A thousand years of variability in grassland climate

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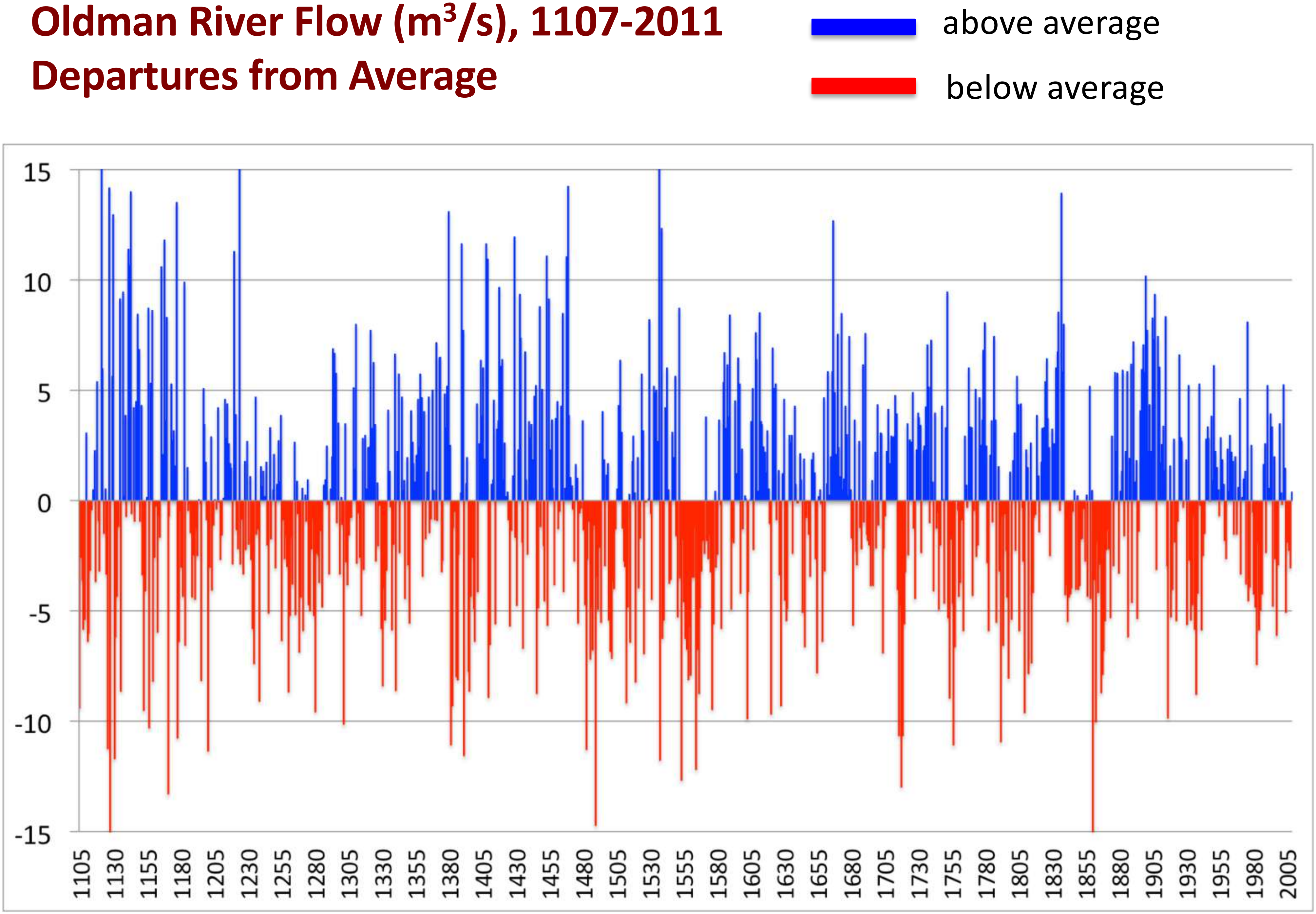
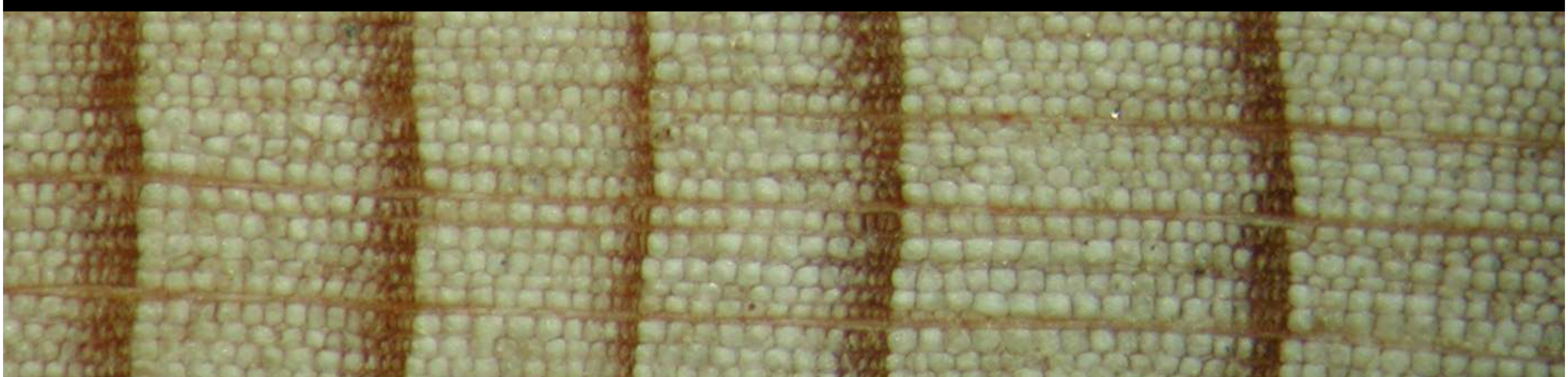
Mary Vetter, Professor Emerita, Luther College, University of Regina

Foothills Restoration Forum, Claresholm, 16 November 2017

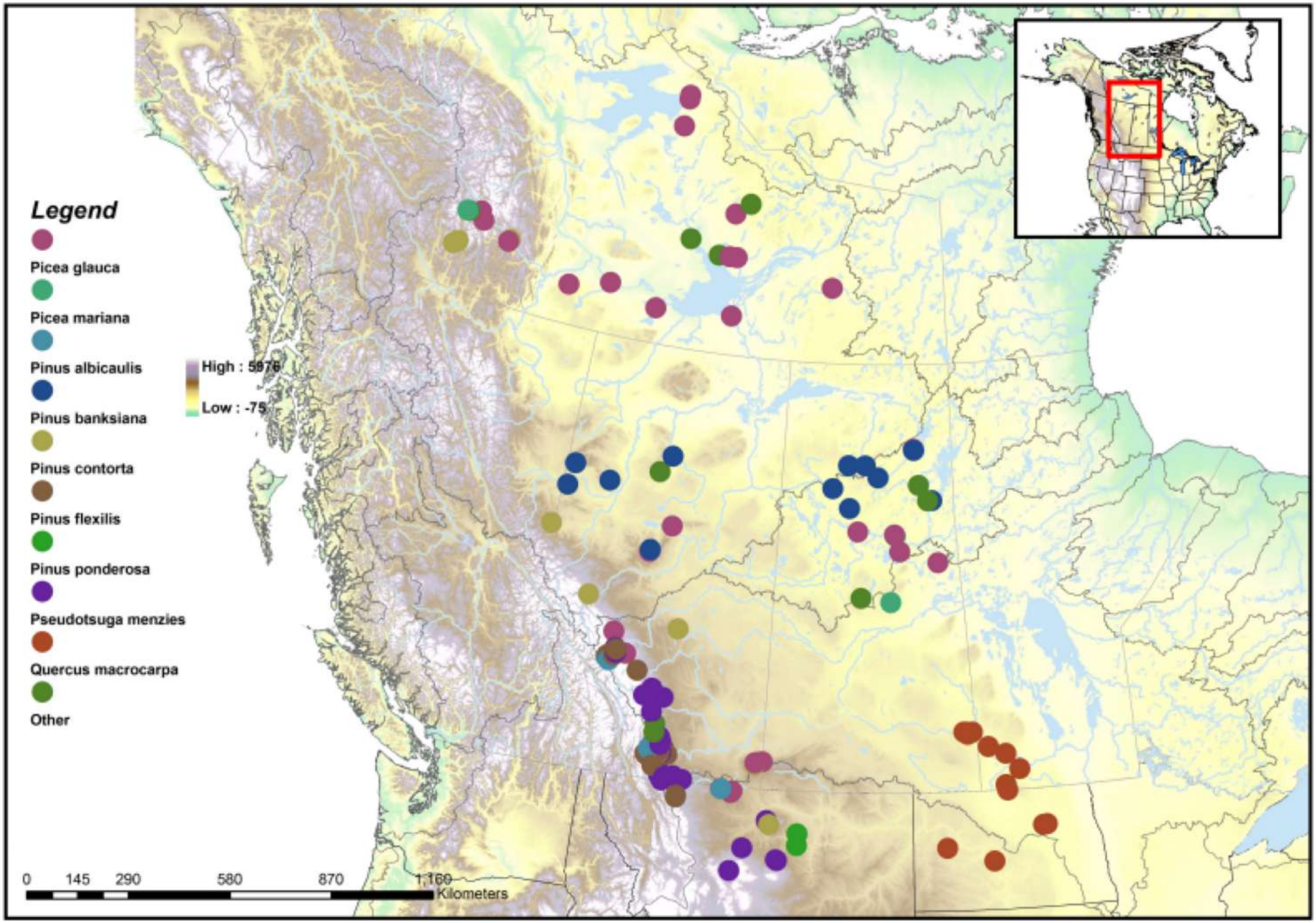
Oldman River Flow (m^3/s), 1107-2011 Departures from Average




