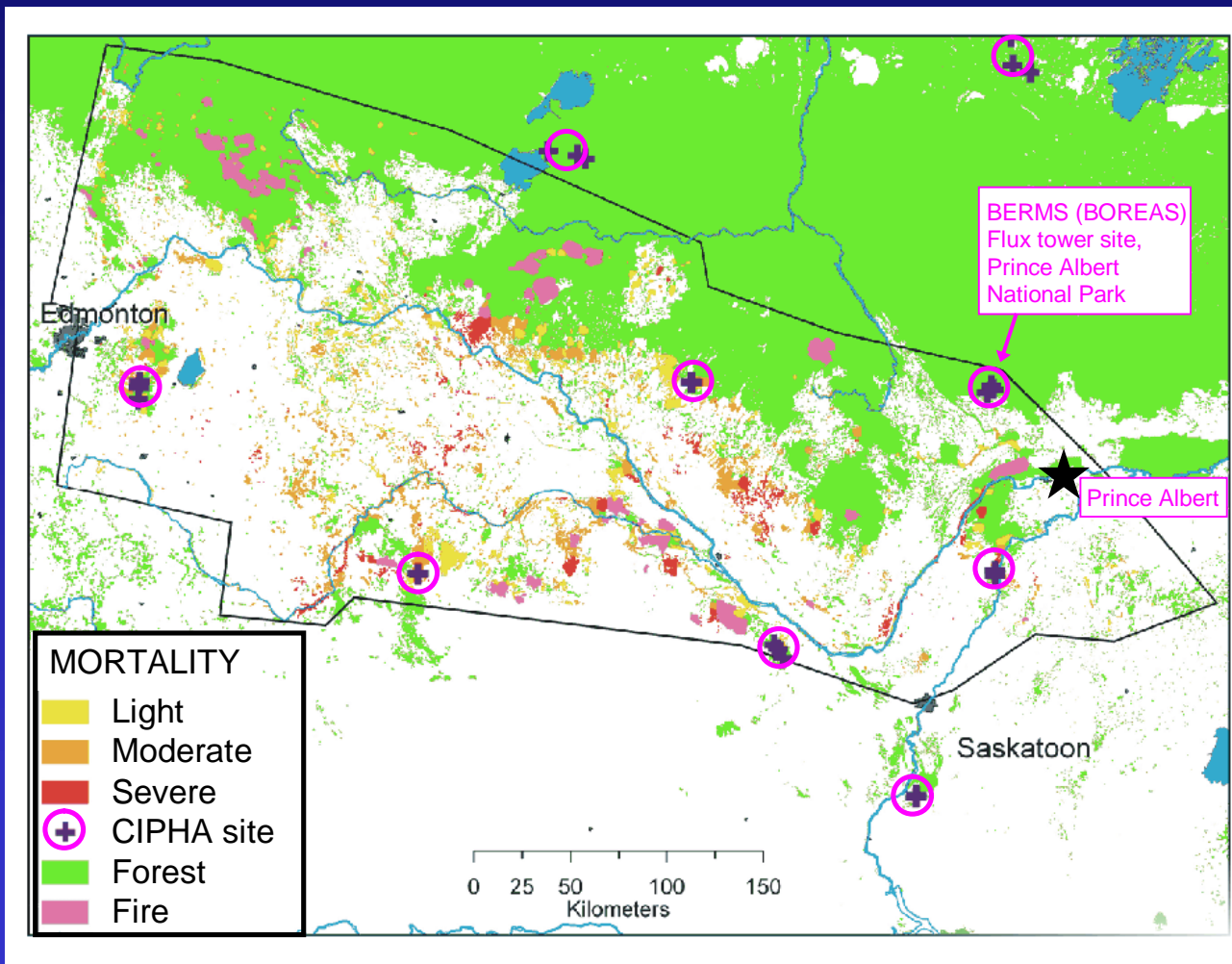
Severe aspen mortality following drought near North Battleford, Sask. (Michaelian, Aug. 2004)



