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Canada

Challenges of Monitoring Drought in the North

Barrie Bonsal

Environment and Climate Change Canada

Saskatoon, SK, Canada

(with help from Allan Howard; AAFC)

Outline

- Northern Canada
- Current Monitoring and Limitations
- How Do We Define a Northern Drought?
- Future Considerations

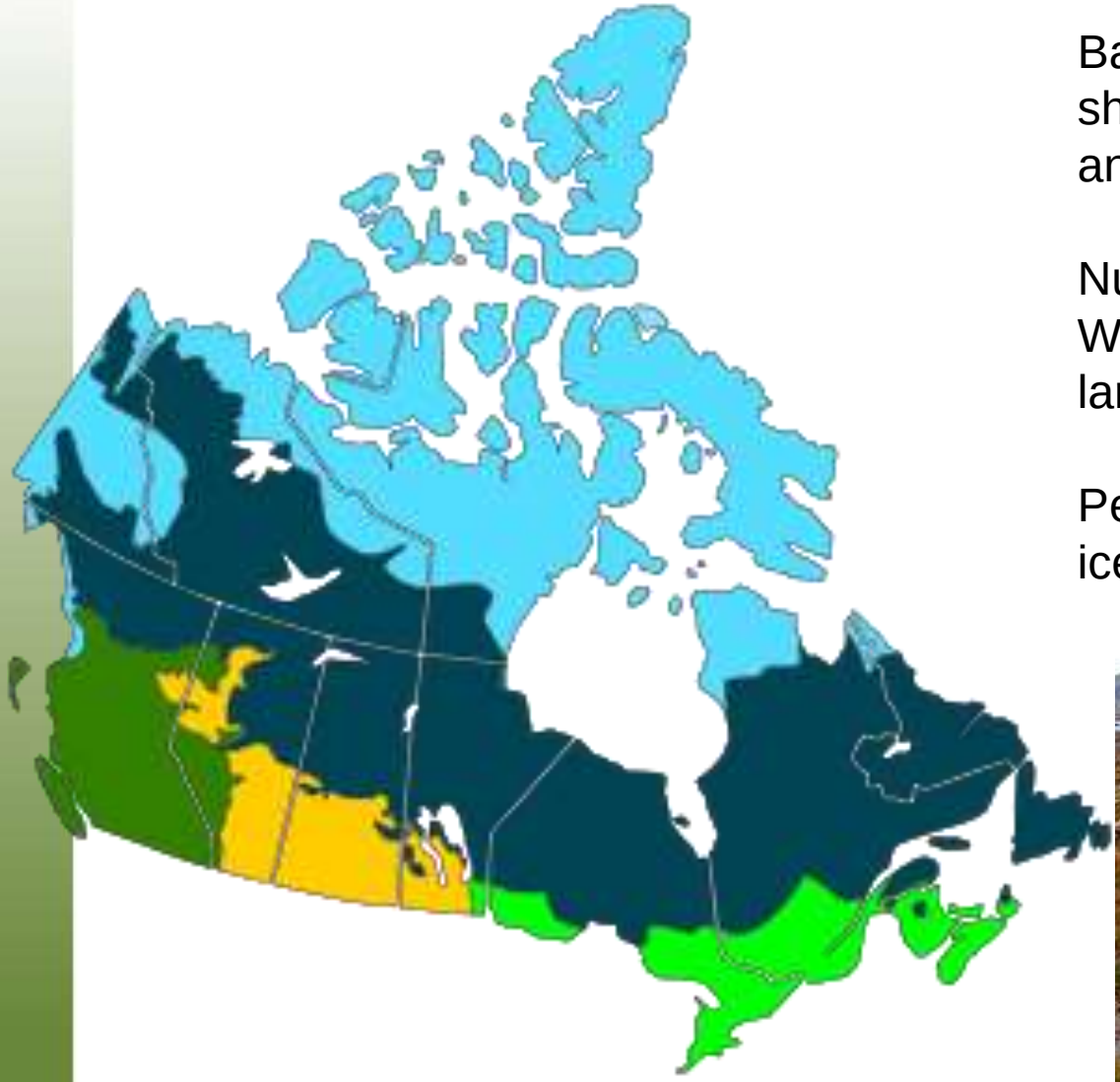
Northern Canada

Yukon, Northwest Territories, Nunavut
Area: 3,535,263 km^2 (1,364,973 sq mi)