UNITED
DEWALT
DW735
UNITED
Van Lines

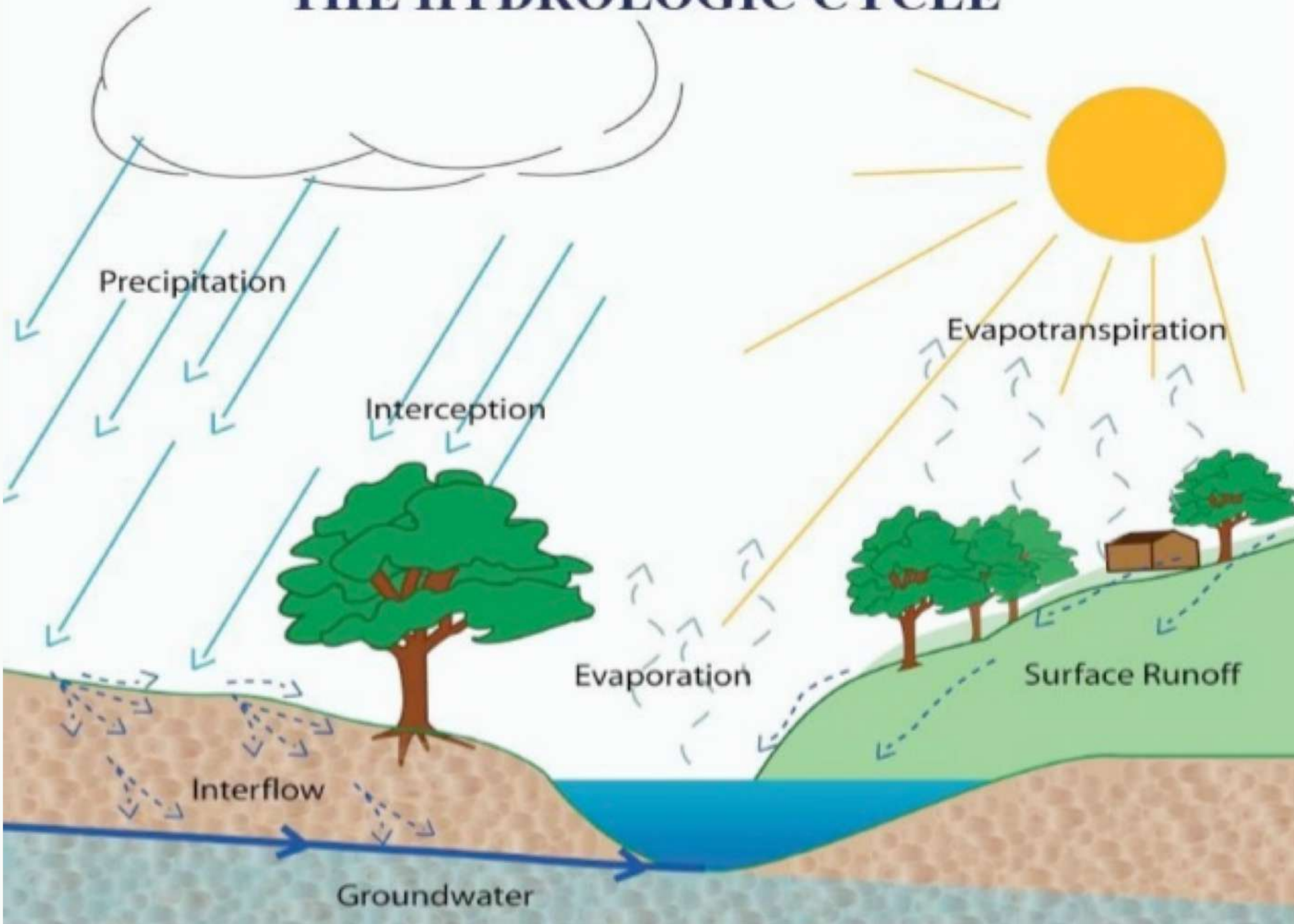


University of Regina, Tree-Ring Lab Network

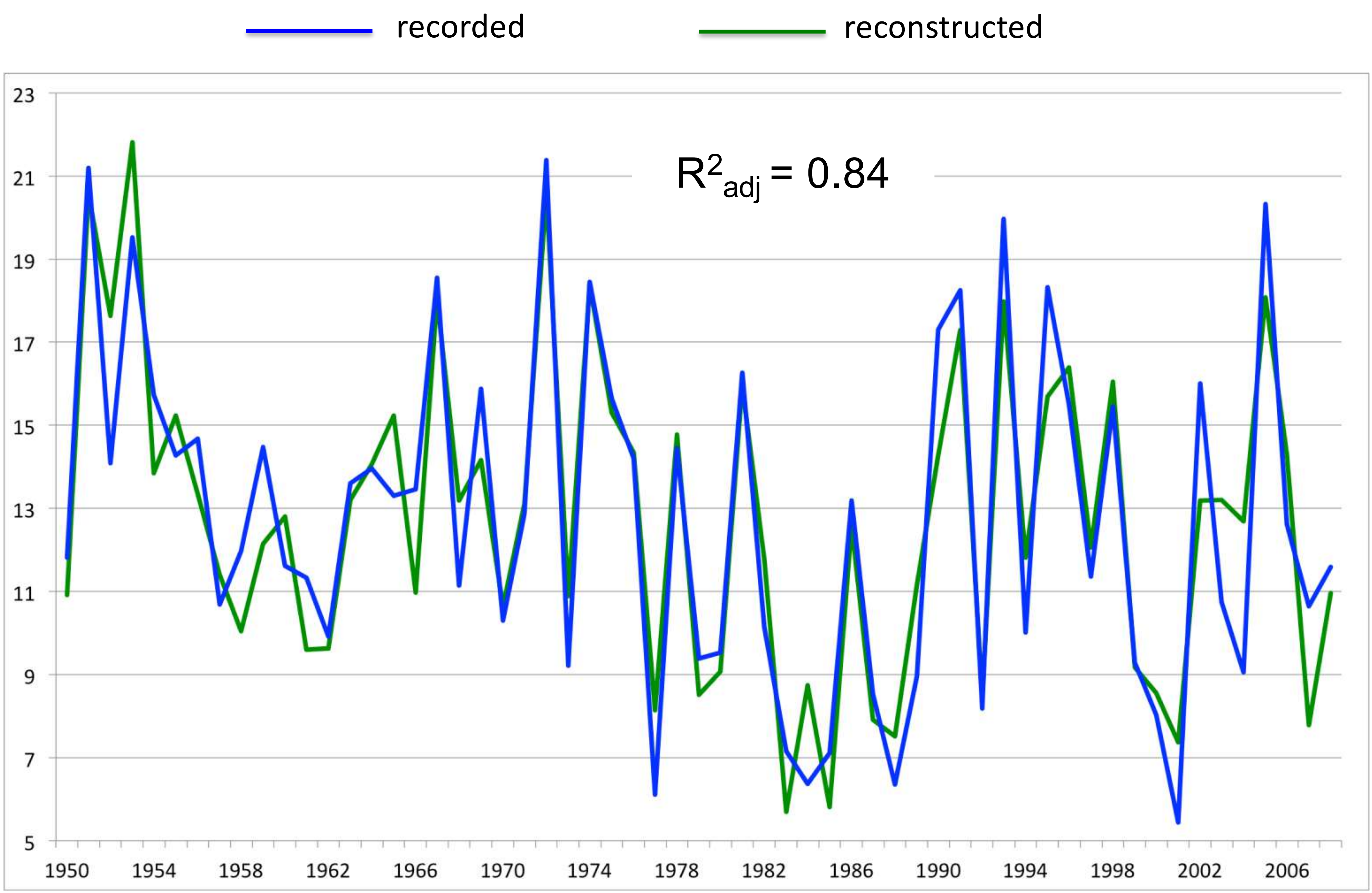


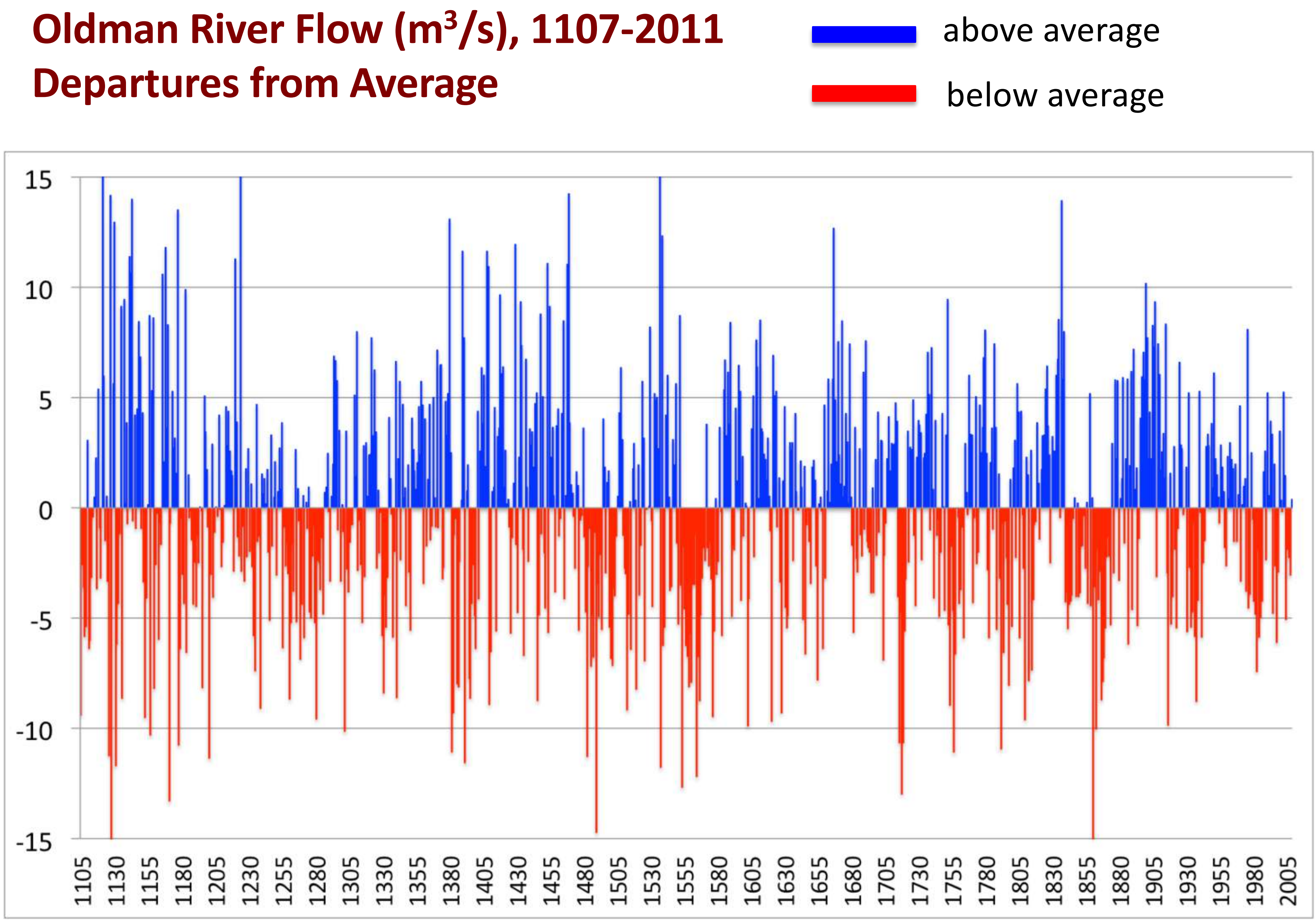

Saskatchewan
Alberta
Montana

THE HYDROLOGIC CYCLE

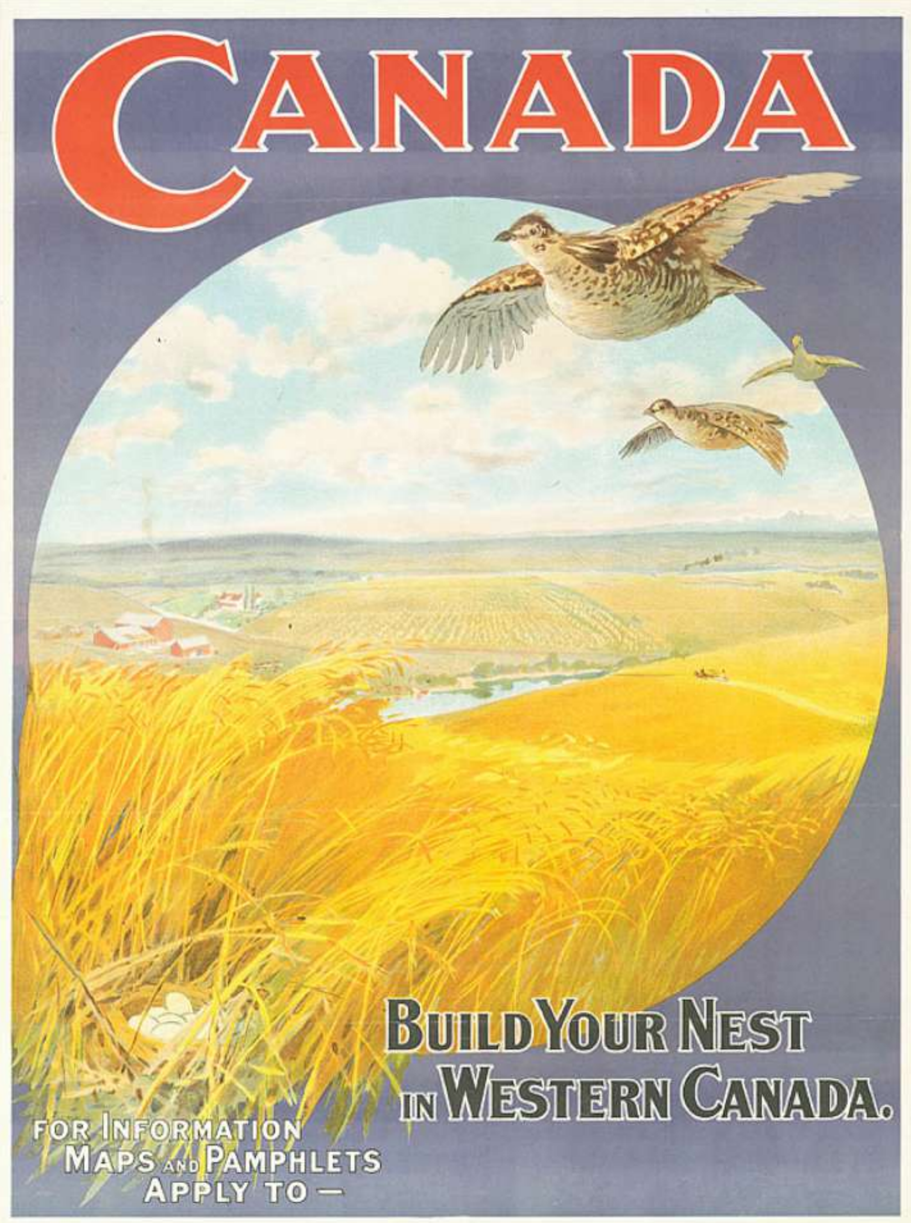


Oldman River Flow (m^3/s), 1950-2008




Oldman River Flow (m^3/s), 1107-2011
Departures from Average
above average
below average
15
10
5
0
-5
-10
-15
1105
1130
1155
1180
1205
1230
1255
1280
1305
1330
1355
1380
1405
1430
1455
1480
1505
1530
1555
1580
1605
1630
1655
1680
1705
1730
1755
1780
1805
1830
1855
1880
1905
1930
1955
1980
2005

This large belt of country embraces districts, some of which are valuable for the purposes of the agriculturalist, while others **will forever be comparatively useless**. ...
John Palliser, London, July 8, 1860


CANADA
BUILD YOUR NEST IN WESTERN CANADA.
FOR INFORMATION MAPS AND PAMPHLETS APPLY TO —

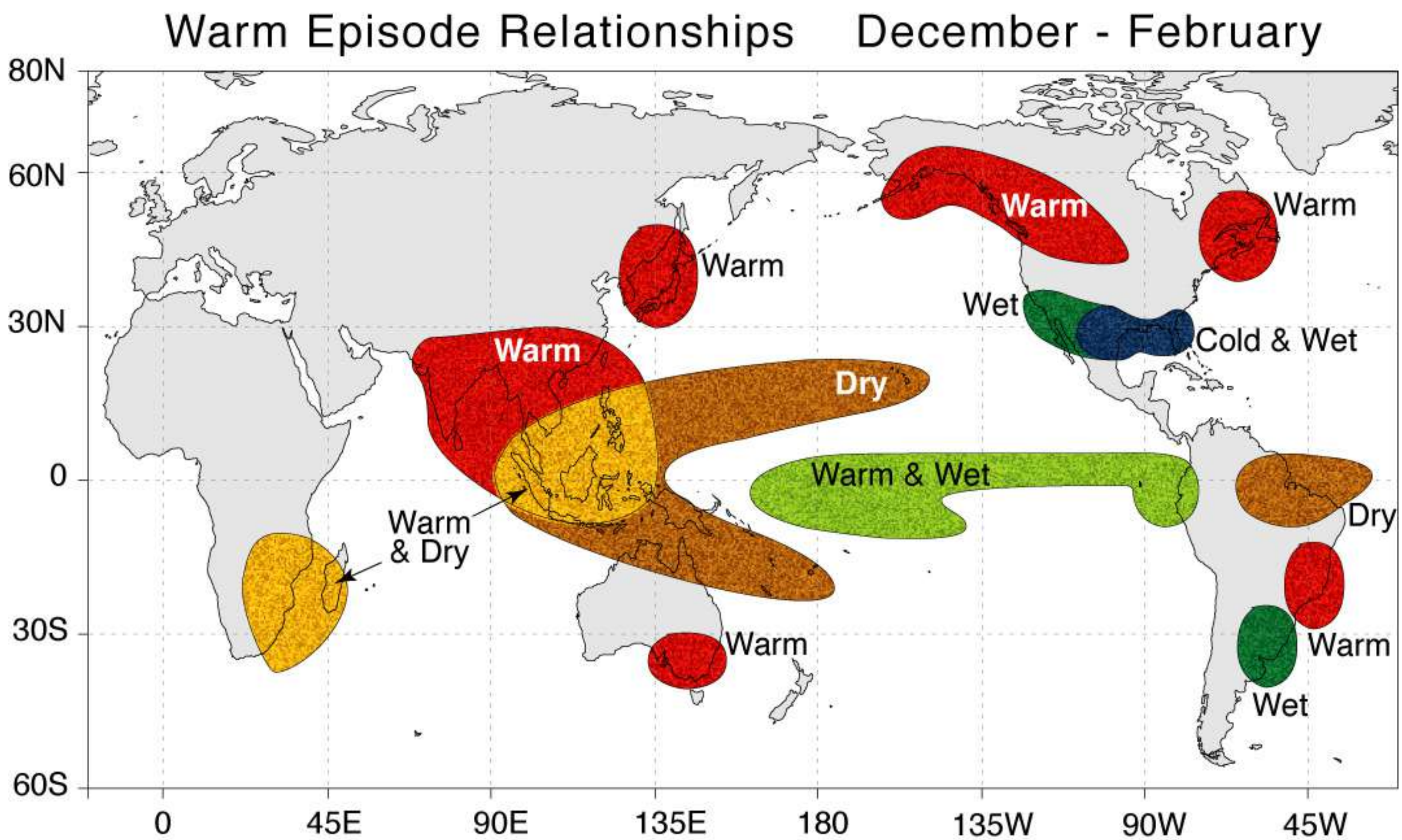

Canada West
THE LAST BEST WEST
HOMES FOR MILLIONS
RANCHING
DAIRYING
GRAIN RAISING
FRUIT RAISING
MIXED FARMING
ISSUED BY DIRECTION OF HON. FRANK OLIVER
MINISTER OF THE INTERIOR, OTTAWA, CANADA.
1909

