



# **The Changing Cold Regions Network: Observation, Diagnosis, and Prediction of Environmental Change in the Saskatchewan and Mackenzie River Basins**

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**Saskatoon, Canada**

**GEWEX Hydroclimate Panel, Entebbe,  
Uganda, 17 November, 2015**



# CCRN: Changing Cold Regions Network

Funded by the Natural Science and Engineering Research Council,  
Climate Change and Atmospheric Research initiative  
2013-2018

*“This Network aims to **understand, diagnose and predict** interactions amongst the cryospheric, ecological, hydrological, and climatic components of **the changing Earth system** at multiple scales with a geographic focus on **Western Canada’s rapidly changing cold interior.**”*

# Network Development

- CCRN has developed a large, multi-disciplinary team of researchers
  - 42 investigators and 136 students, post-doctoral fellows, and other HQP from 8 Canadian universities and 4 federal government agencies
  - International collaboration includes 18 scientists from Germany, France, the U.S., U.K., and China
- Linked to GEWEX, CLiC, GEO, NCAR, NASA, and more
  - In December 2014, the World Climate Research Programme endorsed CCRN as a GEWEX Regional Hydroclimate Project

# List of CCRN Participants

## Network Co-Investigators and Collaborators

- Vivek Arora (Env. Can.)
- Jenifer Baltzer (Wilfrid Laurier U.)
- Alan Barr (Env. Can.)
- Paul Bartlett (Env. Can.)
- Aaron Berg (U. Guelph)
- Andy Black (U. British Columbia)
- Barrie Bonsal (Env. Can.)
- **Sean Carey (McMaster U.)**
- Garry Clarke (U. British Columbia)
- Mike Demuth (Nat. Resources Can.)
- John Diiwu (AB Env. and Sus. Res. Dev.)
- Vincent Fortin (Env. Can.)
- John Hanesiak (U. Manitoba)
- Masaki Hayashi (U. Calgary)
- Warren Helgason (U. Sask.)
- **Al Howard (Ag. and Agri-Food Can.)**
- Dave Hudak (Env. Can.)
- Andrew Ireson (U. Sask.)
- Richard Janowicz (Yukon Environment)
- Ed Johnson (U. Calgary)
- Jill Johnstone (U. Sask.)
- Bob Kochtubajda (Env. Can.)
- Yanping Li (U. Sask.)
- **Murray MacKay (Env. Can.)**

- **Phil Marsh (Wilfrid Laurier U.)**
- Sean Marshall (U. Calgary)
- Jeff McDonnell (U. Sask.)
- **Al Pietroniro (Env. Can.)**
- **John Pomeroy (U. Sask.)**
- **William Quinton (Wilfrid Laurier U.)**
- Garry Scrimgeour (Parks Can.)
- Chris Spence (Env. Can.)
- Craig Smith (Env. Can.)
- Saman Razavi (U. Sask.)
- **Ron Stewart (U. Manitoba)**
- Kit Szeto (Env. Can.)
- Julie Thériault (U. Québec à Montréal)
- **Merritt Turetsky (U. Guelph)**
- Garth van der Kamp (Env. Can.)
- **Howard Wheeler (U. Sask.; CCRN PI)**
- Daqing Yang (Env. Can.)
- Xuebin Zhang (Env. Can.)

## Board of Directors

- Ming-Ko (Hok) Woo (McMaster U., ret., BOD Chair)
- Jim Bruce (Env. Can., ret.)
- Wayne Dybvig (SK WSA)
- Ken Greenway (AB Env. & Sus. Res. Dev.)

- Michel Jean (Env. Can.)
- Donna Kirkwood (Nat. Resources Can.)
- David Livingstone (Gov. NWT, ret.)
- Denis Petitclerc (Ag. and Agri-Food Can.)

## International Advisory Panel

- Don Cline (National Oceanic and Atmospheric Administration)
- Richard Harding (UK Centre Ecology and Hydrology)
- Larry Hinzman (U. Alaska)
- Eric Kasischke (U. Maryland; NASA ABoVE)

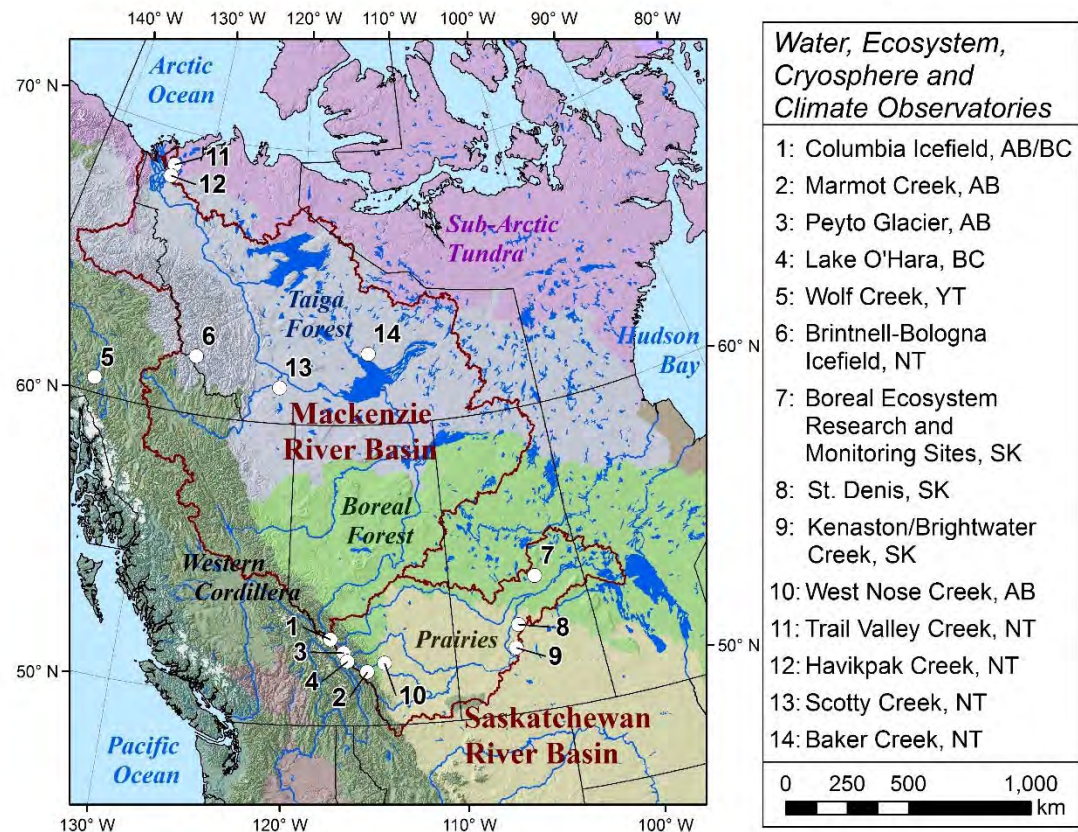
## Secretariat (@ GIWS, U. Sask.)