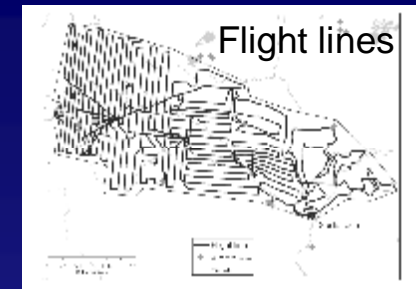
Impacts of the 2001-2002 drought

Aerial survey of aspen mortality

August 2004, CIPHA study



Surveys and preliminary map by M. Michaelian



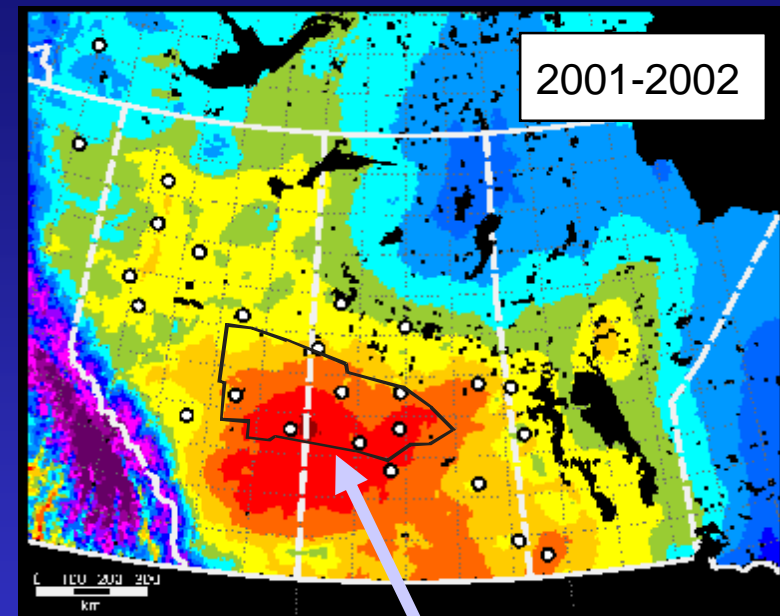
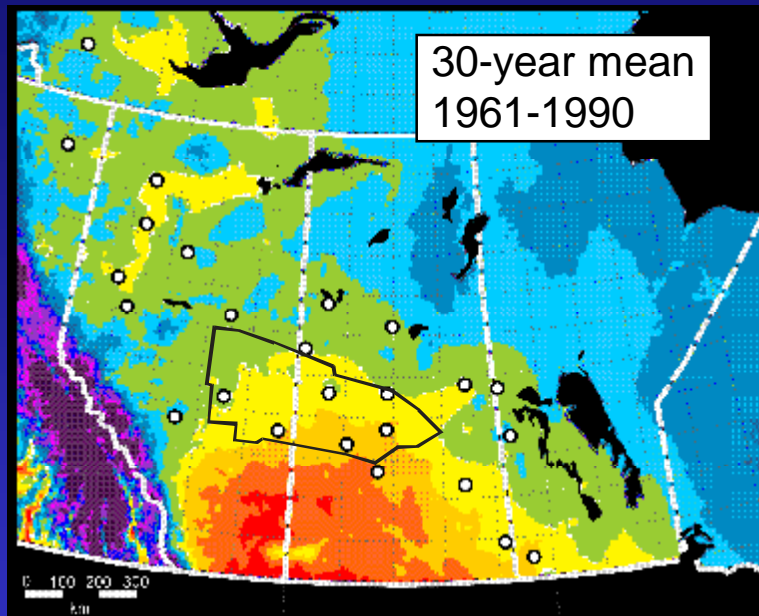
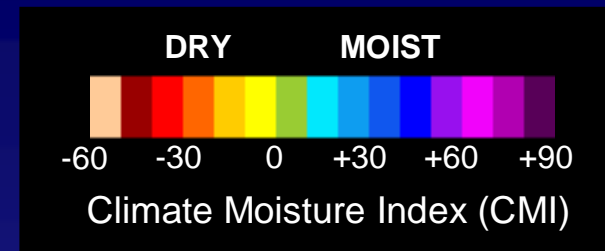
Drought was the worst on record across most of the area surveyed