Population:113,604 (*2016)*

Density: 0.0321/km^2

Physiographic Regions

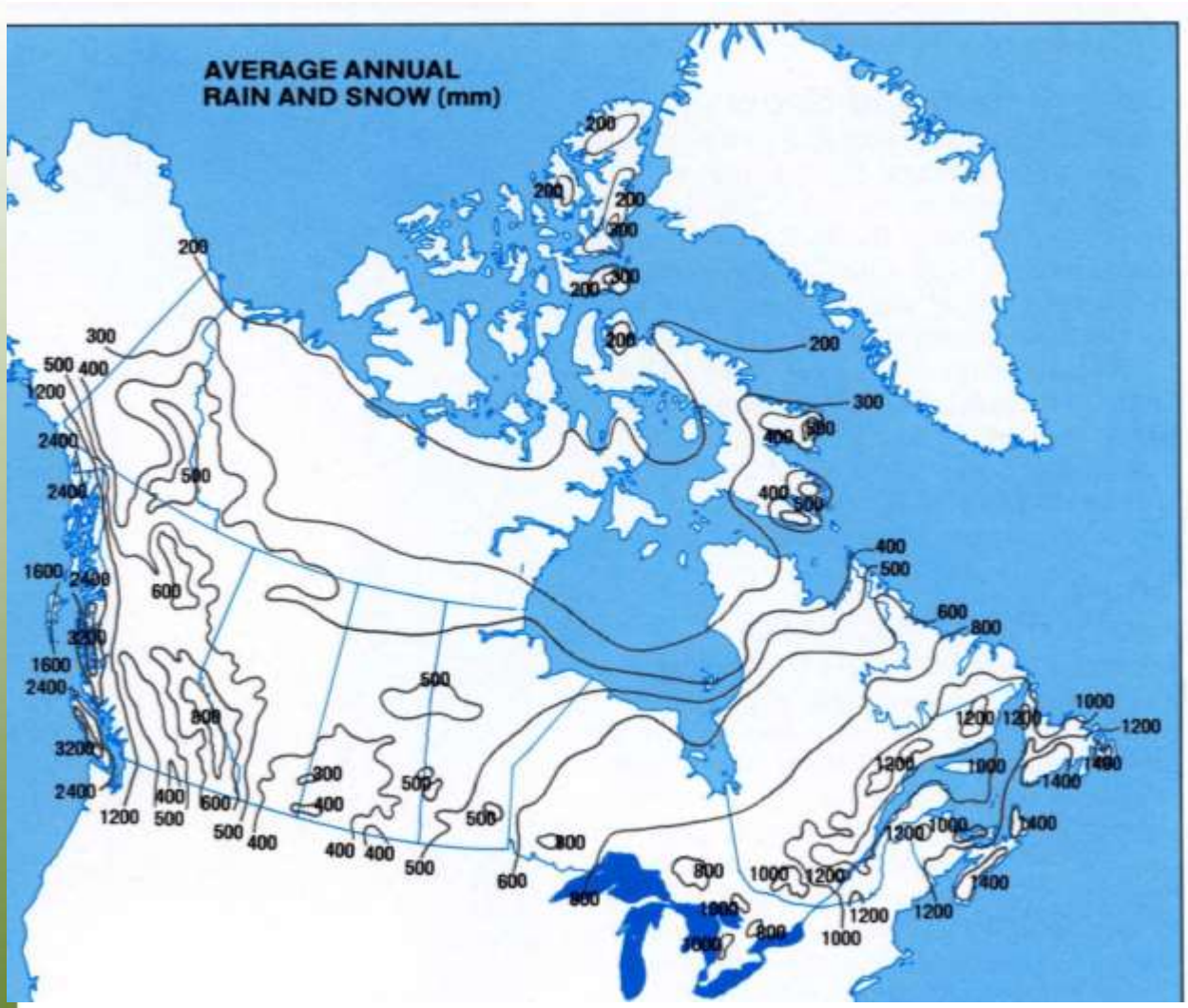


Barren grounds and tundra are shown in light blue, and the taiga and boreal forest in dark blue.