- Chris DeBeer (CCRN Project Manager)
- Meagan Hinthier (Communications Specialist)
- Michelle Martel-Andre (Executive Assistant)
- Sherry Olason (Clerical Assistant)
- Graham Strickert (Outreach Co-ordinator)
- Tim Zagozewski (Finance Officer)
- Branko Zdravkovic (Database Manager)

\*Indicates member of Science Committee

# CCRN Research Programme: Geographic Focus / Water, Ecosystem, Cryosphere and Climate (WECC) Observatories

- A network of WECC Observatories combine meteorological, hydrological, ecosystem, and cryospheric observations with multi-scale coupled models from the surface to the atmosphere.
- Observatories contain long-term legacy data sets, including hydro-meteorological variables, remote sensing observations, LiDAR topography, and soils, geology, and vegetation characterization



# CCRN Geophysical and and Program s / Water, Eco (CC) Observato

Trail Valley Creek

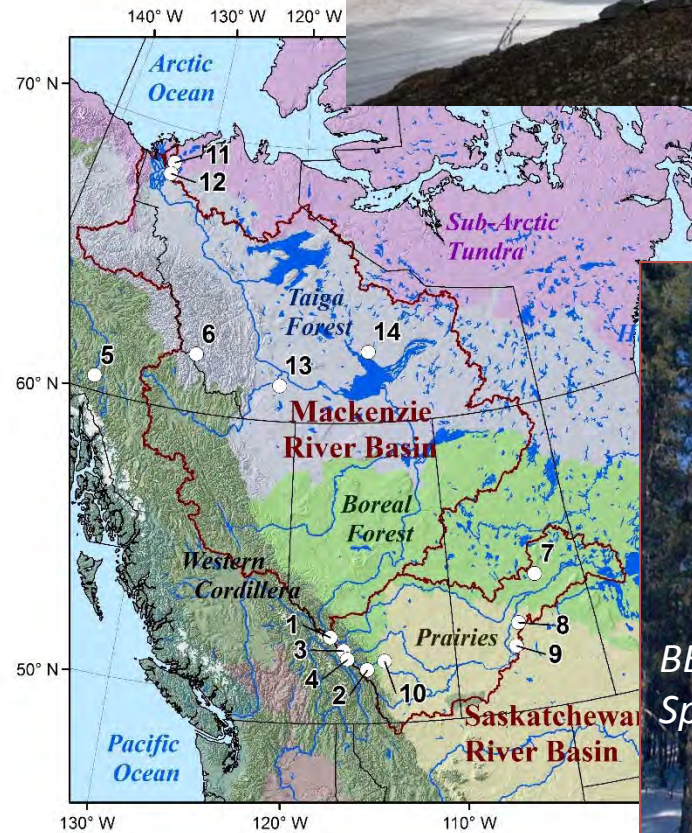


- A  
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surface to the atmosphere.

Kenaston /  
Brightwater  
Creek

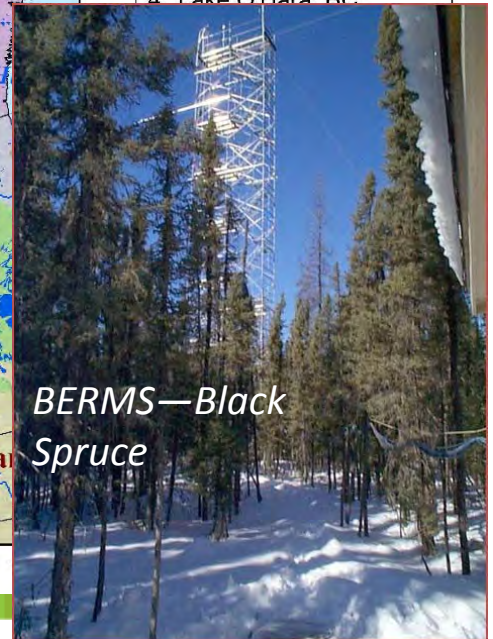


Brintnell  
Glacier



Climate Observations

- 1: Columbia Icefield, AB/BC
- 2: Marmot Creek, AB
- 3: Peyto Glacier, AB
- 4: Lake O'Hara, BC



BERMS—Black  
Spruce

# CCRN Research Programme: Thematic Components

The CCRN's research programme and its objectives are organized based on 5 inter-related and inter-dependent Themes:

- A. Observed Earth System Change in Cold Regions—Inventory and Statistical Evaluation;
- B. Improved Understanding and Diagnosis of Local-Scale Change;
- C. Upscaling for Improved Atmospheric Modelling and River Basin-Scale Prediction;
- D. Analysis and Prediction of Regional and Large-Scale Variability and Change; and
- E. User Community Outreach and Engagement

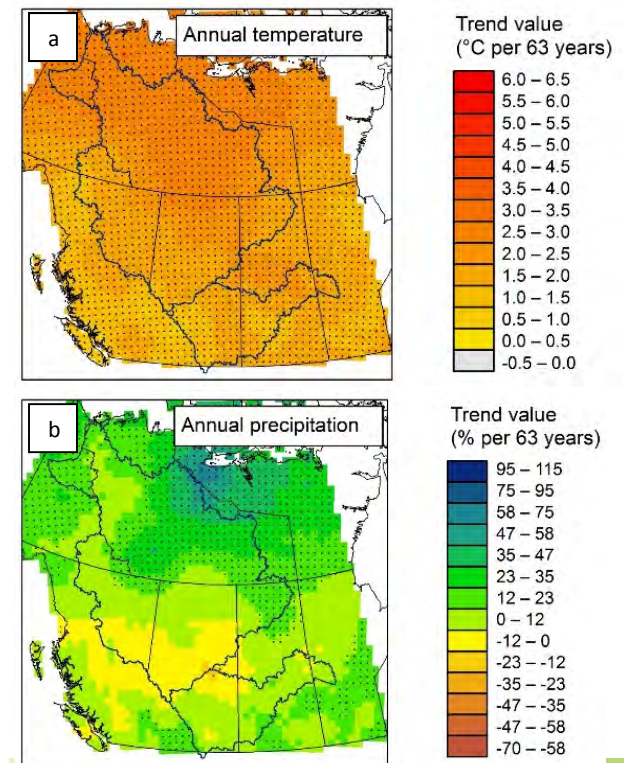
# Progress to Date and Future Directions: Theme A—Inventory of Observed Change

- The objectives of this early Theme are now nearly complete; targeted products are being developed as deliverables

- Activities have included:

- Local-scale assessments and inventories of change at WECC sites;
- Collection of extensive set of dendro-chronological tree core data;
- Regional-scale synthesis of Earth system change in western Canada;
- Development of conceptual models of mechanisms and drivers of change for WECC sites and major ecoregions to be diagnosed in Theme B.