Drought-induced aspen mortality at Fort Carlton, Sask., August 2006

Mapping of the CMI

For monitoring & retrospective analyses
of forest responses to drought



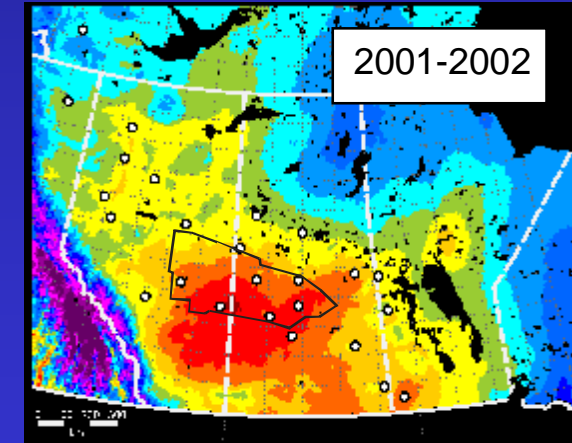
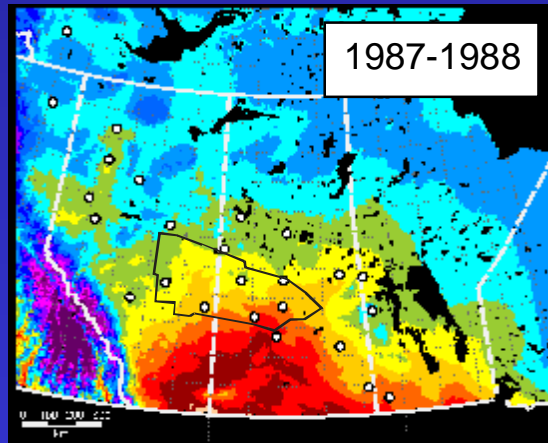
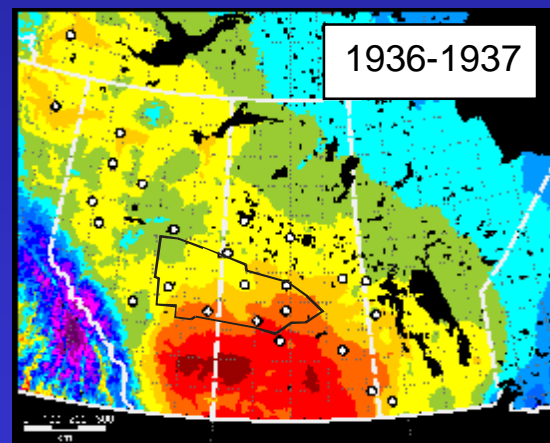
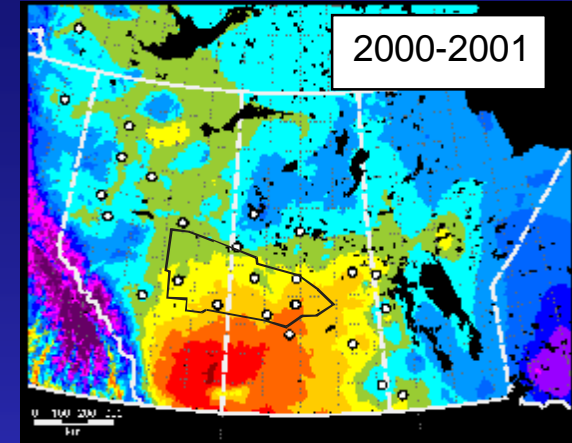
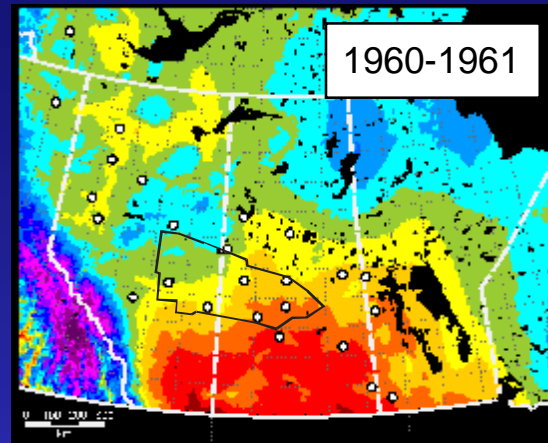
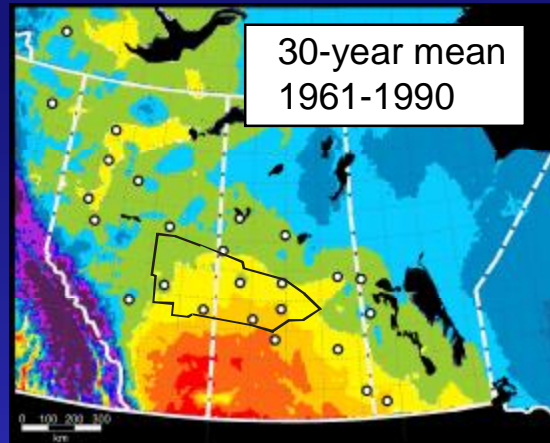
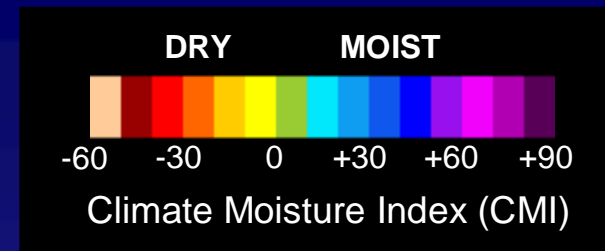
Area covered by aerial survey
of aspen dieback and mortality