Numerous surface water bodies: Wetlands, ponds, lakes (some large), rivers.

Permafrost in most of the region, ice caps in high Arctic Islands.

Climate

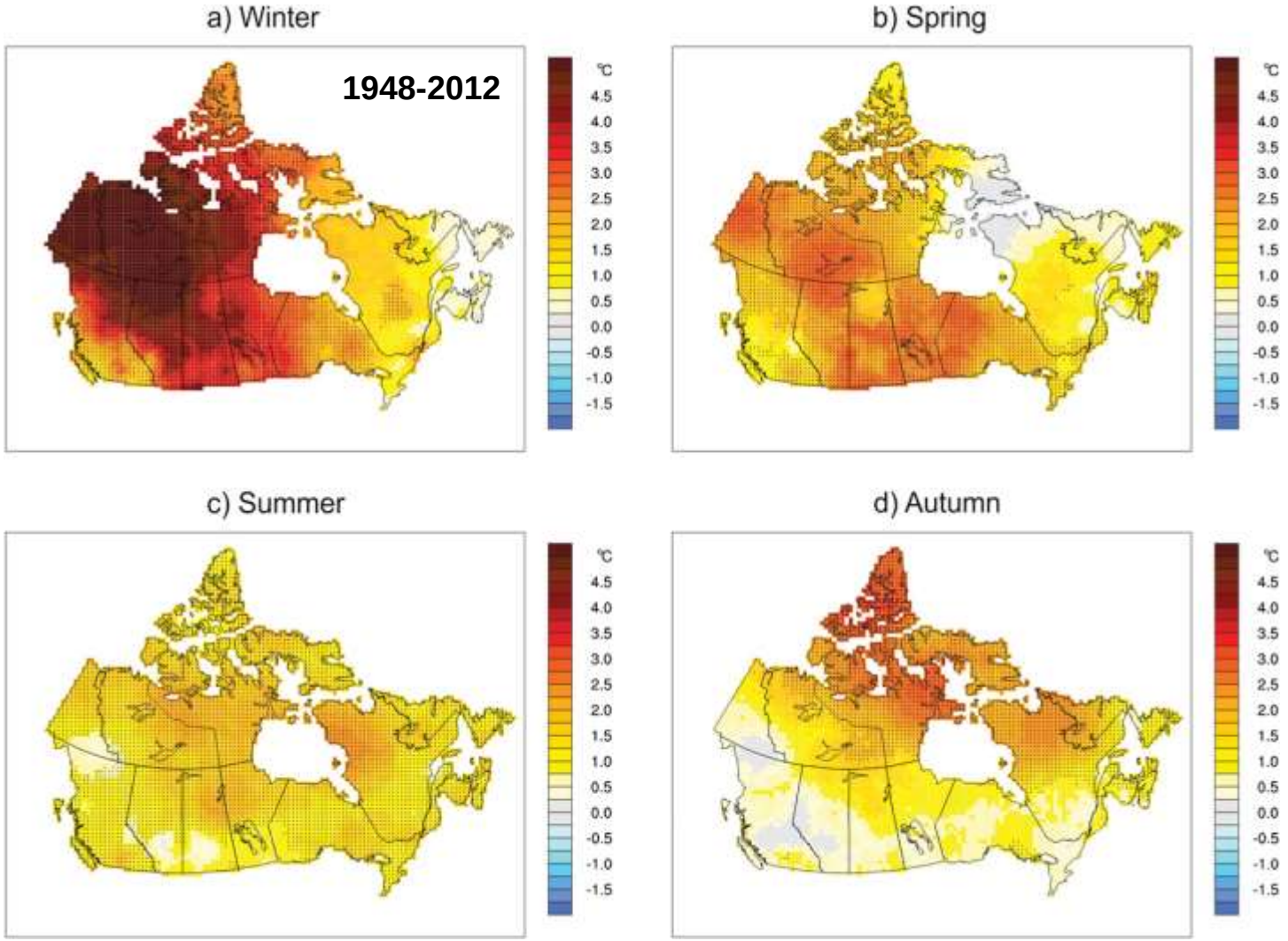


Most of Northern Canada has a subarctic and tundra climate.