*Climate trends  
(1950–2012)*

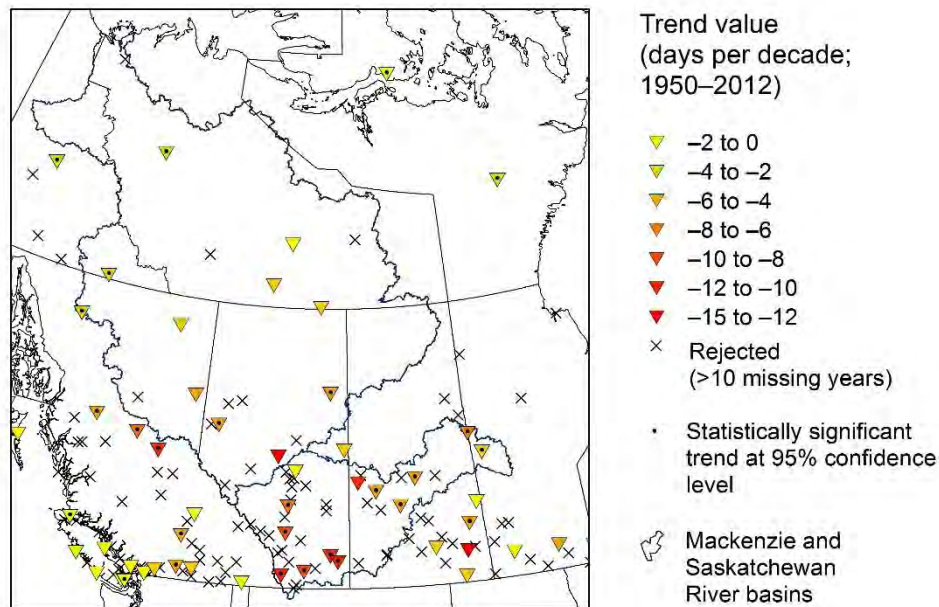




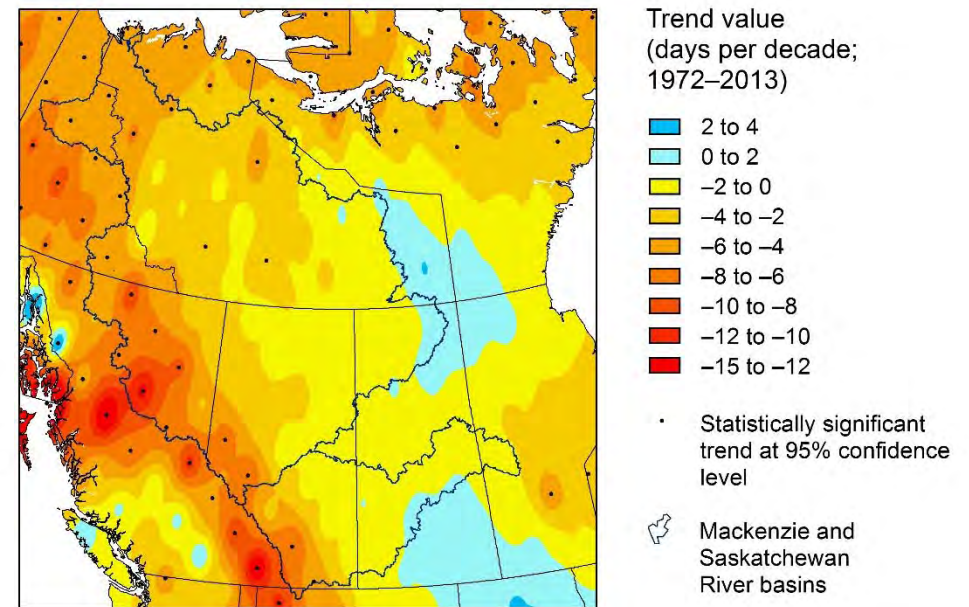
# Observed Changes: Snow Cover

- Trends in annual and spring snow cover duration (Results provided by Ross Brown)

Annual snow cover duration trends, 1950–2012, from surface observations in the Canadian Daily Snow Depth Dataset



Spring season snow cover duration trends, 1972–2013, from NOAA weekly snow cover product, Rutgers University