Methods:

- uses 10-km gridded elevation and monthly temperature & precipitation (1901-2003)
- interpolation by ANUSPLIN for all of Canada (McKenney et al.)
- applied CMI equations ($P - PET$) for 12-month periods ending 31 July

Mapping of the CMI

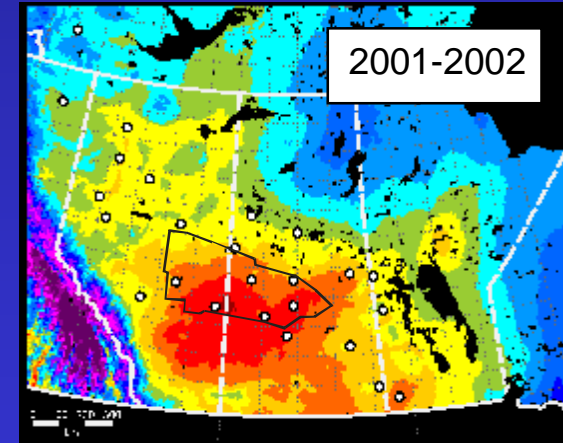
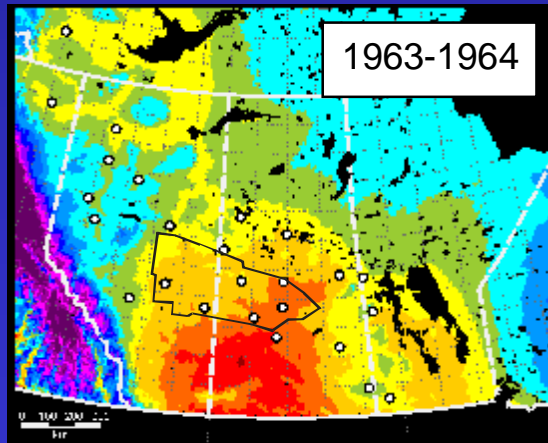
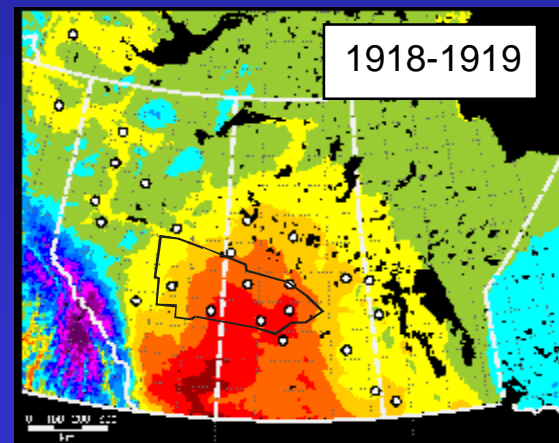
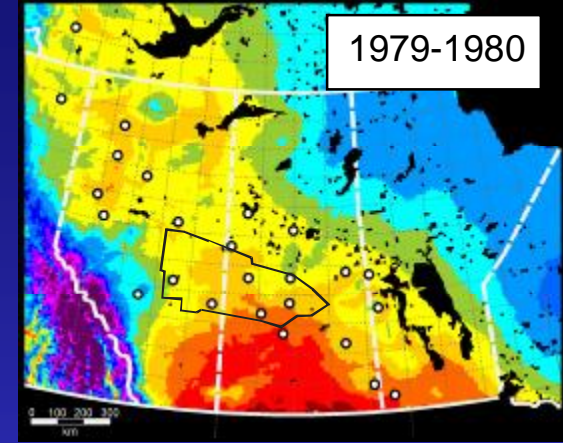
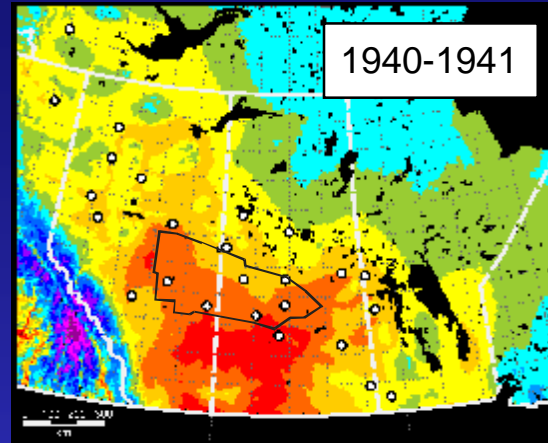
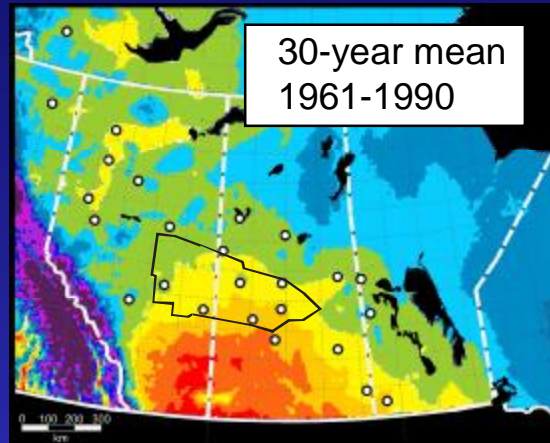
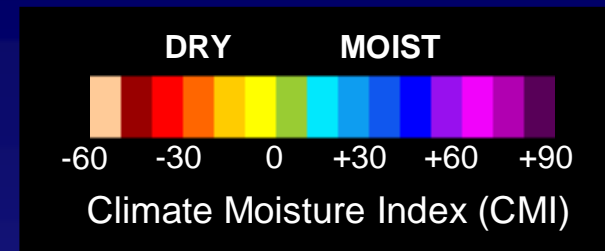
Comparison with previous prairie drought years



In the affected areas of aspen parkland, the 2001-2002 drought was more severe than during some previous well-known years of prairie drought

Mapping of the CMI

Comparison with previous boreal drought years



But: there were other years with a more northerly extent of drought that were of comparable severity to the 2001-2002 drought in parts of the CIPHA study region

Future applications of the CMI

- “Scaling up” regional-scale impacts of the recent drought
Includes remote sensing component (with Hall, Arsenault et al.)
- Assessing impacts of recent drought on C uptake & release
- Estimating impacts of past droughts on forest growth, biomass and C uptake
- Assessing risks to urban forests, plantations & afforestation projects
See Volney et al. (2005), *Unasylva* 221: 20-25
- Inclusion of drought as a disturbance type in forest carbon accounting
Potential for inclusion in the CFS Carbon Budget Model (Kurz et al.)
- Development of climate-driven models of forest growth & dieback
Potential tool for managing forests under a changing climate

Team members & collaborators

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and others

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