It would be almost criminal to bring settlers here to try to make a living out of straight farming.
Our True Immigration Policy, Medicine Hat Times, Feb 5, 1891

1901	73,022	
1911	374,295	413%
1921	588,454	57%

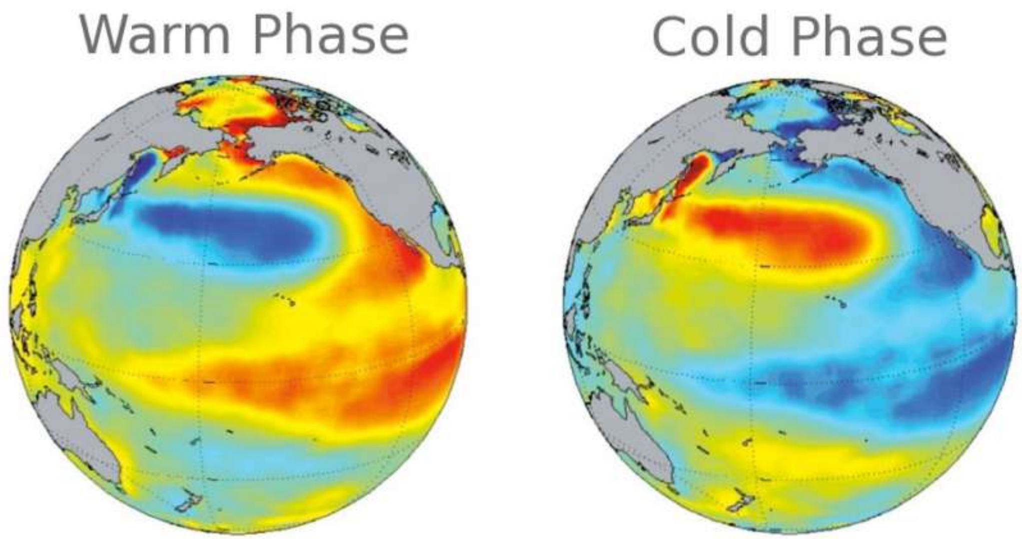
El Niño remote impacts: Teleconnections

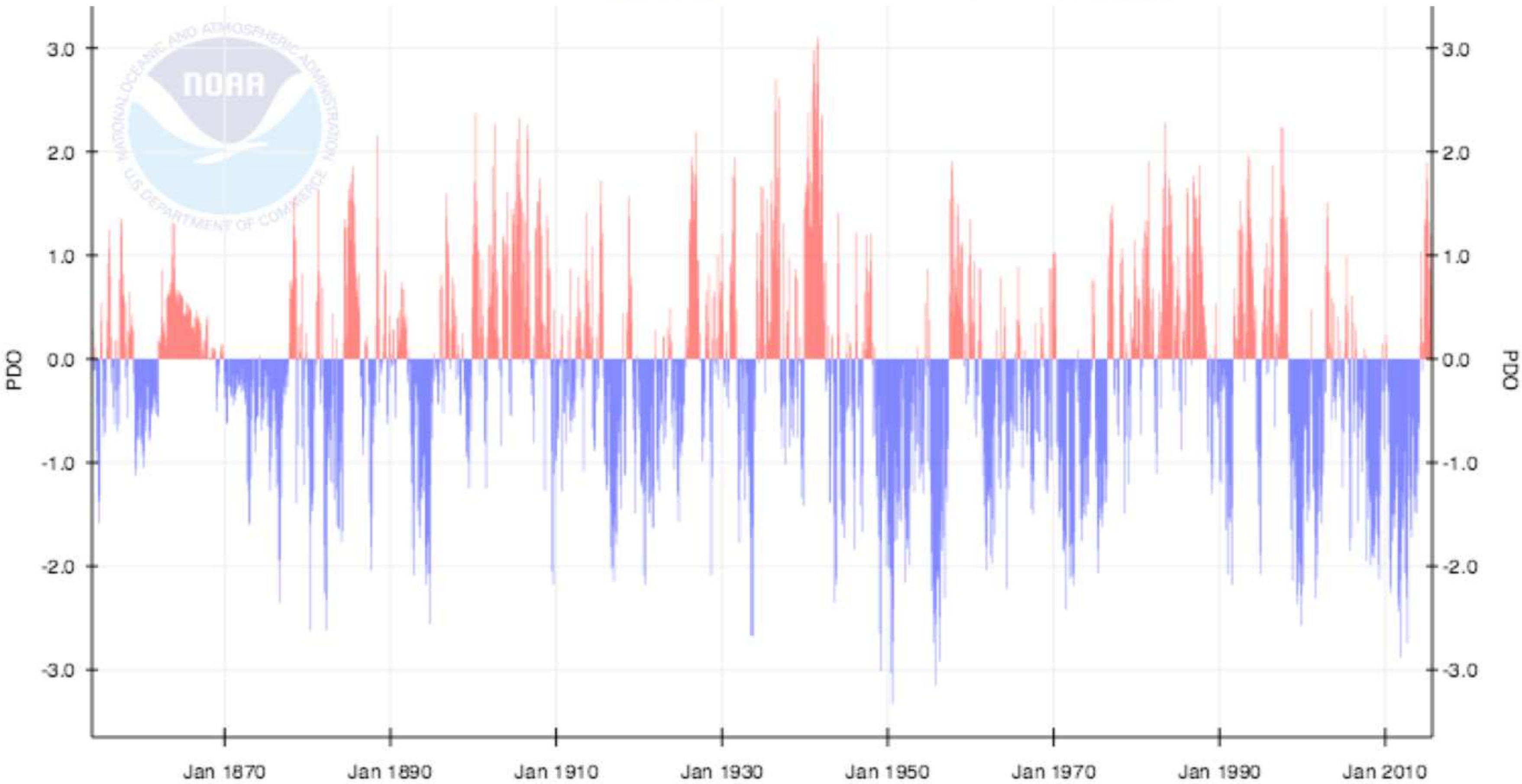
La Niña teleconnections have the opposite effect