Temperatures generally below 0°C from Oct to May.

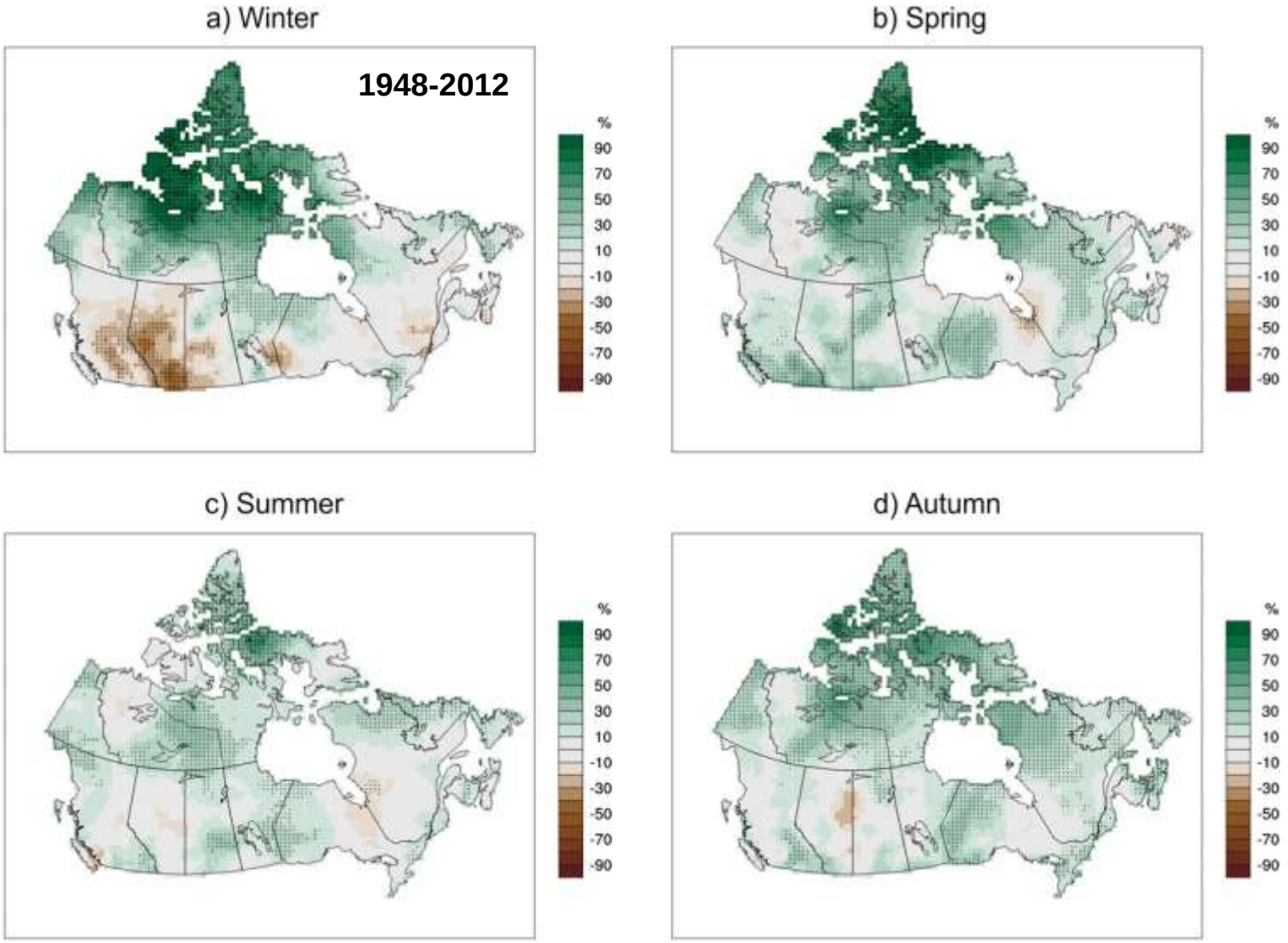
Precipitation is low; most falls during summer.