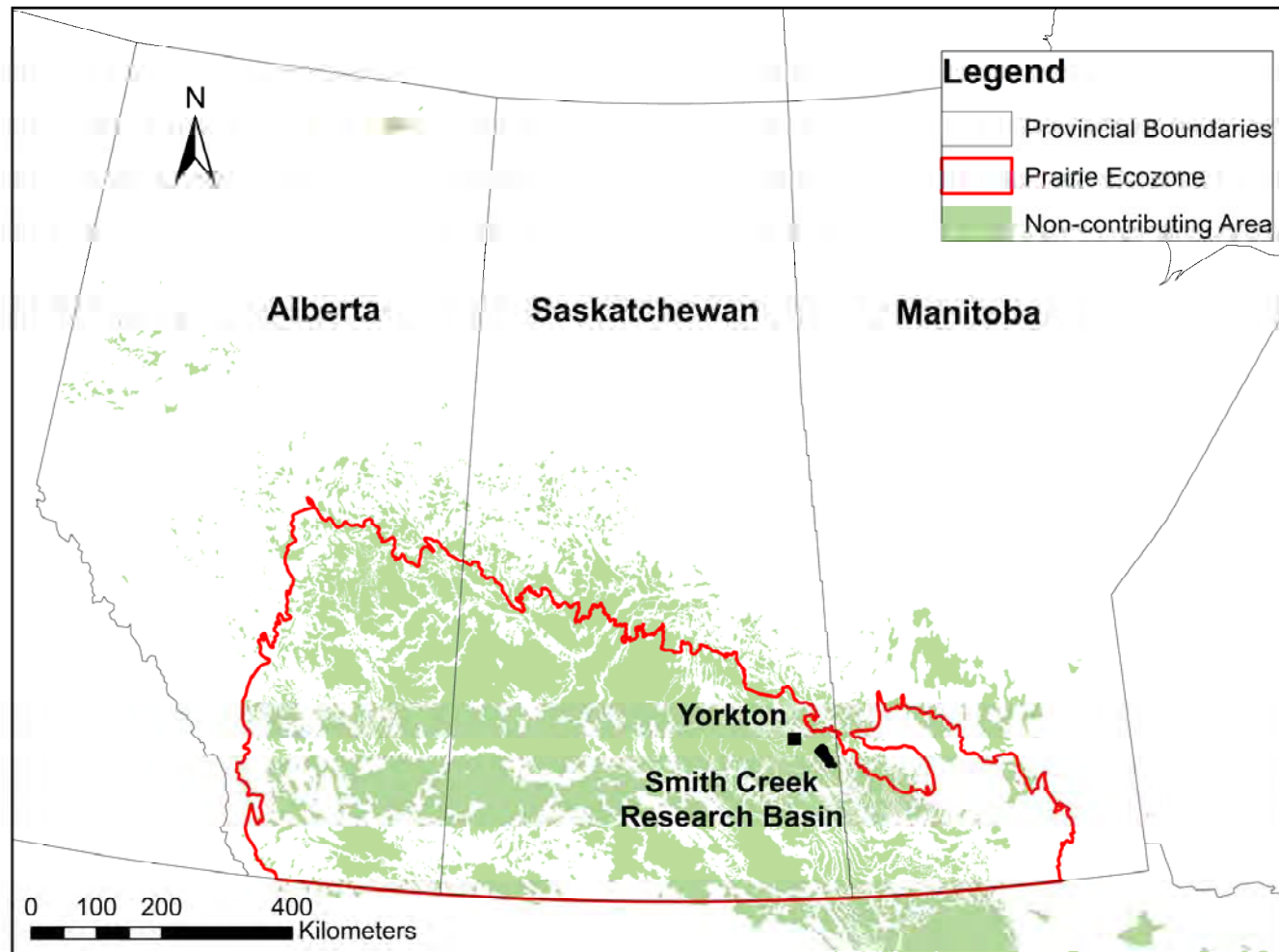


**1 to 2 month decline in snowcover period over most of the CCRN domain**

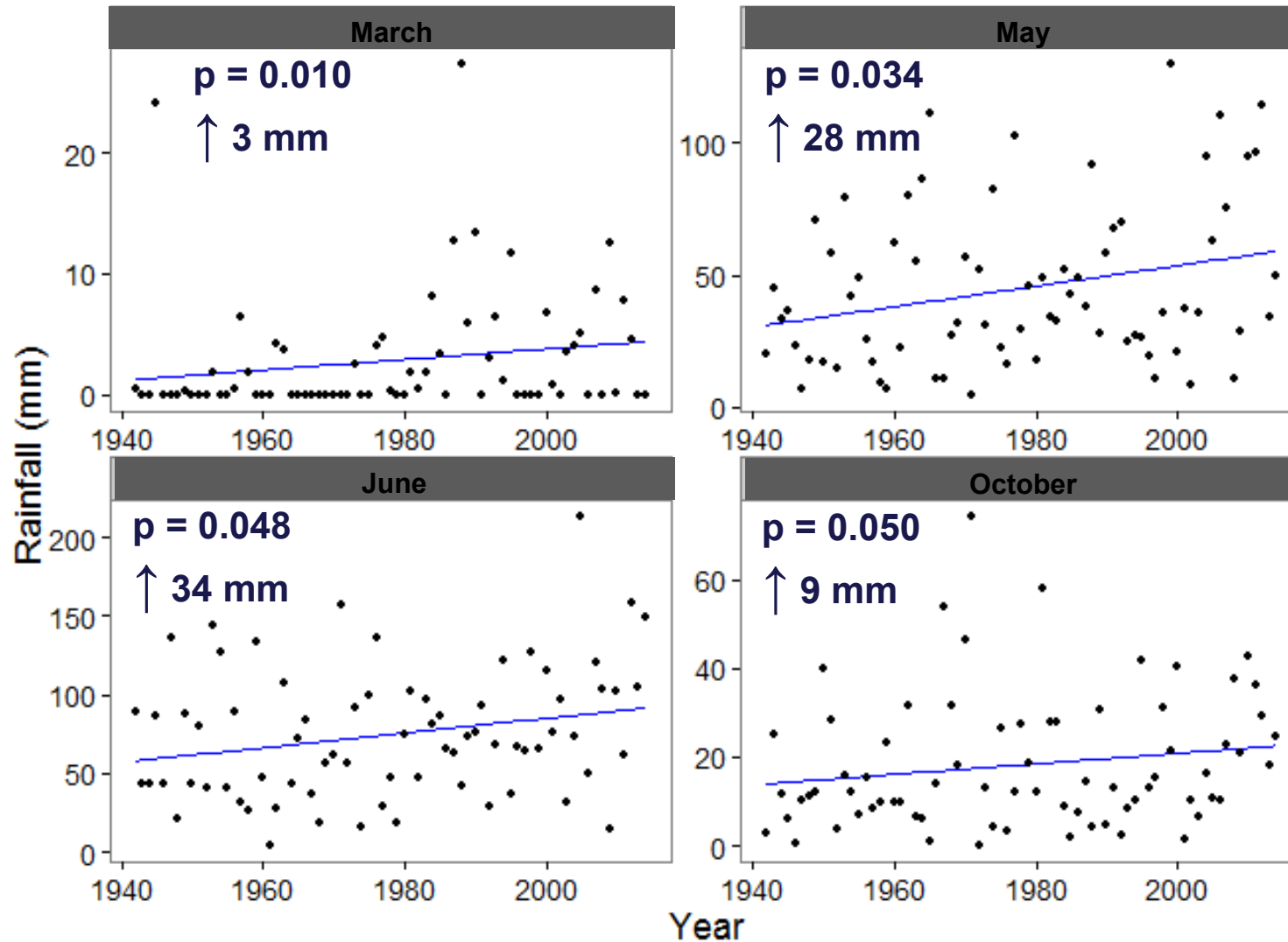
# Example of observed change

## Smith Creek Research Basin (SCRB), Saskatchewan

- Small, agriculturally dominated basin (393 km<sup>2</sup>)