Neelin, 2011. *Climate Change and Climate Modeling,* Cambridge UP

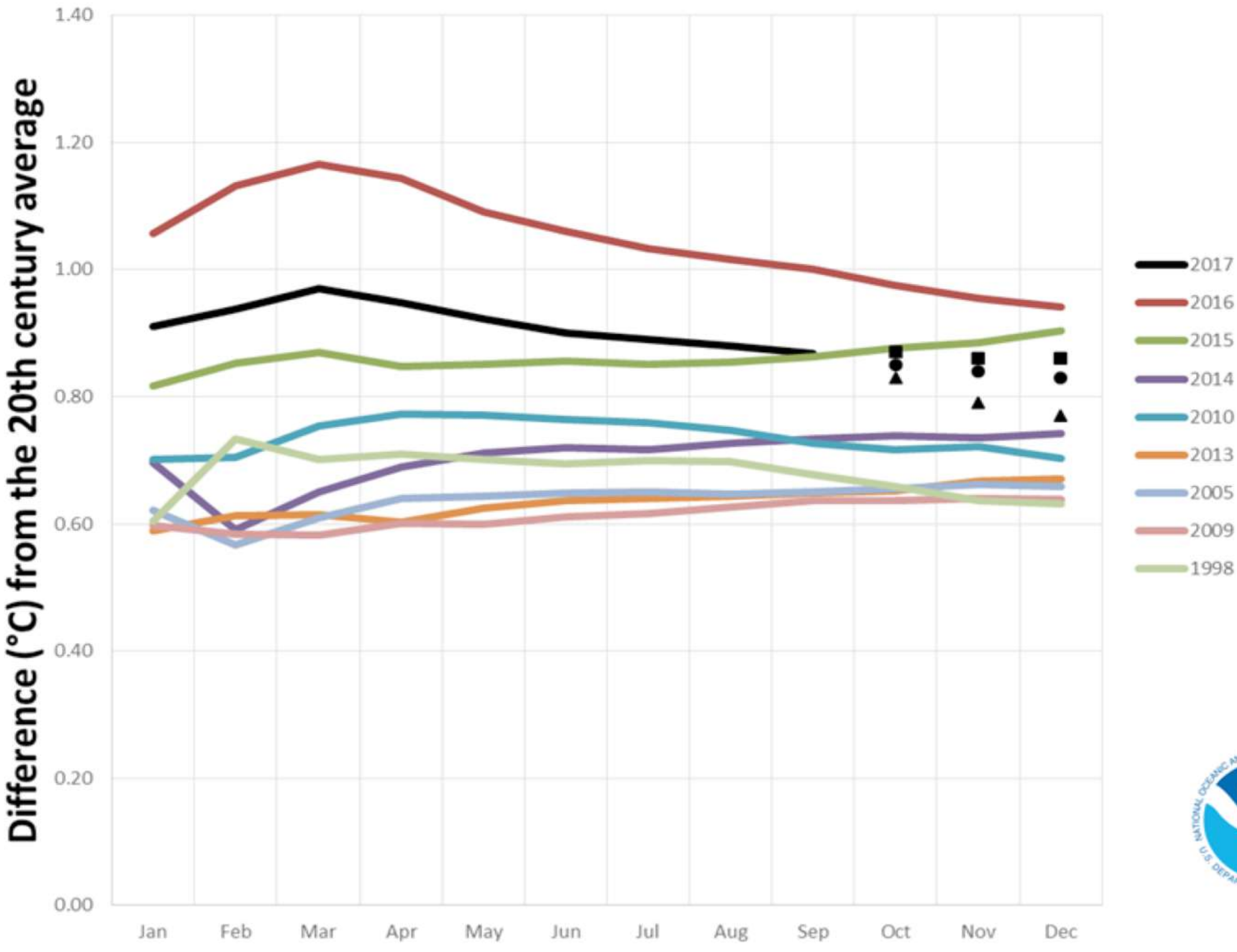
Pacific Decadal Oscillation



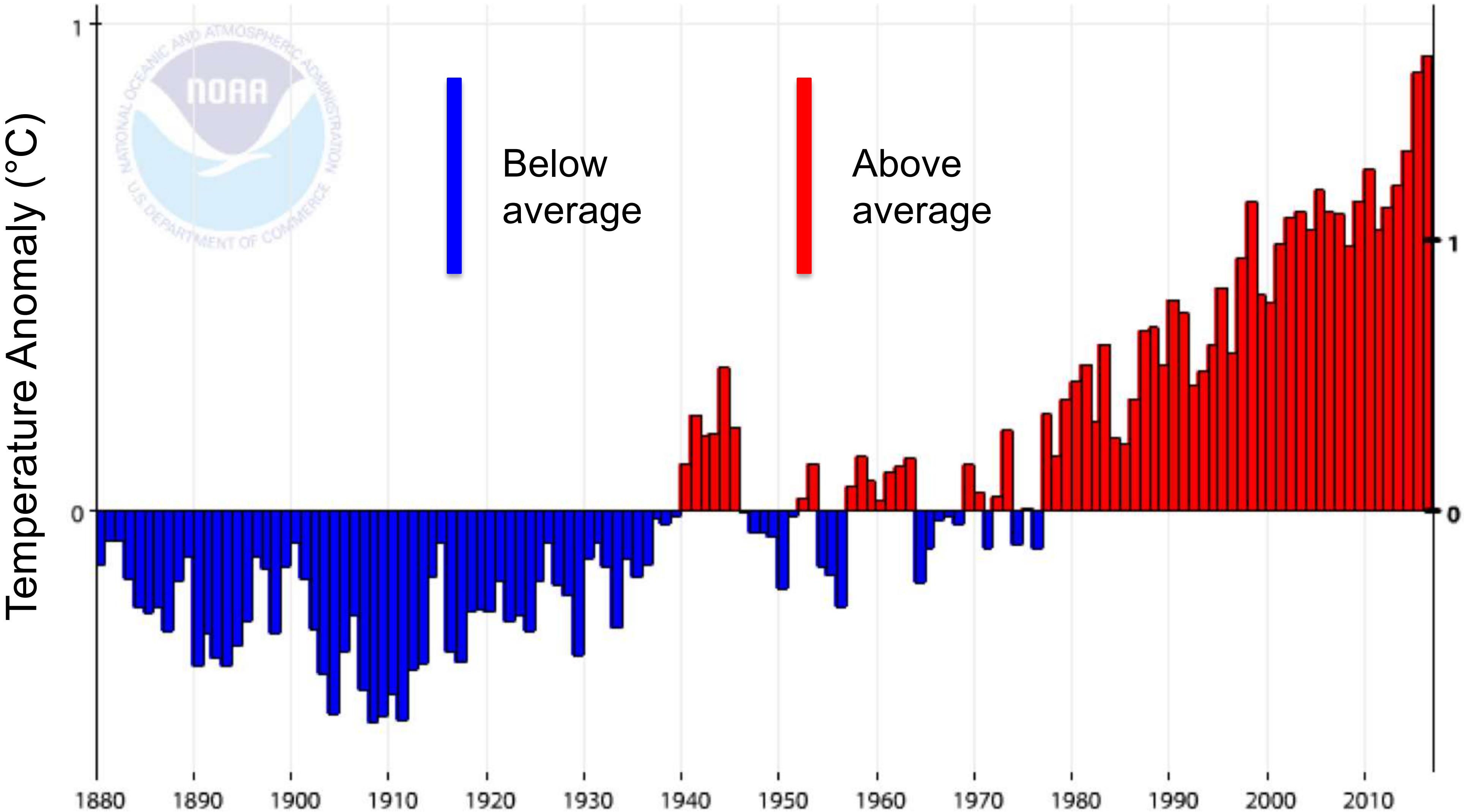


Forage Yield (kg/ha), OneFour, AB, 1930-2014

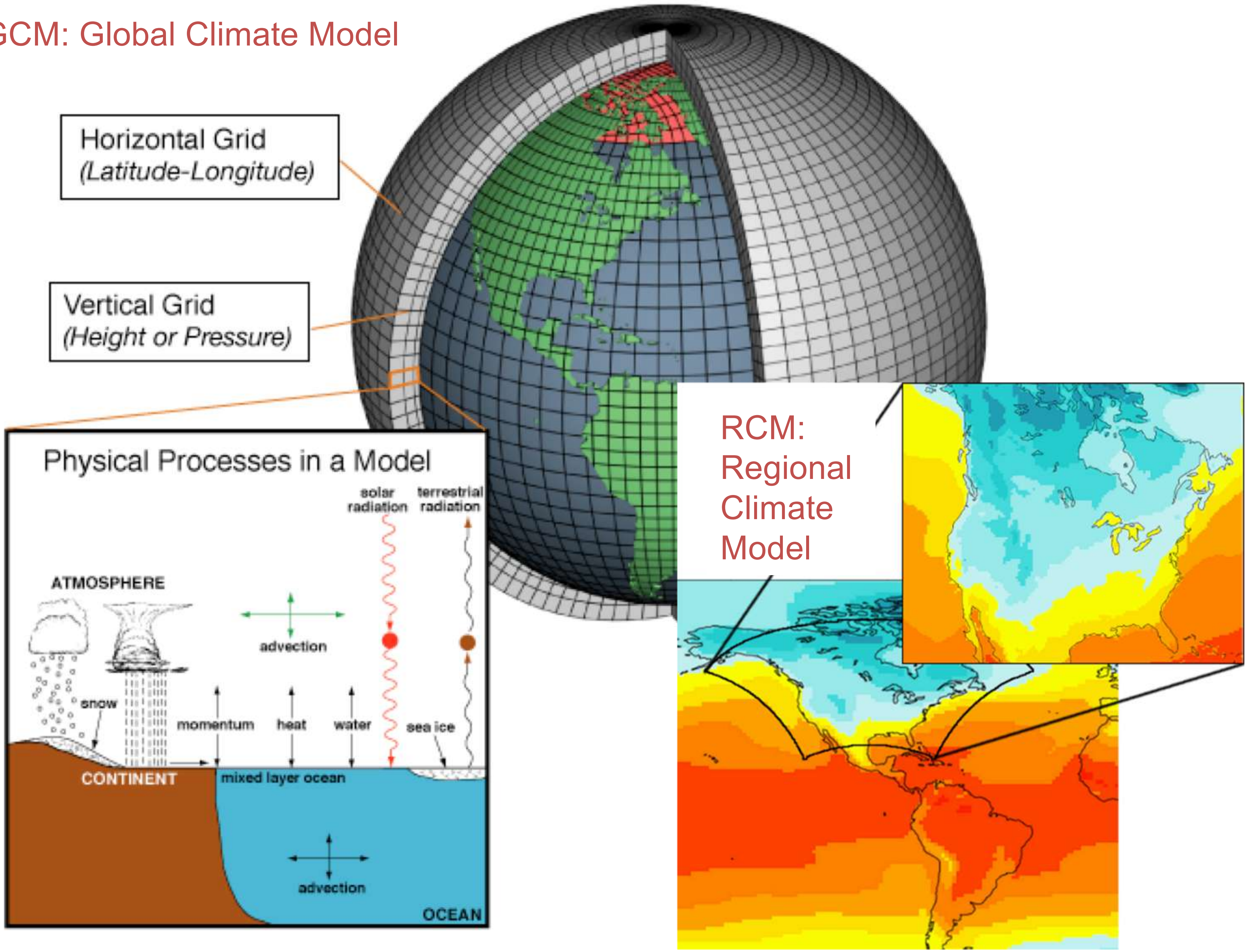
Eight Warmest Years Since 1880 – Monthly Global Temperatures



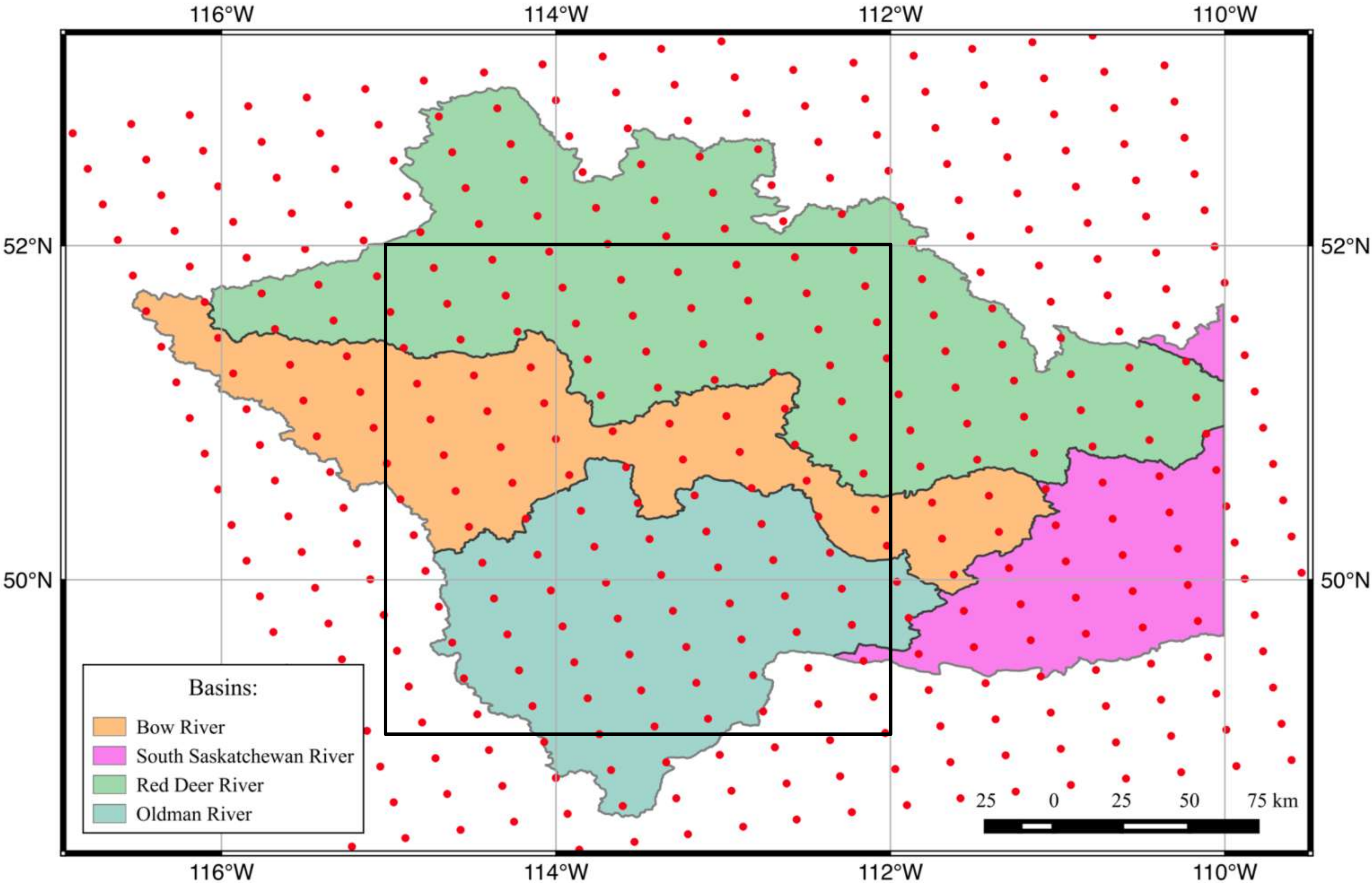
October 2017 was the **393rd consecutive month** with a global temperature above the 20th century average