Rapidly Changing Climate (Temp)



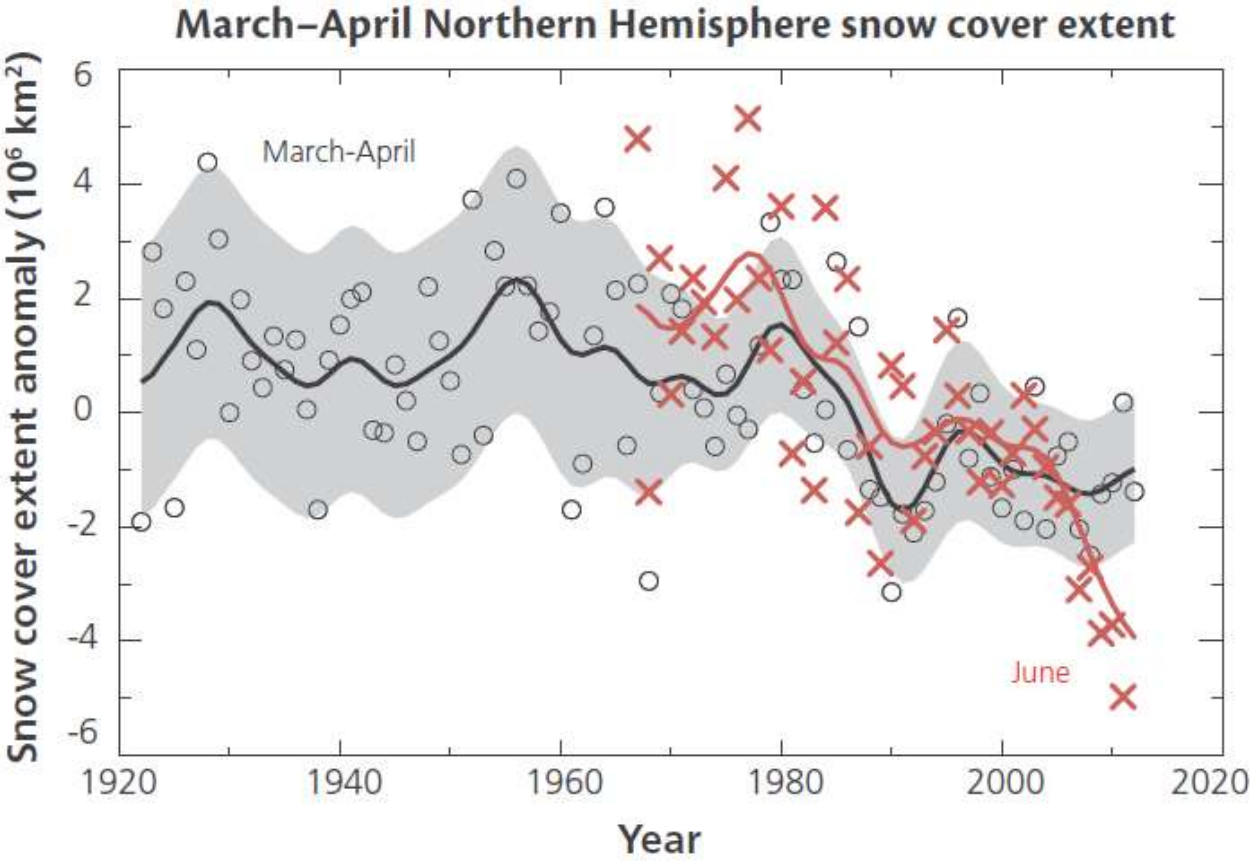
Source: Vincent et al. (2015): Observed Trends in Canada's Climate and Influence of Low-Frequency Variability Modes

Rapidly Changing Climate (Precip)



Source: Vincent et al. (2015): Observed Trends in Canada's Climate and Influence of Low-Frequency Variability Modes

Rapidly Changing Climate (Snow Cover)