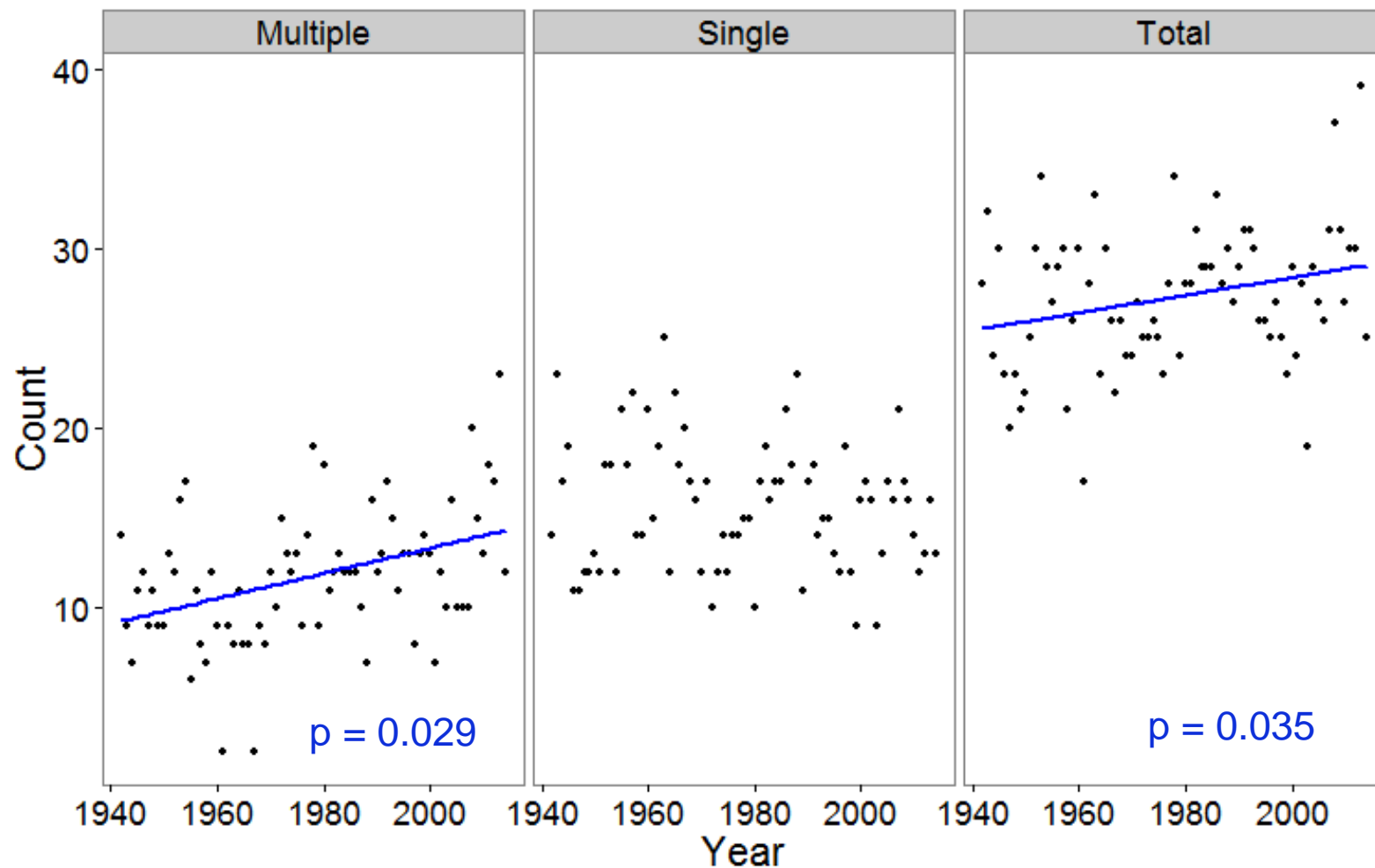


# Monthly Rainfall – no change in annual precipitation



# Rainfall Duration (May – Sept; 1942 - 2014)

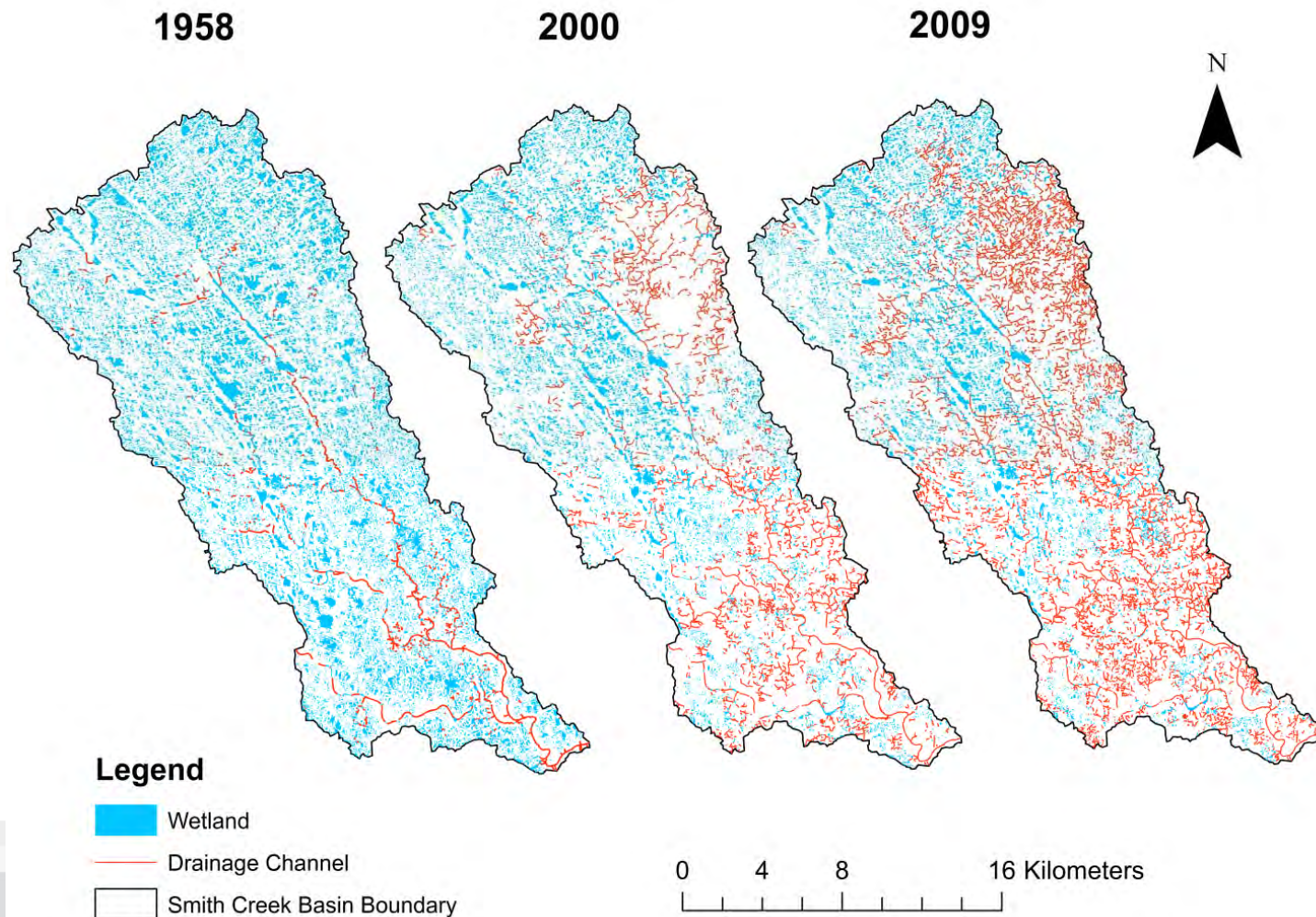
- Multiple day vs. single day rainfall events (Frontal vs. Convective)
- 50% increase in number of multiple day events



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# Depressional Storage Drainage

- Depression extent reduced from 24% to 10% (58% reduction)
- Drainage channel length increased 8-fold