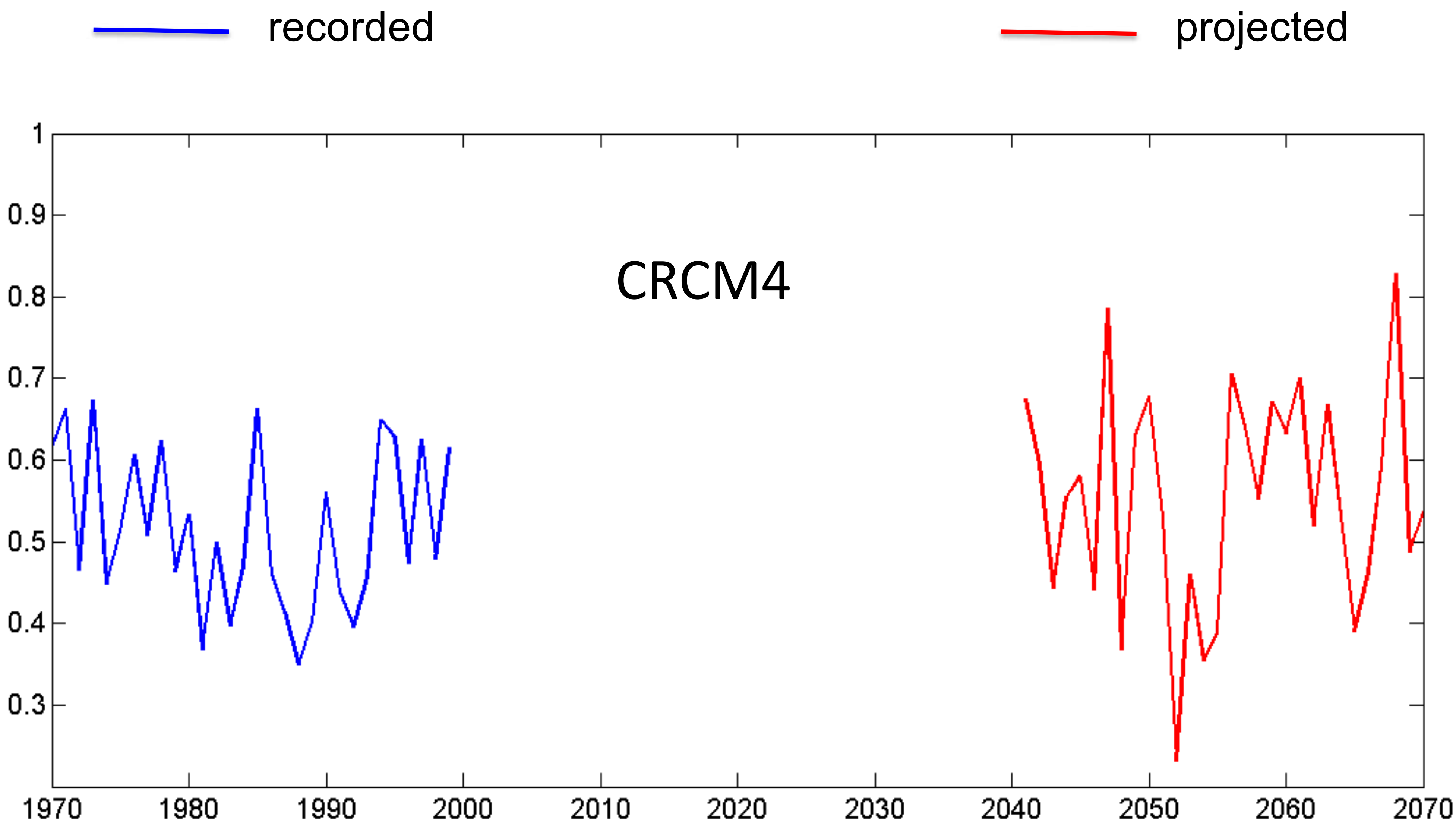
GCM: Global Climate Model



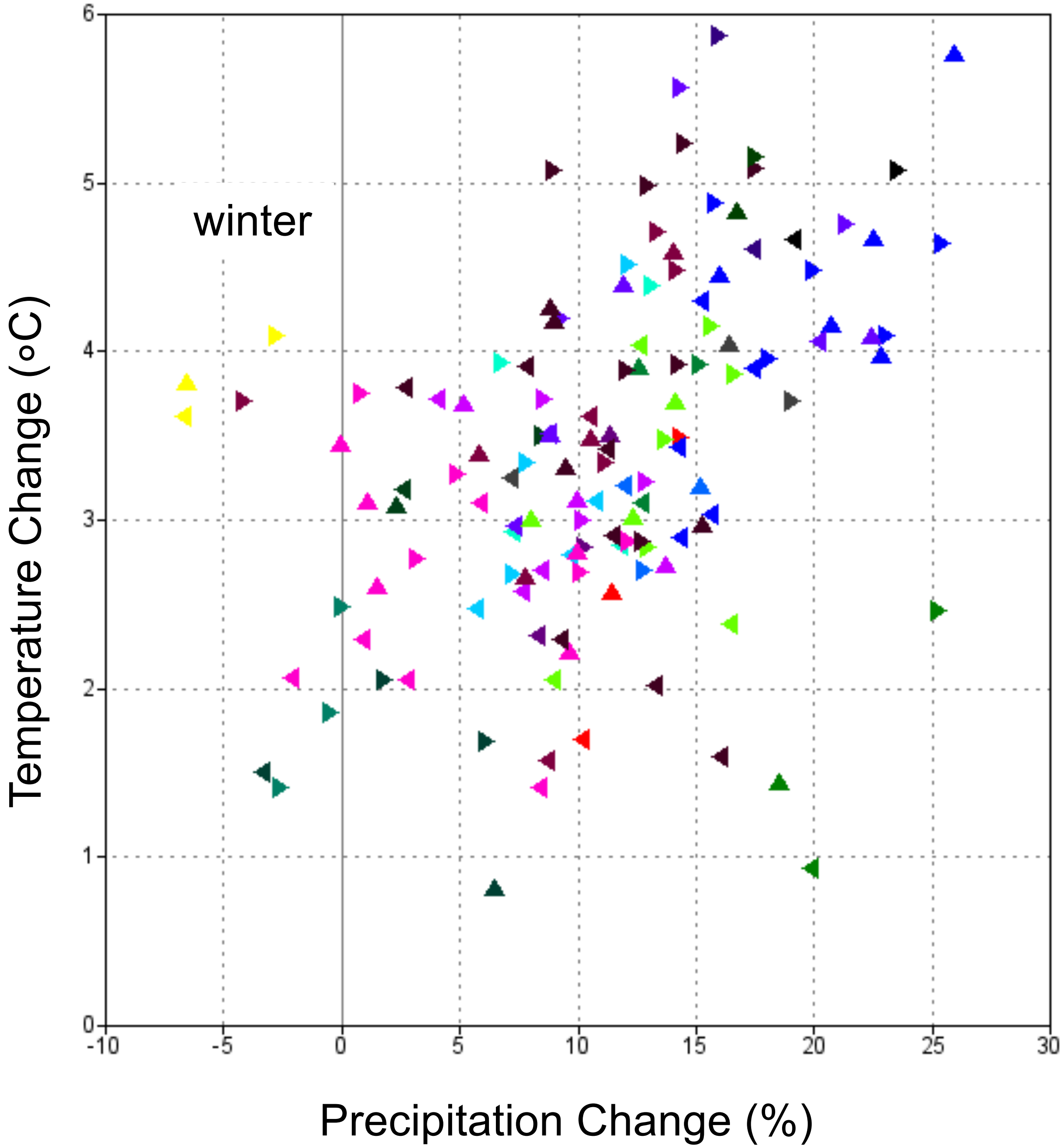
SSRB - GCM grid cell and **RCM grid**



Oldman River Basin Runoff (mm/day), 1970-2000, 2040-2070

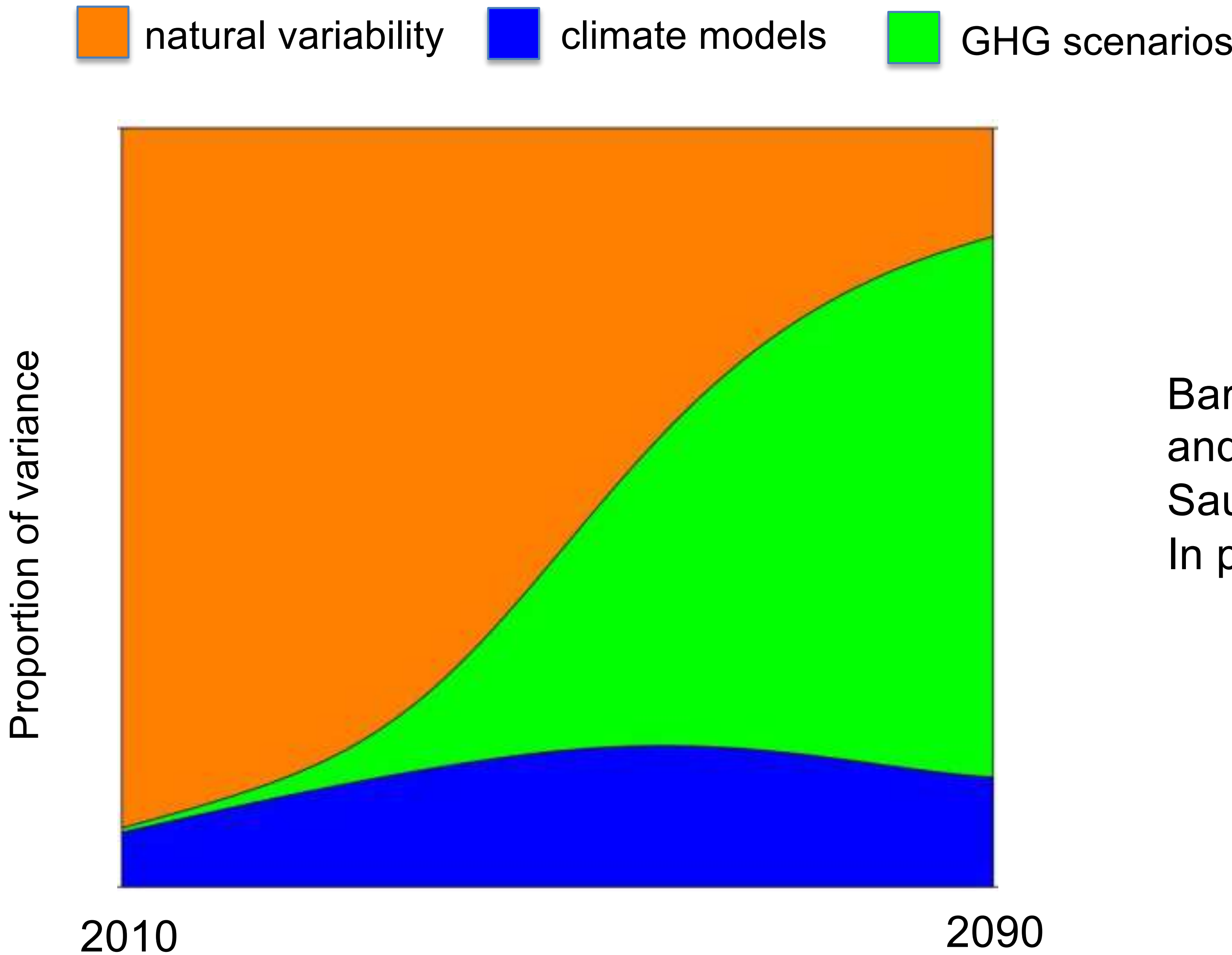


Projected Climate Changes, 2040-69 versus 1971-2000



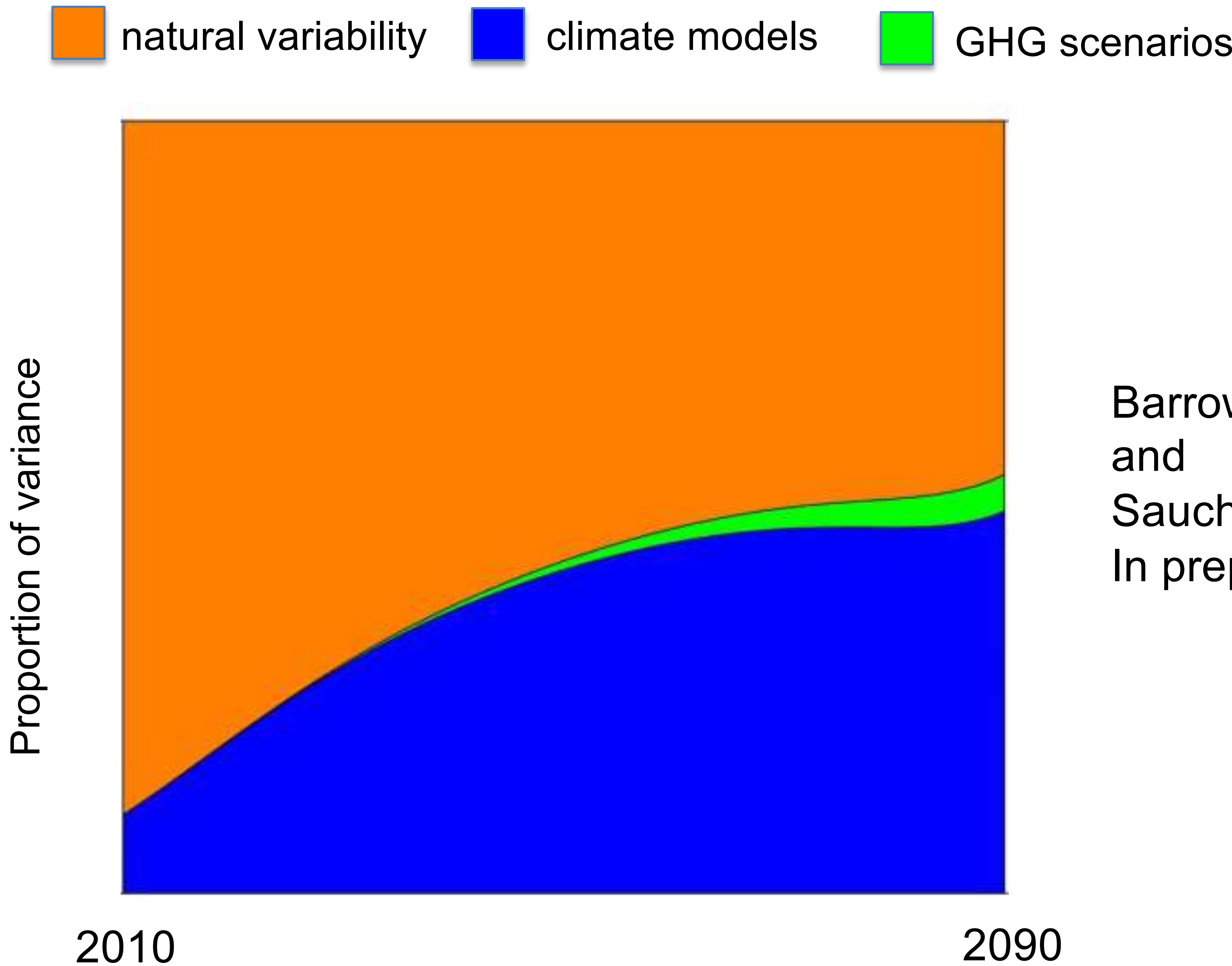
Source: PCIC

Future Temperature – Sources of Uncertainty

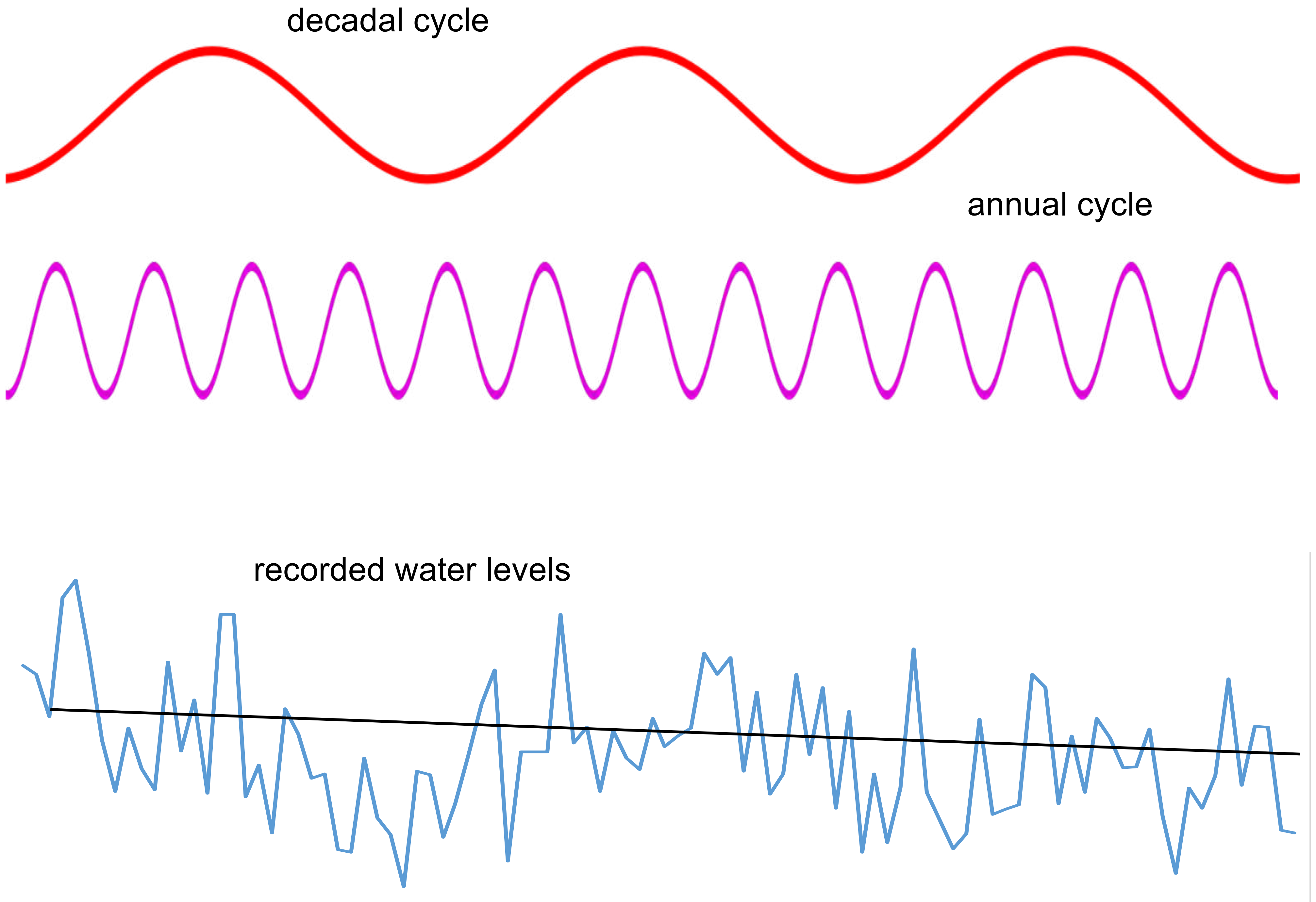


Barrow
and
Sauchyn,
In prep.