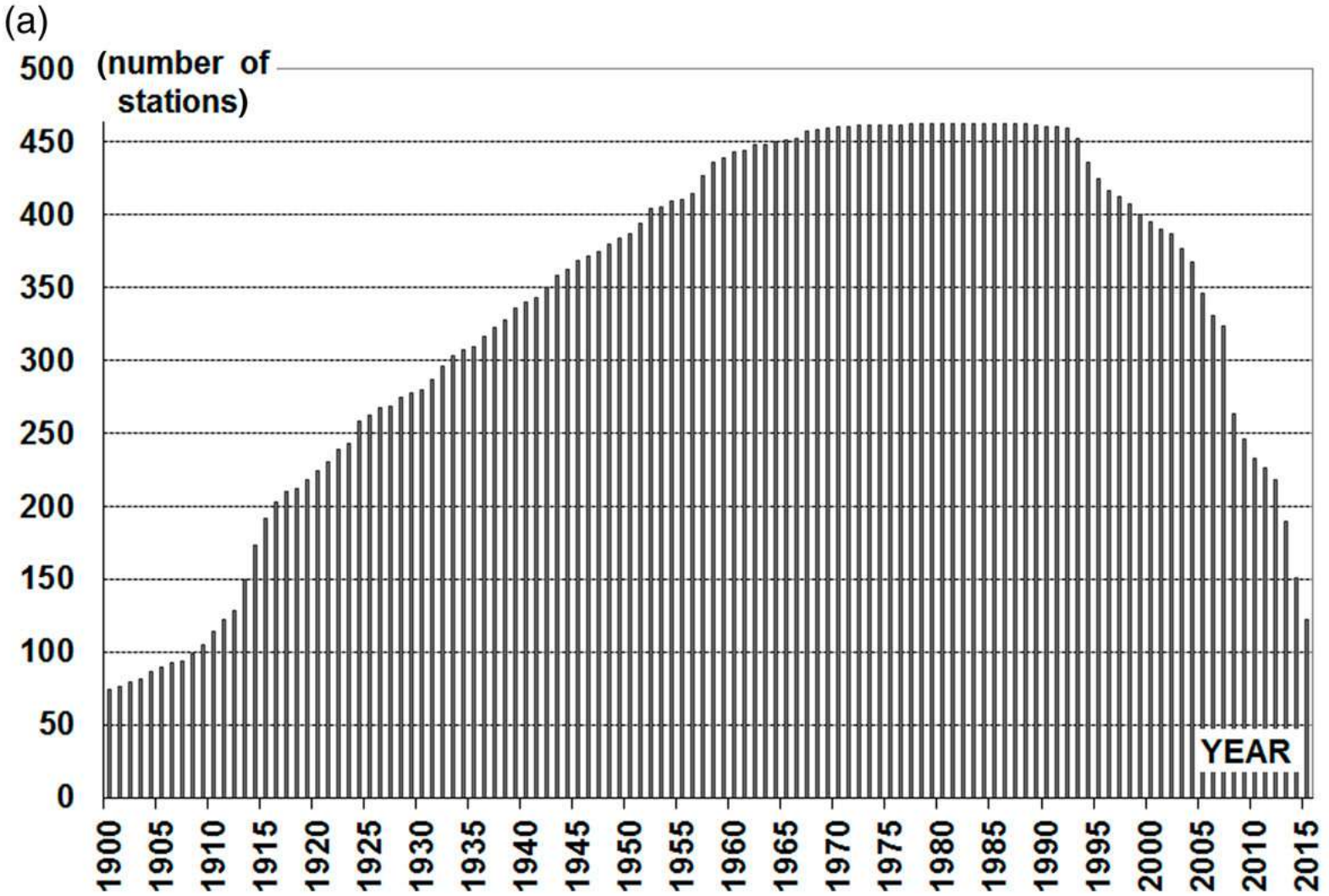


Northern hemisphere snow cover extent (SCE) from March to April *in situ data (black line) and June SCE (red crosses, from satellite data alone). The gray area indicates the 95% confidence level. Source: IPCC 2013, data from Brown and Robinson 2011.*