# Depressional Storage Drainage

- **Loss of depressional storage capacity, increase in channelization**

No Drainage

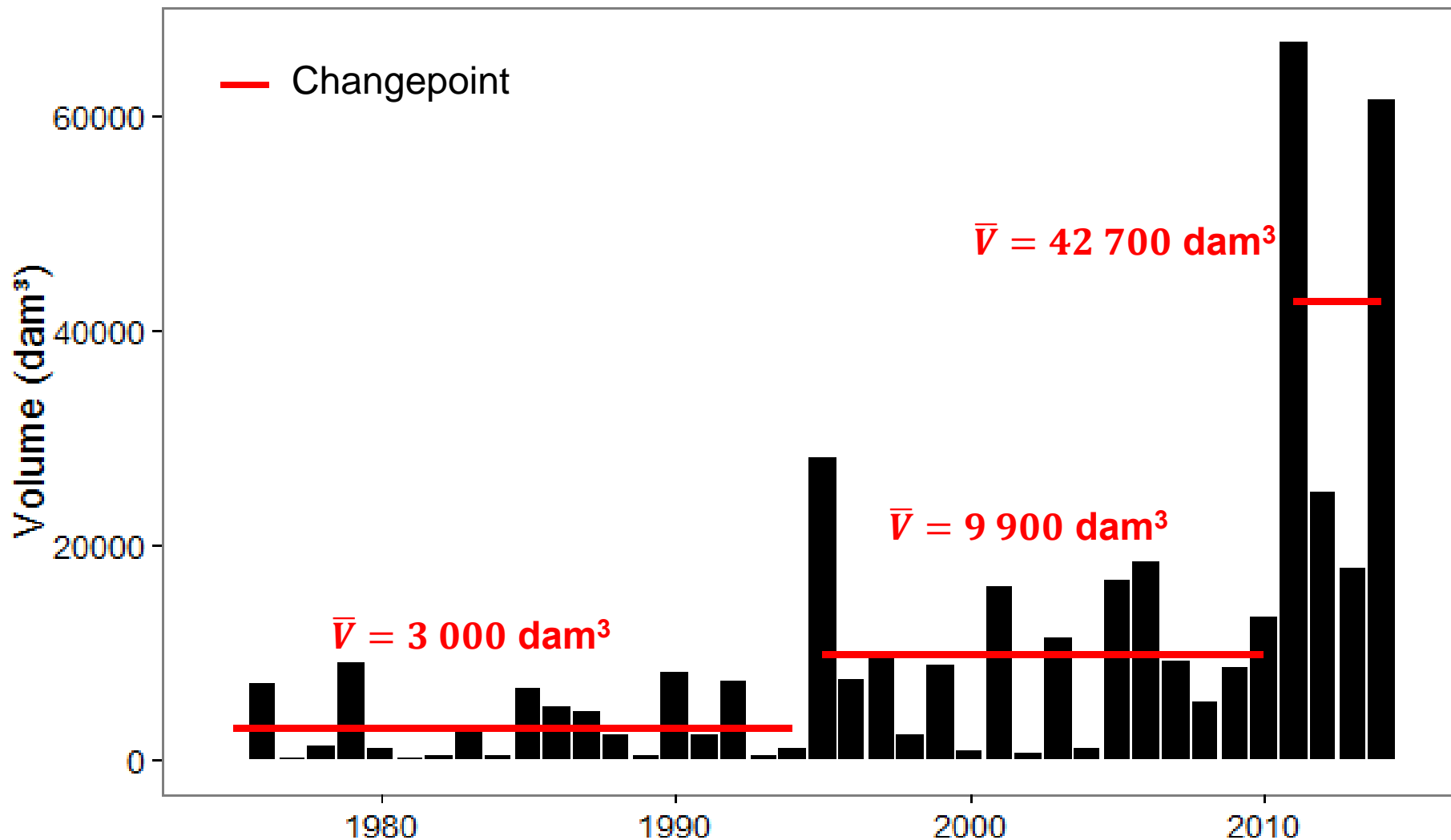


Artificial Drainage



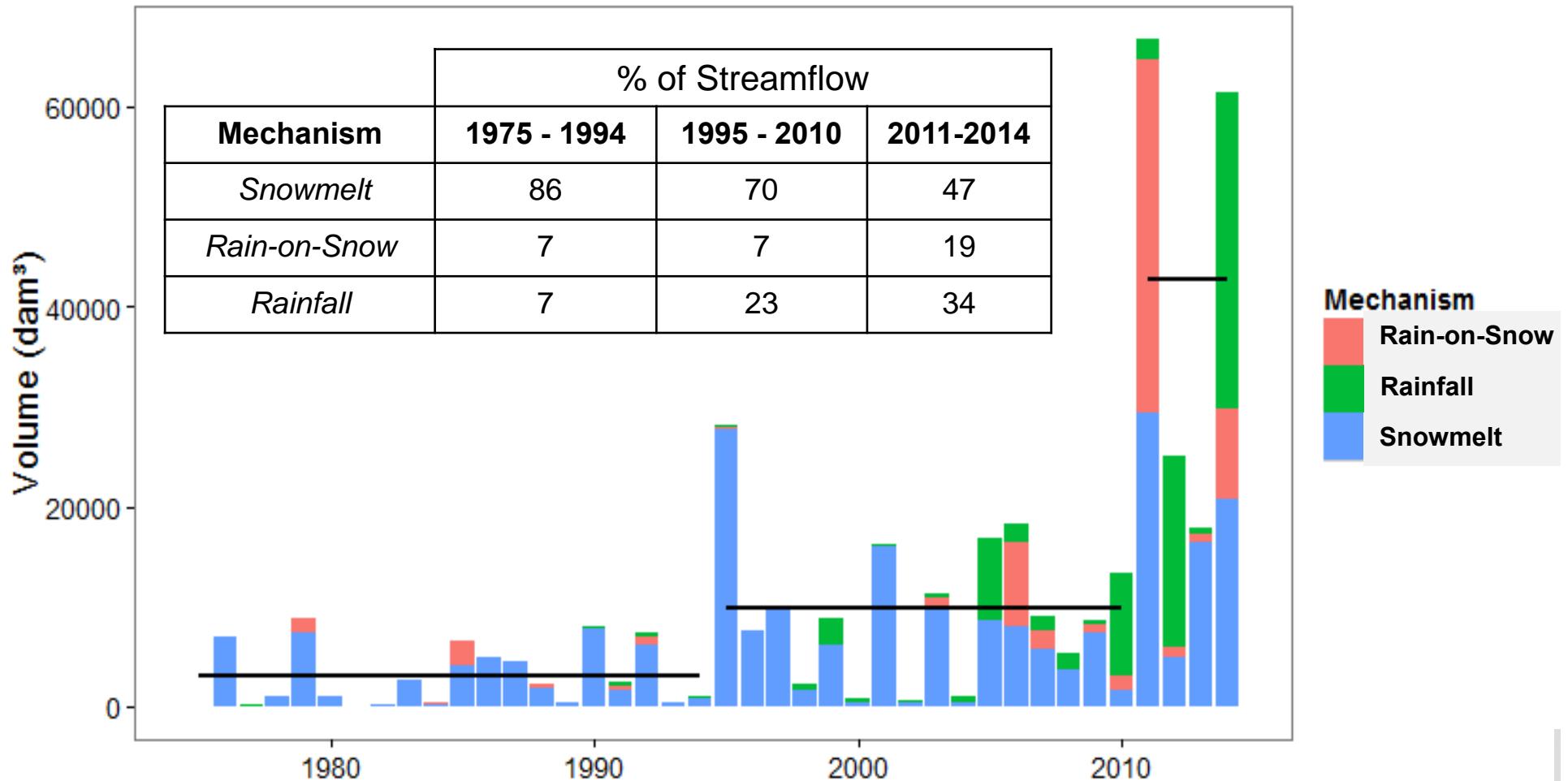
# Annual Streamflow Volume (1975 – 2014)

- 14-fold increase in streamflow volumes ( $p < 0.001$ )