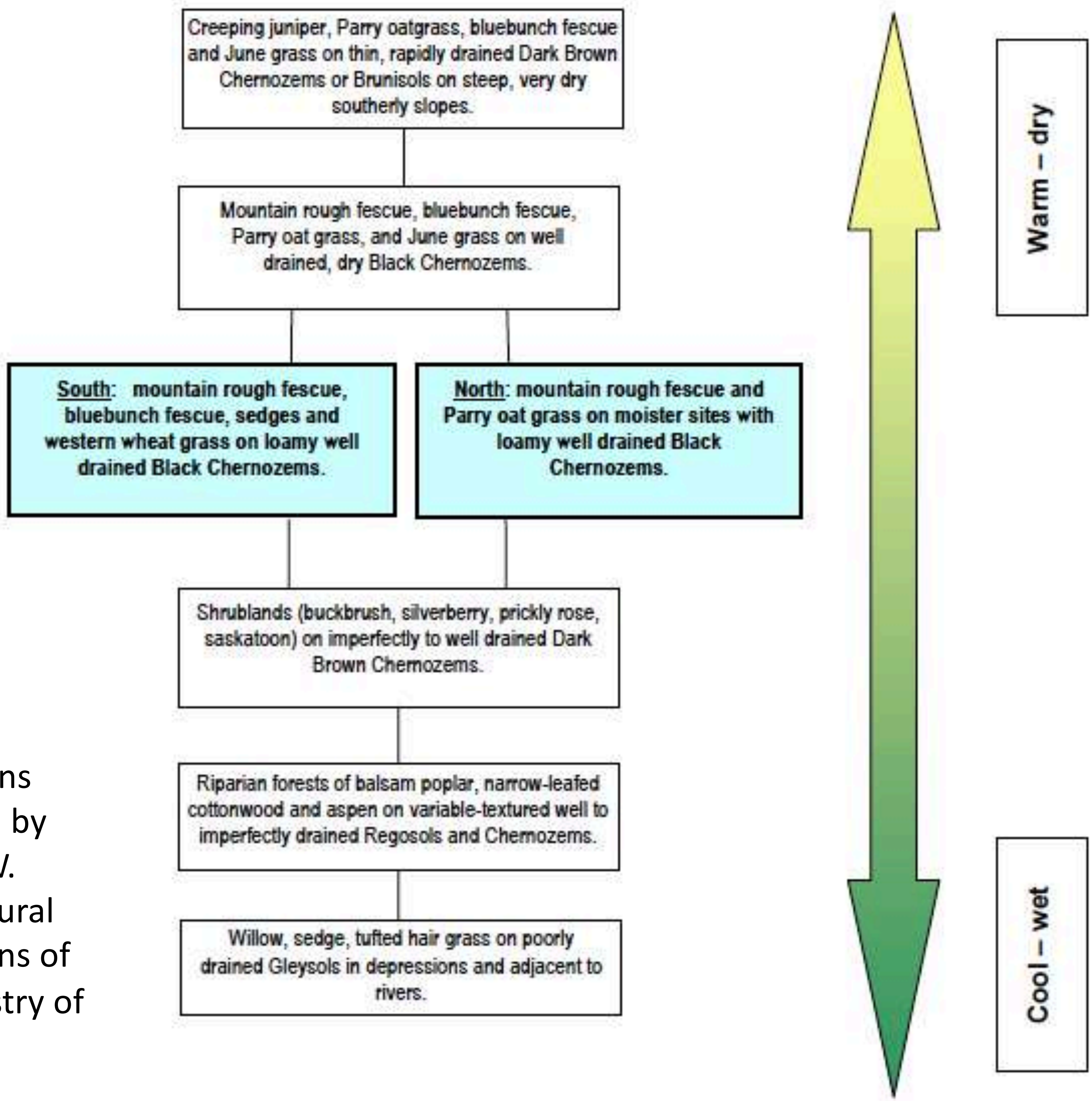
Future Precipitation – Sources of Uncertainty



Barrow and Sauchyn, In prep.


decadal cycle
annual cycle
recorded water levels

Foothills Fescue Natural Subregion: Common Ecosystems Arranged Along Environmental Gradient

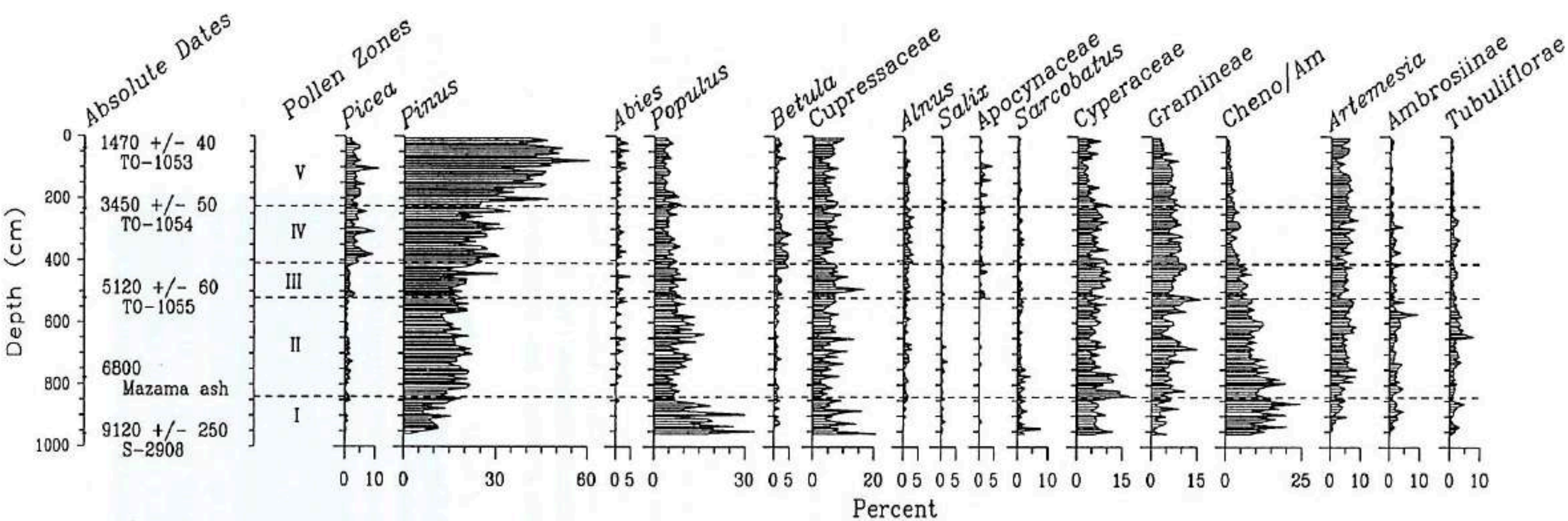


Source: Natural Regions Committee, Compiled by D.J. Downing and W.W. Pettapiece. 2006. Natural Regions and Subregions of Alberta. Alberta Ministry of Environment.


Holocene Paleoecology

Harris Lake, Cypress Hills, Saskatchewan
(Vetter in Sauchyn and Sauchyn, 1991)

- 8500-7900 years BP: four severe droughts, with grass pollen levels of around 5%
- modern pollen inputs across the Great Plains are very rarely as low as 5% and mostly 20% or higher even in the driest regions
- severe drought also during the Medieval Warm Period around 1000 years ago

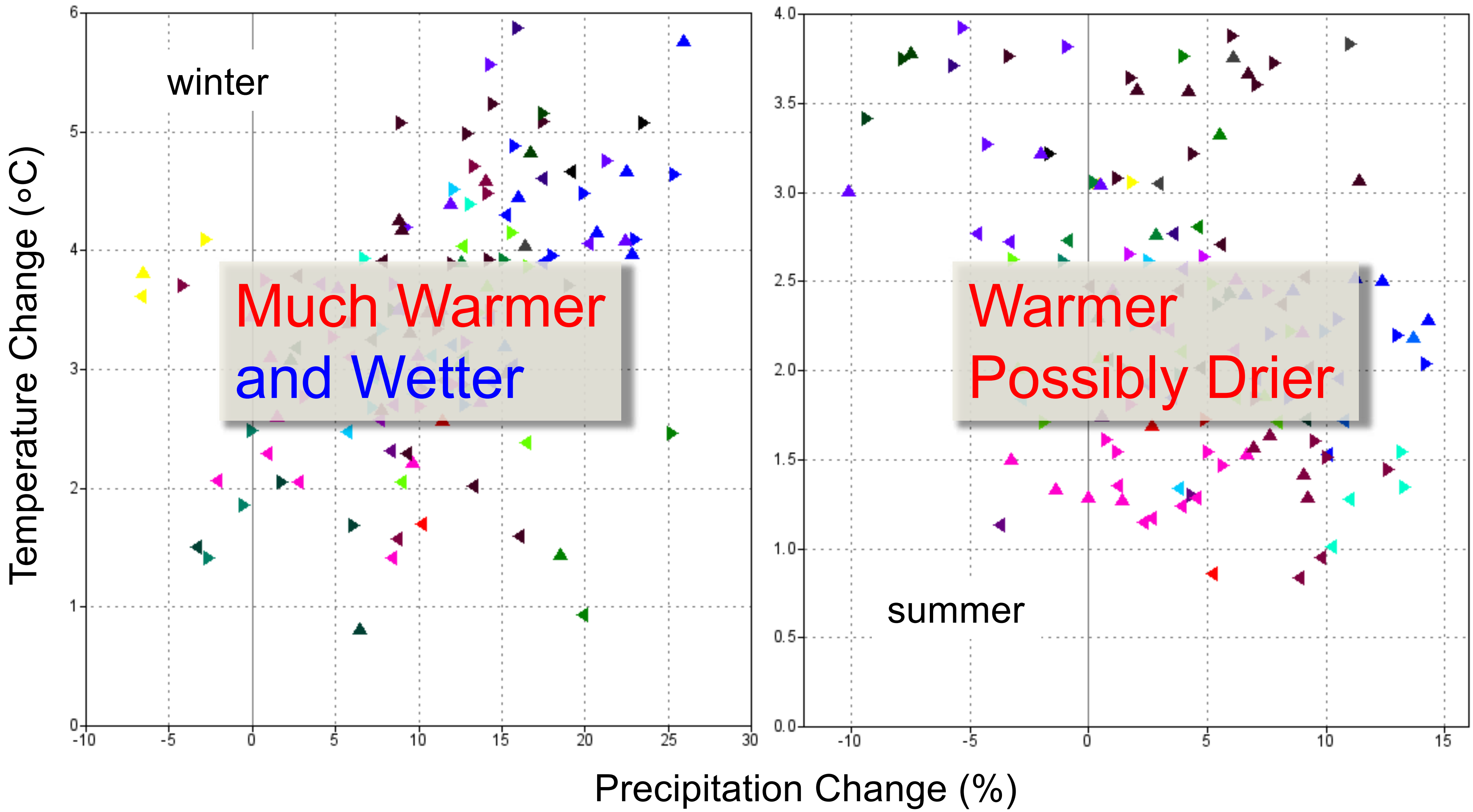


Kettle Lake, northwestern North Dakota (Clark et al., 2002)

- 8500-7900 years BP - 5 drought cycles of 100-130 years in length
- grass pollen inputs dropped to between less than 5% to about 8%
- quartz levels spiked, indicating erosion; and charcoal amounts dropped to near zero suggesting the vegetation was too dry to support prairie fires
- repeated drought cycles shifted the vegetation composition permanently to more C_3 grasses; drought tolerance of C_4 grasses was exceeded in summer

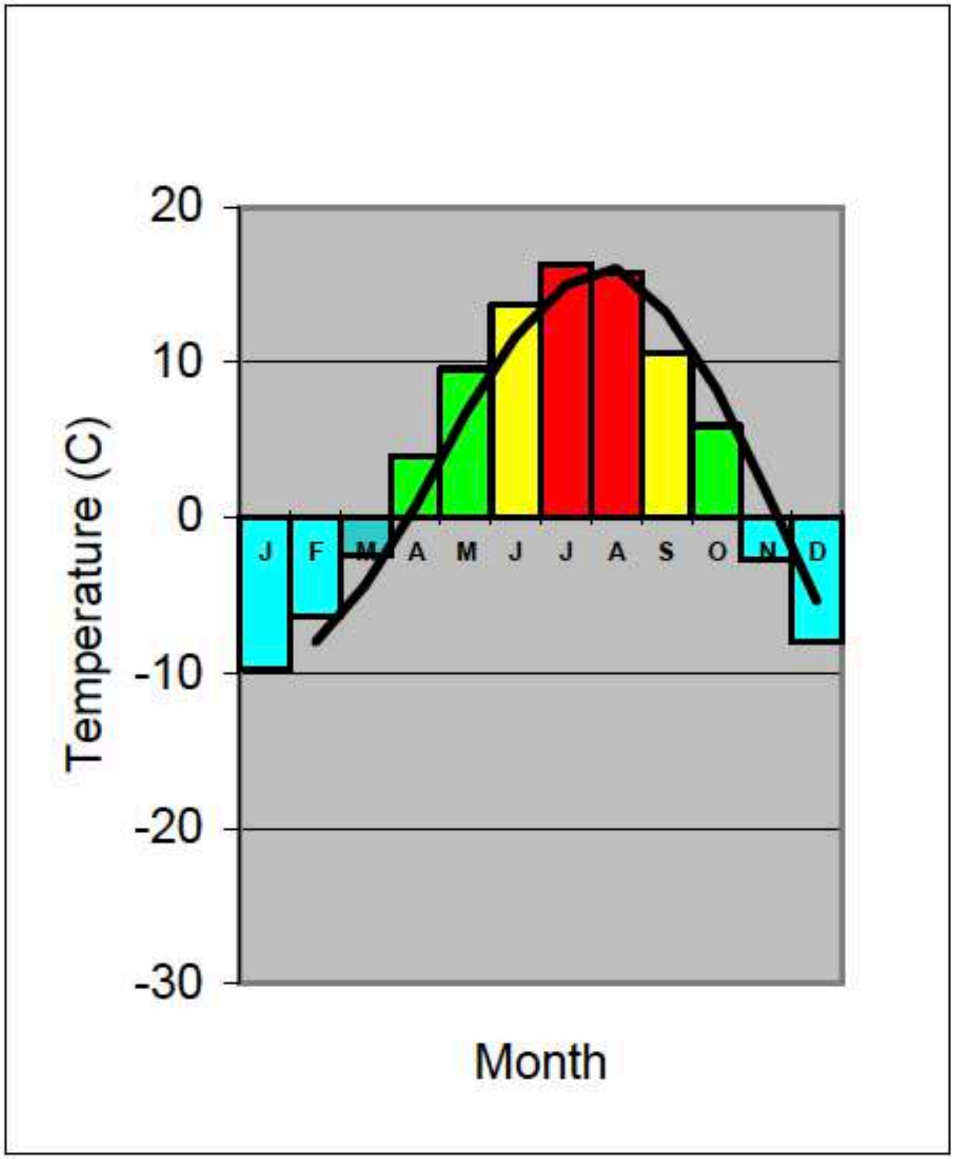
"drought severity during past, and possibly future, arid phases cannot be anticipated from the attenuated [historical] climate variability … **the Dust Bowl was unremarkable in the context of the last two millennia**"