Drought Monitoring in the North

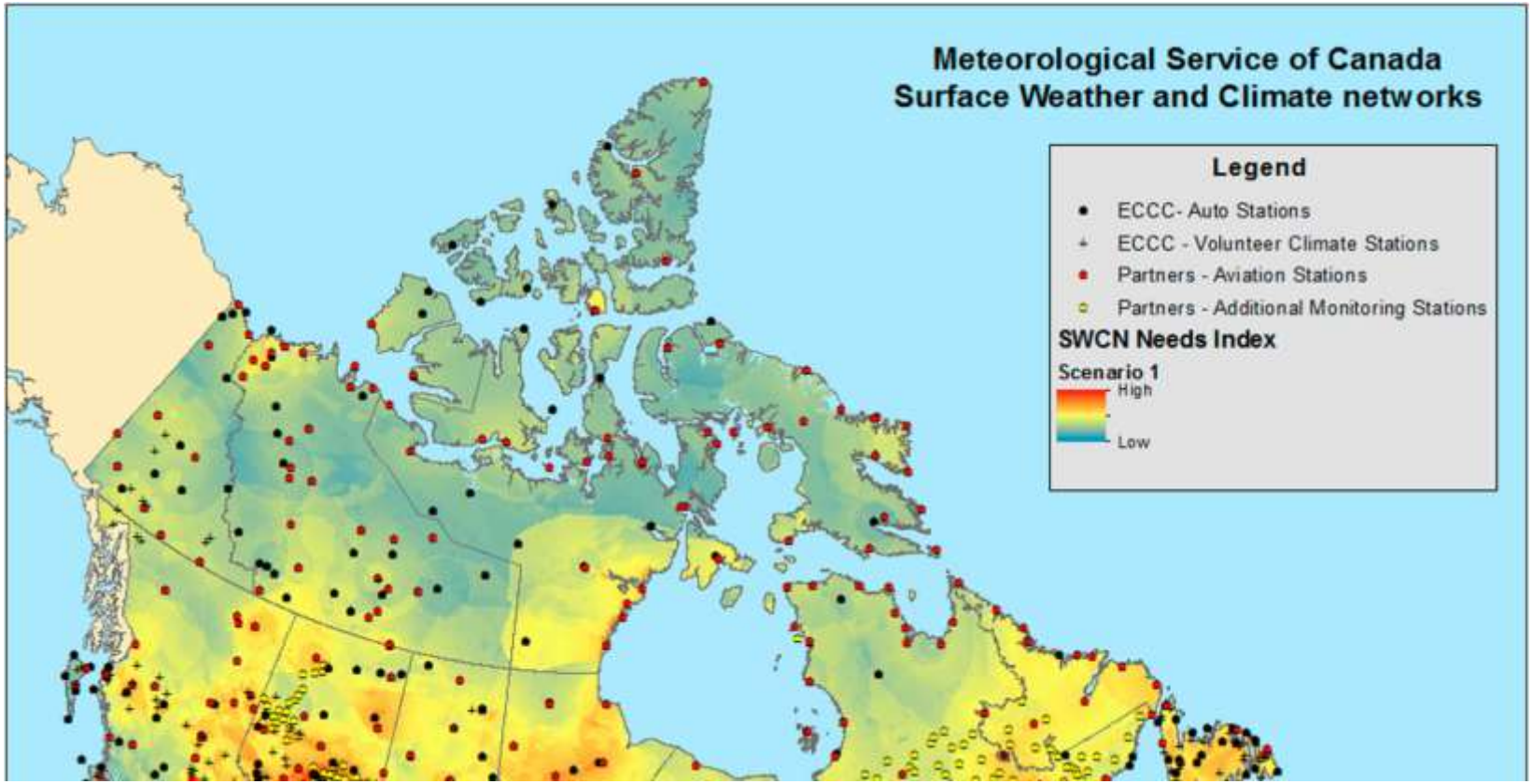
- AAFC wishes to improve and extend monitoring and reporting across northern Canada.
- Improve current monitoring and reporting in Yukon and Northwest Territories.
- Extend to Nunavut, to provide full coverage for Canada.
- Therefore, reliable input data are needed.