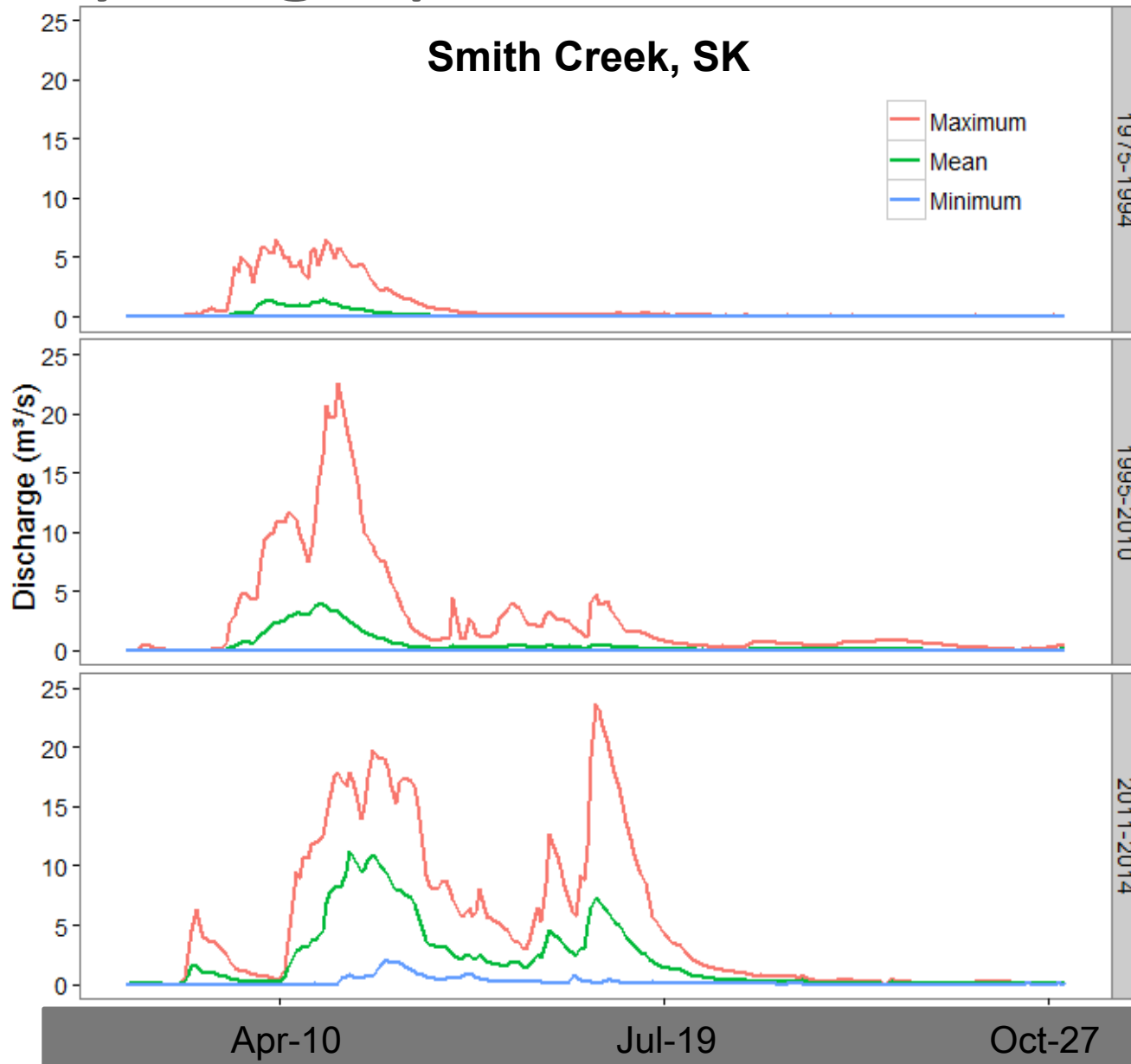
# Runoff Processes (1975 – 2014)

- Increased runoff contributions from:  
 Snowmelt (**5-fold**), rain-on-snow (**34-fold**), rainfall (**150-fold**)





# Hydrographs



## 1975-1994

Snowmelt driven

## 1995-2010

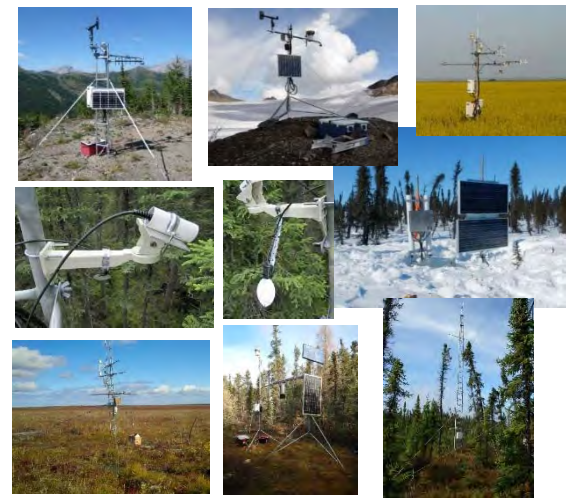
Increased spring  
and summer runoff

## 2011-2014

Second peak flow in  
summer months  
caused solely by  
rainfall runoff

# Progress to Date and Future Directions: Theme B—Local-Scale Understanding/Diagnosis

- Activities have included:
  - Targeted process studies in most WECC observatories;
  - Continued operation and enhancement of observatories, with a *Special Observation and Analysis Period (SOAP)* across the network of sites underway for the hydrological year Oct 2014 – Sept 2015
  - Development/improvement of many new process algorithms within the *Cold Regions Hydrological Model (CRHM)* platform
  - Set-up and initial testing of CRHM models, and for select basins, change detection and sensitivity analysis, with plans in place for extending this all observatories
- A major focus is on the diagnosis of change (September 2015 workshop)



The SOAP initiative involves coordinated, consistent, high-quality observations—CCRN is positioned to provide a world-class legacy dataset for process insights and model application over interior western Canada



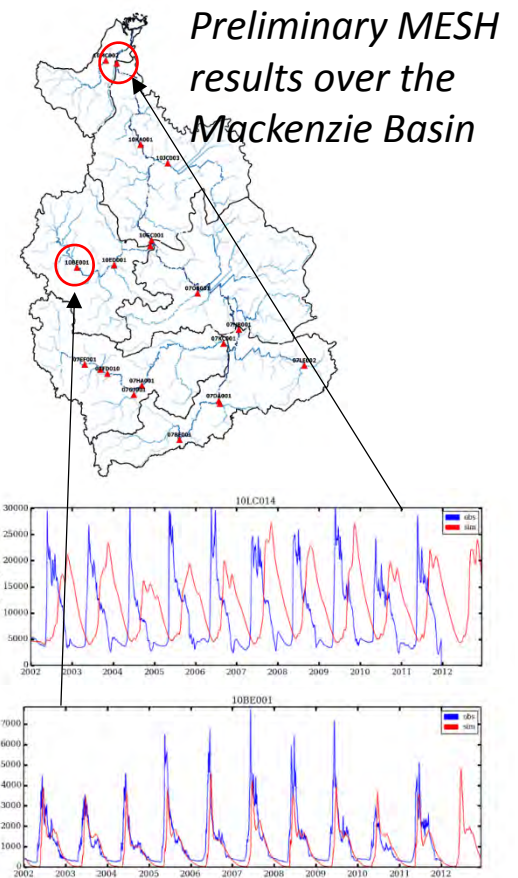
# Future Diagnosis



- With the warmer and wetter climate predicted for mid-21<sup>st</sup> C, peak SWE **increases slightly** in the subarctic mountain basin and **decreases substantially** in the mid-latitude mountain basin. These effects are **magnified** if transient vegetation change of vegetation expansion in the subarctic and vegetation retreat in the mid-latitude basin occur.
- Shrub expansion in WCRB causes **greater peak SWE** over the basin as a result of **reduction in blowing snow sublimation**.
- Forest and shrub expansion to higher elevations **reduce the peak streamflow** in WCRB because of the vegetation growth that enhances the surface roughness.
- The impact of warming of 2.5 °C and an increase of 30% in precipitation in WCRB on increasing peak flows can be **compensated** for by transient increases in vegetation.