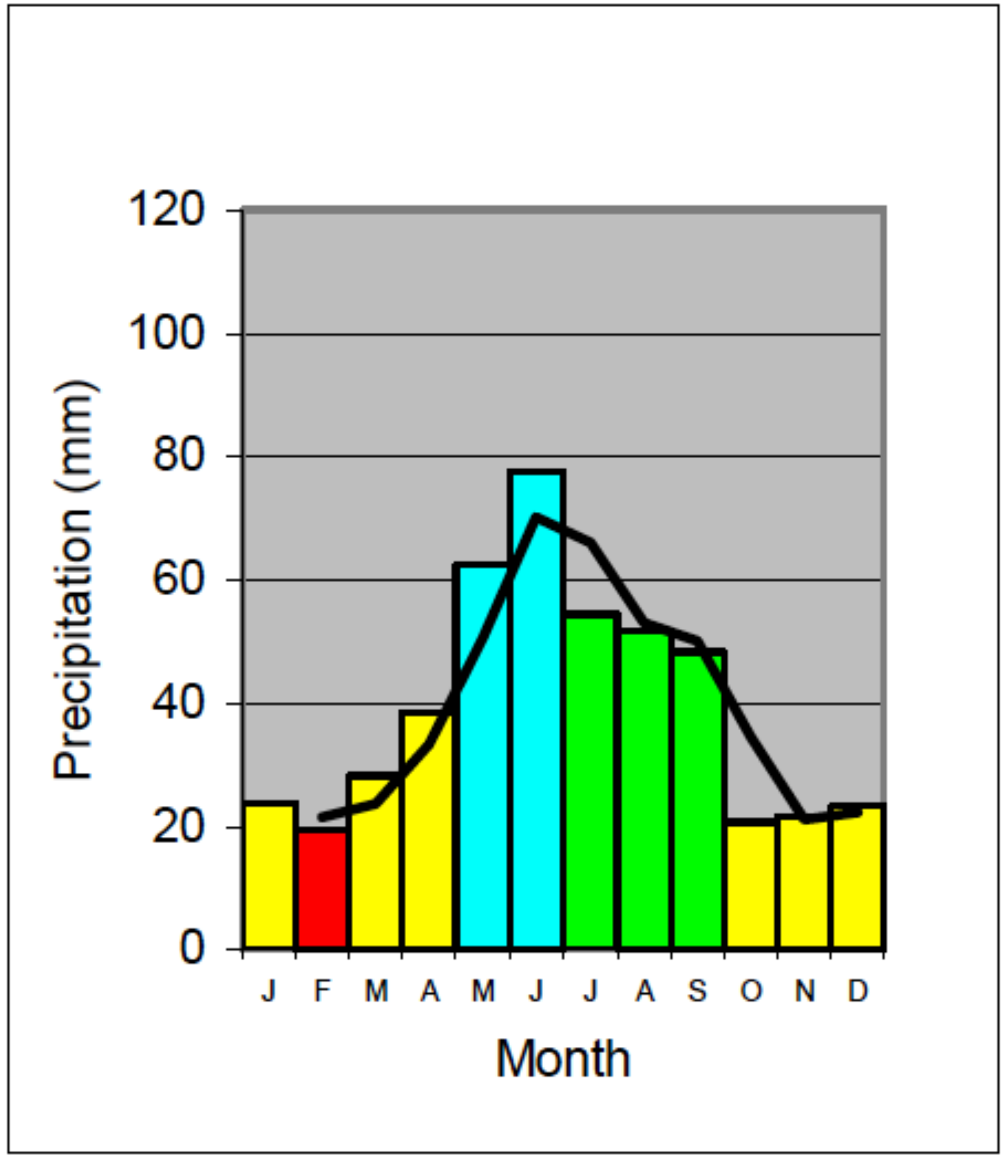
Projected Climate Changes, Western Prairies, 2040-69 versus 1971-2000



Source: PCIC

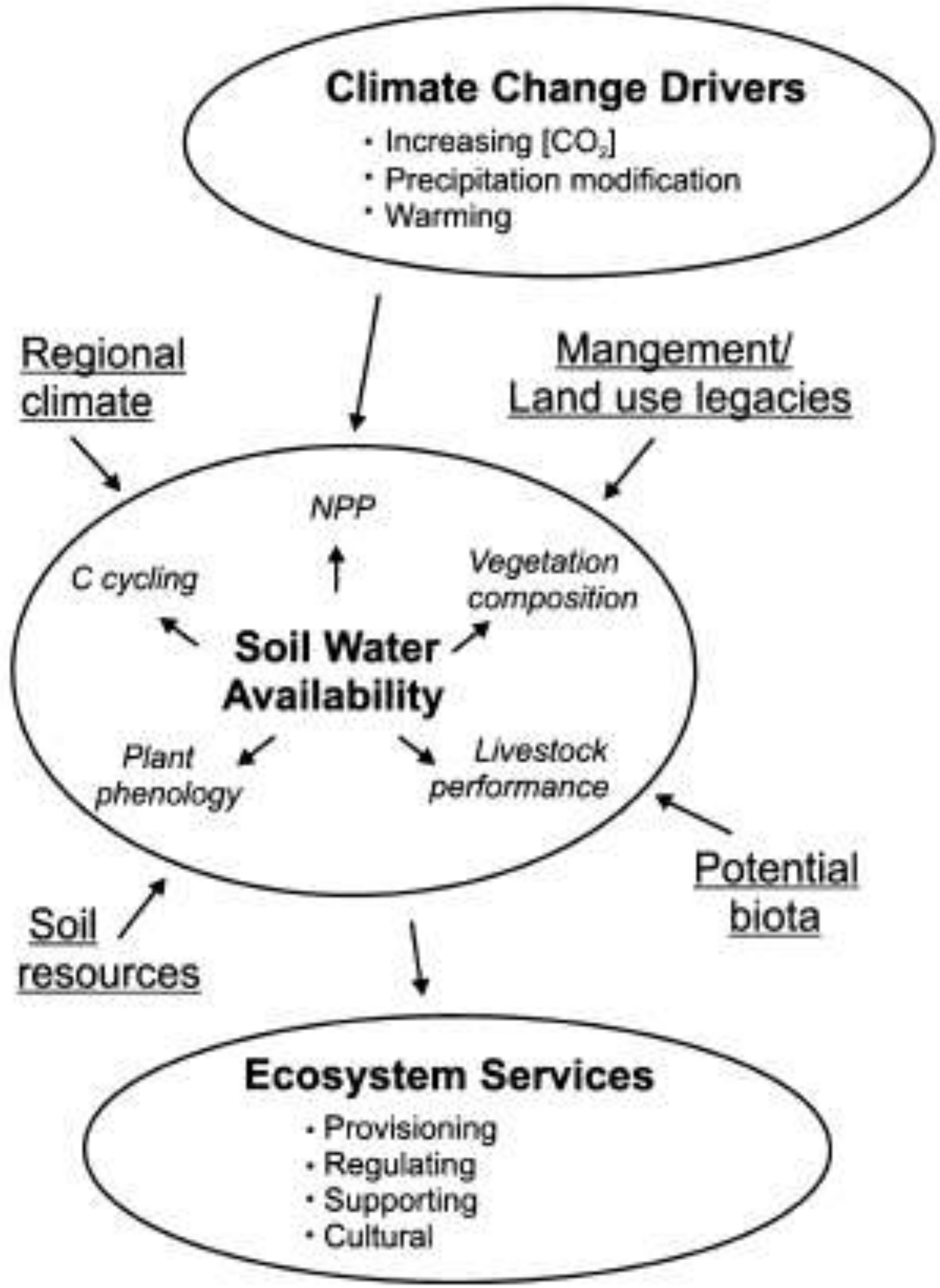
Foothills Fescue Natural Subregion, Climate Data Summaries





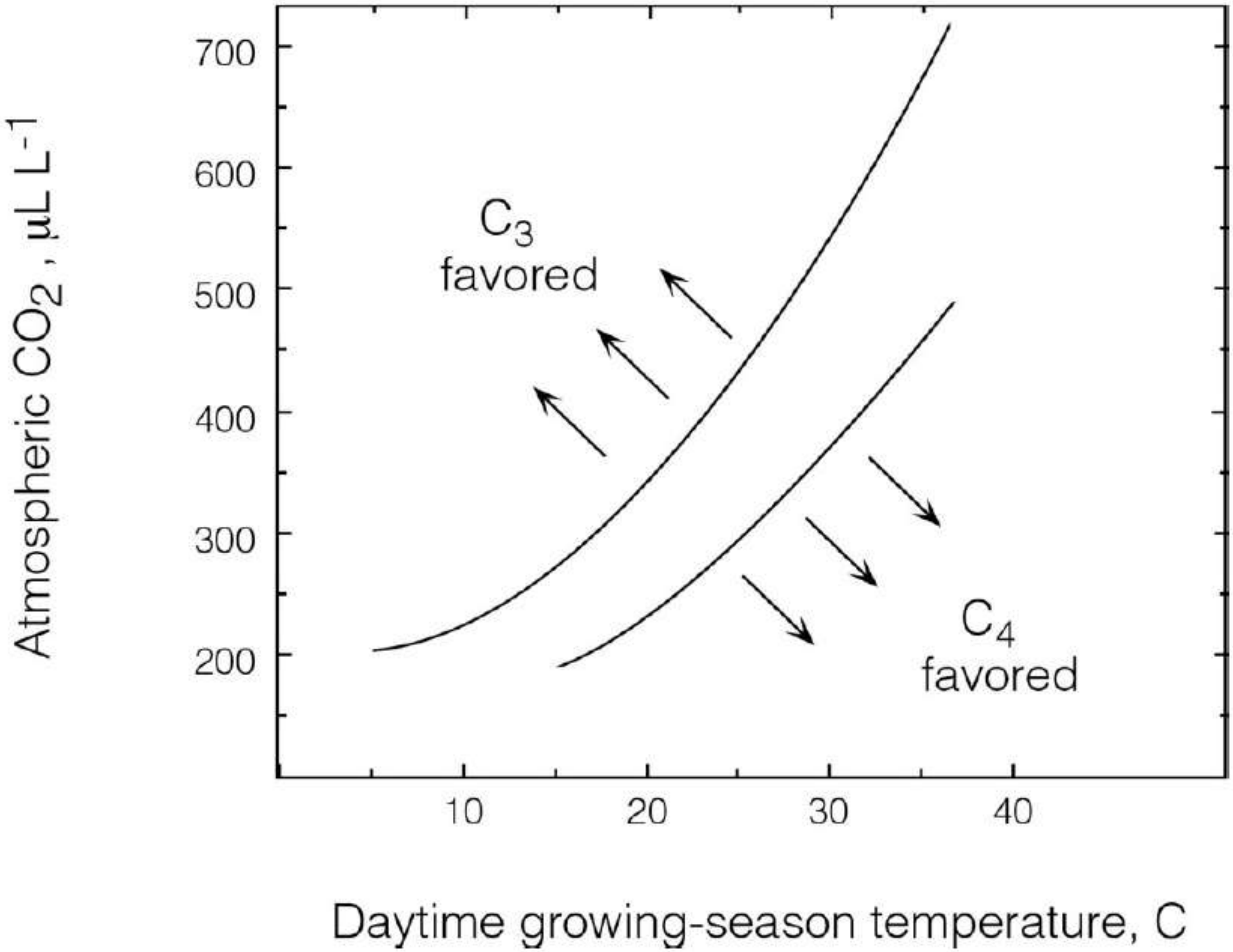
Source: Regions and Subregions of Alberta

Figure 5. A conceptual model illustrating the response of rangeland ecosystems to climate change.



Polley, H.W., D.D. Briske, J.A. Morgan, K. Wolter, D.W. Bailey, and J.R. Brown. 2013. Climate change and North American rangelands: Trends, projections, and implications. Invited Synthesis. Rangeland Ecology & Management 66 (5): 493-511.