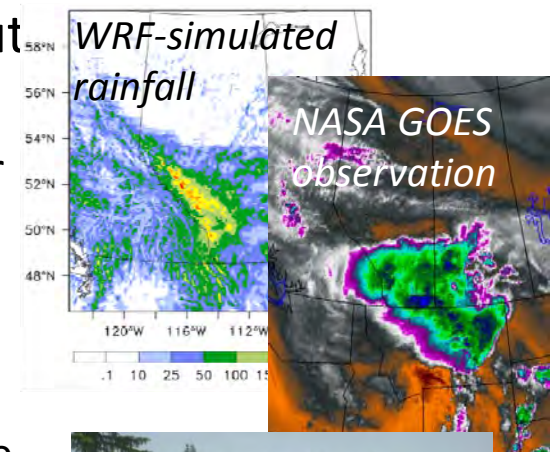
# Progress to Date and Future Directions: Theme C—Improved Large-Scale Modelling

- Activities are aligned with the needs of many of our government partners, and have included:
  - Completion of baseline CLASS simulations at most WECC observatories, together with other international LSS's (e.g. **WRF, JULES**);
  - Various improvements to CLASS for Prairie landscapes and cold-region lakes and wetlands;
  - Setup and evaluation of MESH over the Mackenzie and Saskatchewan River Basins;
  - Publication of key research reviews on water management representation in large-scale models
  - Use of soil moisture monitoring networks for observation and scaling properties at resolutions applicable to SMAP
  - Quantification of effects of uncertainty in driving variables
- Collaboration with EC CLASS/MESH
- Collaboration with NCAR WRF Noah-MP



# Progress to Date and Future Directions: Theme D—Analysis/Prediction Large-Scale Change

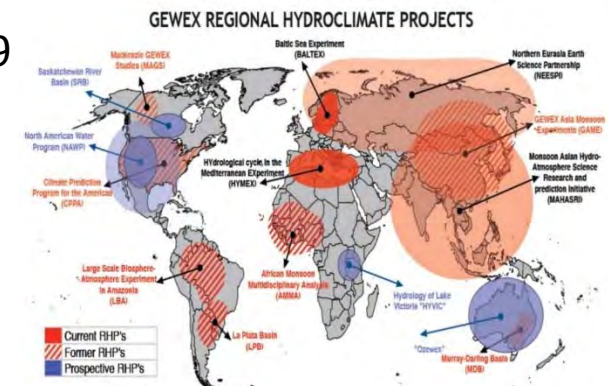
- Most deliverables slated for later years of CCRN, but accomplishments include:
  - Work on atmospheric circulation patterns, instabilities for generating convection, precipitation phase changes, surface hydrologic changes, runoff
  - A comprehensive investigation of the June 2013 extreme weather and flooding events;
  - Initial work toward an interdisciplinary examination of the 2014 forest fires in the Northwest Territories
  - Focal examination of extreme events (floods, drought, fire) in CCRN domain from 2009–11; pubs. forthcoming
- Collaboration agreed with CNRCWP (CanRCM5 - algorithm testing, simulation results)
- 4km WRF simulations available for CCRN domain – historical and pseudo warming (Y. Li)



The extreme weather & flooding events of June 2013 are a focus of CCRN research activities

# Progress to Date and Future Directions: Theme E—Outreach & Engagement

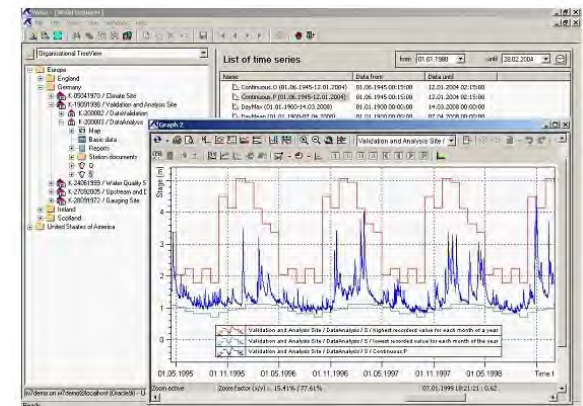
- Through our members, we are linked with 106 different groups
  - 11 First Nations; 11 Canadian and U.S. federal departments, 2 regional water boards, 24 provincial/territorial agencies, 4 urban municipalities, 7 NGOs, 19 environmental stewardship societies, 26 industrial companies, 6 research and education centres, 2 consultancies
- Activities have included:
  - Grassroots level engagement with various groups;
  - Member participation in science conferences, publication in major journals, and media engagement;
  - 5 focused workshops to engage government partners;
  - Linkage with various national/international scientific organizations, including WCRP, NCAR, NASA, CHARS
  - Delivery of CRHM training courses



CCRN as a GEWEX RHP places us in an important international scientific context as the only active North American RHP

# Progress to Date and Future Directions: Data Management

- *“We are committed to produce, document, and archive our results in an integrated, long-term repository.”*
- Data management activities have included:
  - Creation of data access policies and a data management planning document;
  - Setup of a data platform (the Water Information System, KISTERS (WISKI) tool);
  - Provision of training and tutorials on WISKI;
  - Imports of recent and historical WECC data, in coordination with members and partners;
  - Coordination with EC to develop protocols for acquisition and archiving of GEM model outputs;
  - Access provision to select real-time data streams



CCRN uses the WISKI tool to manage, process, and edit time series information

# CCRN Annual General Meeting – Nov '15

- Reviewed science developments, SOAP, data progress
- Reviewed cross-cut activities (2013 Calgary Flood, 2014 NWT Wildfire)
- Developed new cross-cut themes (2015 Drought; Threshold Behaviour, Regime Change, Responses to Climate Change)
- Checked progress towards network strategic goals; identify gaps and opportunities
- Reported to and received feedback from our International Advisory Panel and Board of Directors



# The Future:

- Over the remainder of the CCRN programme, we will continue to:
  - Improve our understanding of recent Earth system change in the cold interior of western and northern Canada;
  - Advance water, weather, climate and environmental prediction; and
  - Improve our understanding of Earth system processes and their representation in hydrological, atmospheric and ecological models.
- In doing so, we will:
  - Enhance Canada's capability for water management;
  - Train the next generation of Earth System Scientists; and
  - Provide high quality datasets for change assessment and model verification.