Elevated CO_2 levels and warming: C_3 vs C_4 plants



Ehleringer, Jim. 2015. Plant Ecology in a Changing World. http://plantecology.net
http://www.plantecology.net/c3c4-photosynthesis-and-climate.html

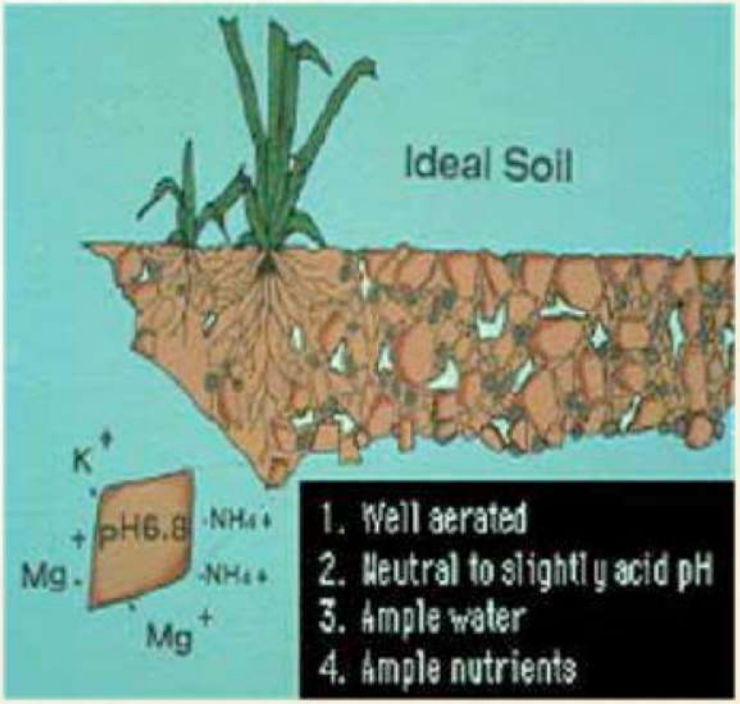
WATER USE EFFICIENCIES

Plant Physiology

C3 VS C4

Return to Course Map

- C3 grasses must have stomates open longer than C4 to capture CO_2
- Open stomates lose more water
- C4 grasses use less water per unit of CO_2 fixed
- C3 grasses are more easily drought stressed during warm weather



http://slideplayer.com/1728317/7/images/83/Water+use+efficiencies.jpg

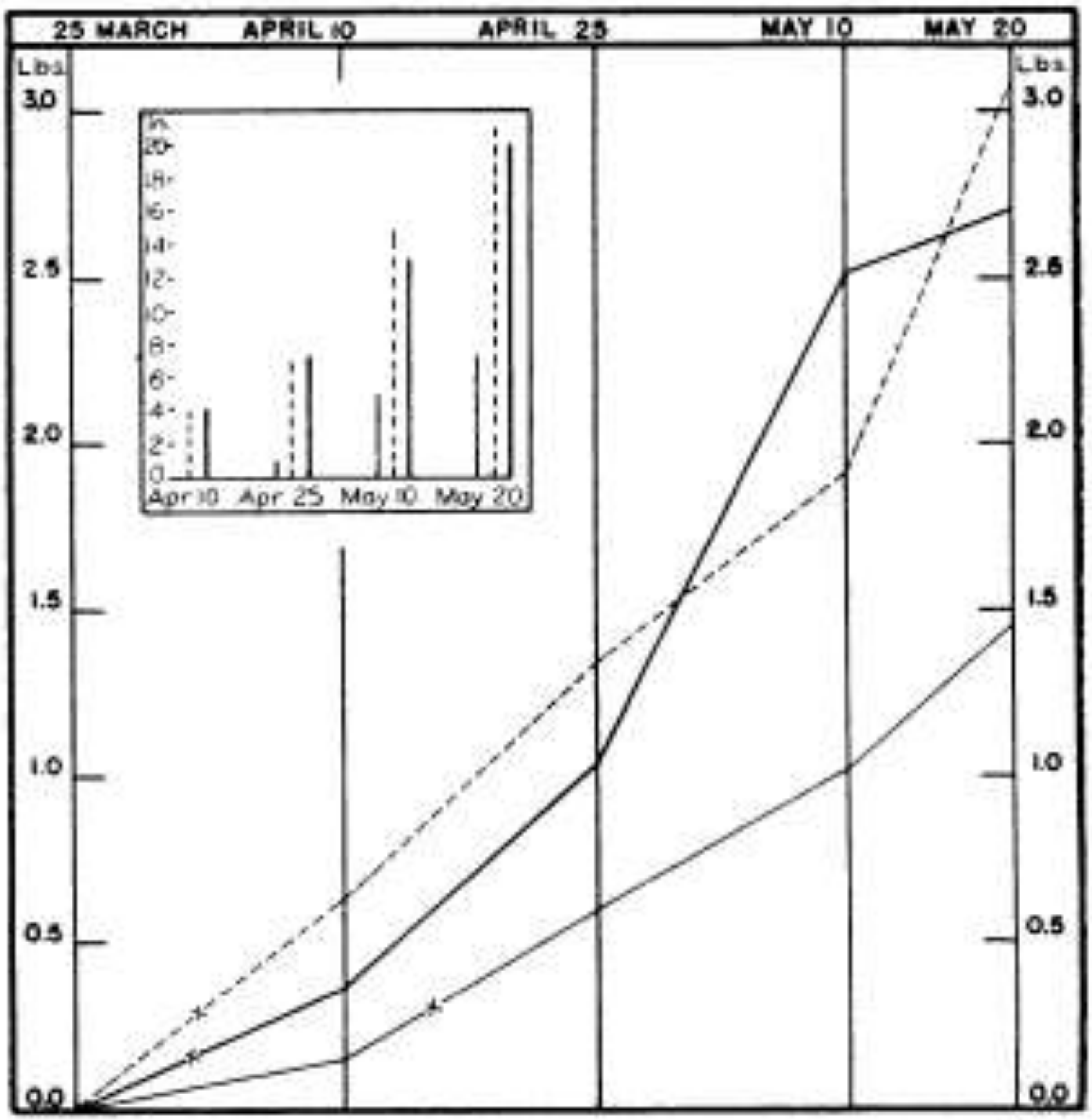
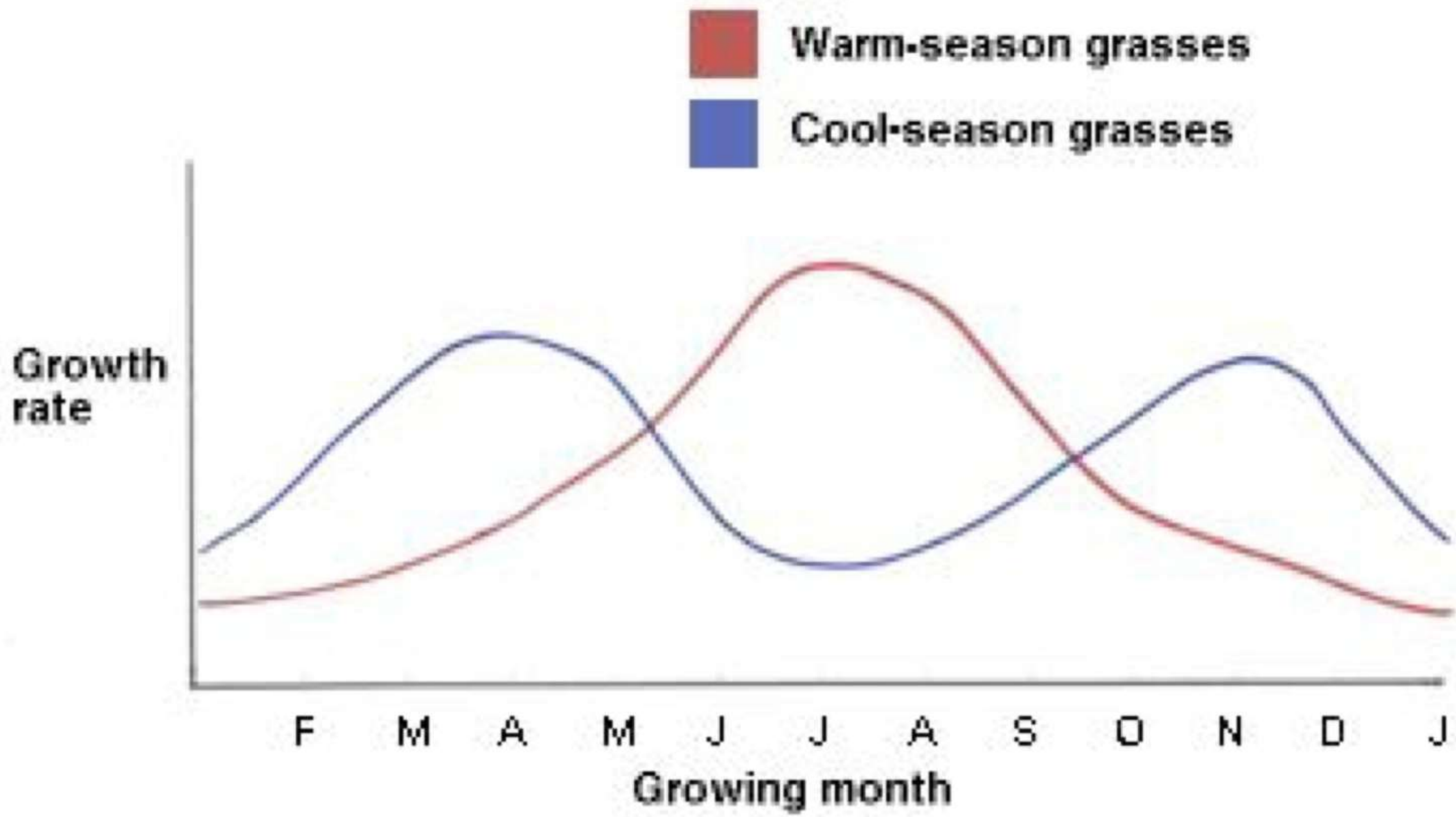


Figure 17. Average daily loss [of pounds of water] per container o *Agropyron smithii* [western wheat grass] (heavy line), *Stipa spartea* [needle grass} (broken line), and *Andropogon scoparius* [little bluestem] (light line), during the spring of 1941. Date of renewal of growth is indicated by X. The insert shows average height of grasses on the several dates indicated.

NOTE: Western wheat grass and needle grass are C_3 plants while little bluestem is a C_4 plant.

J.E. Weaver and F.W. Albertson. 1943. Resurvey of grasses, forbs, and underground plant parts at the end of the Great Drought. Ecological Monographs 13 (1): 63-117.

“The early growth of both western wheat grass and needle grass and consequent depletion of soil moisture by transpiration are important factors in their spread during drought.”



http://ipm.ucanr.edu/TOOLS/TURF/IMAGES/ESTAB/growthrate.jpg

Table 1. Responses of plant attributes to CO_2 enrichment

Rangeland CO_2 experiments	Shortgrass steppe, Colorado[1–3]	Mixed-grass prairie, Wyoming[4,5]
Carbon dioxide (ppmv)	Ambient to 720	Ambient to 600
Plant biomass	+	+,0
	41% increase in ANPP; 100% increase during a dry year	25% increase in ANPP; no response during a wet year
Phenology		0
Water relations	+	+
Functional group responses for biomass	+ C_3 grasses + C_3 shrub 0 C_4	+ C_3 grasses +,0 C_4 grasses

Polley, H.W. *et al.* 2013. Climate change and North American rangelands: Trends, projections, and implications. Invited Synthesis. Rangeland Ecology & Management 66 (5): 493-511.

Intra-annual (seasonality) changes in precipitation

https://upload.wikimedia.org/wikipedia/commons/5/5e/Cheatgrass_%28Bromus_tectorum%29%3B_Hidden_Valley.jpg

Invasive *Bromus tectorum* on (Downy Brome) Spruce Mountain, Nevada.

By Famartin - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=27062278

Prevéy, J.S. and T.R. Seastedt. 2015. Effects of precipitation change and neighboring plants on population dynamics of *Bromus tectorum*. Oecologia 179 (3): 765-775. https://link-springer-com.libproxy.uregina.ca:8443/article/10.1007%2Fs00442-015-3398-z

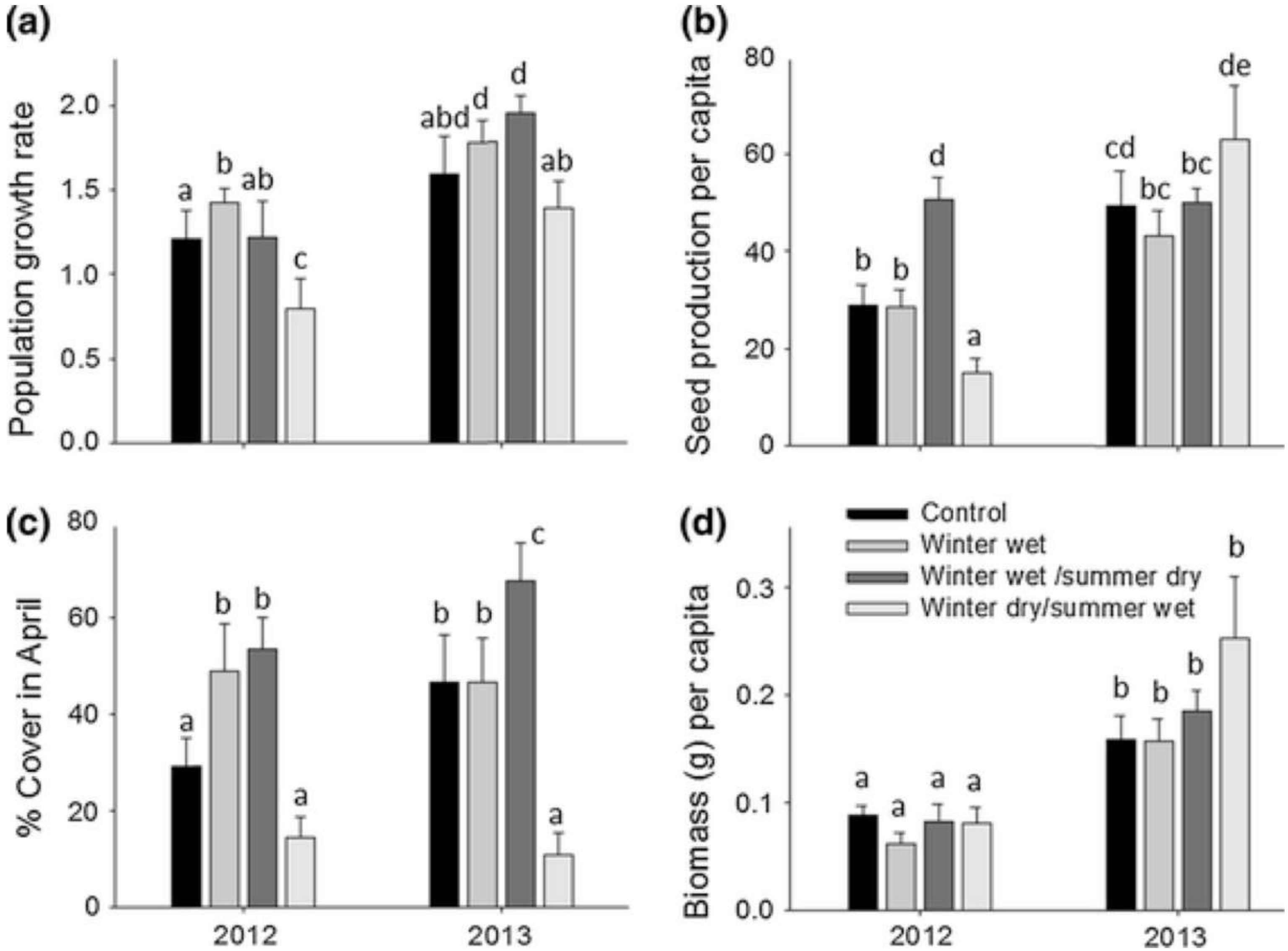


Fig. 2. Responses of *B. tectorum* to the four precipitation manipulations in 2012 and 2013. a Average population growth rates (λ), b numbers of seeds produced per individual, c percentage cover, d aboveground biomass per individual of *B. tectorum*.