ECCC Manual Observing Stations



Source: Mekis et.al (2018): An Overview of Surface-Based Precipitation Observations at Environment and Climate Change Canada; *Atmosphere-Ocean*

Limited gauging stations in the North



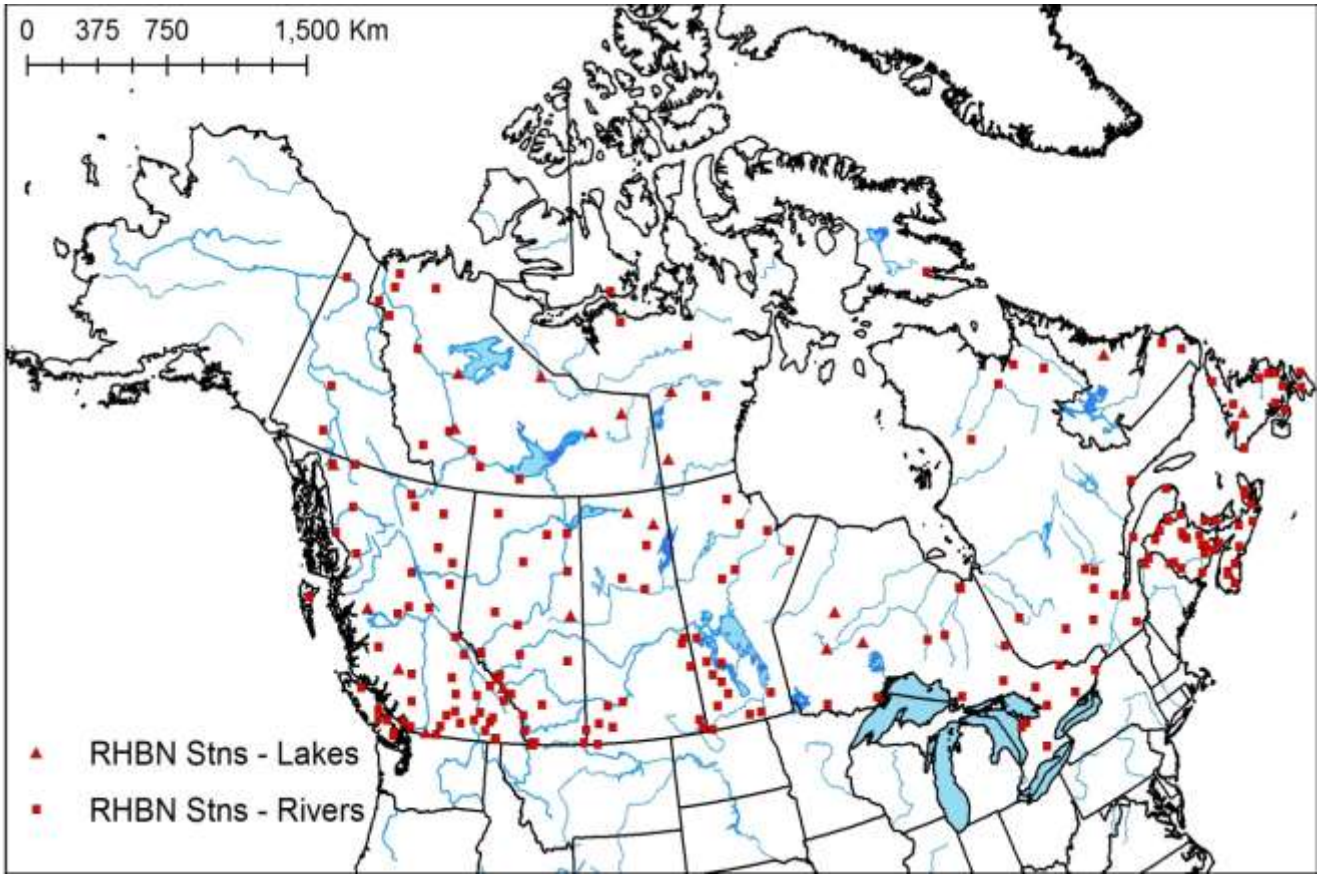
- Auto Stations: Temp, Precip, Snow Depth, Pressure, Wind Speed/Direction
- Aviation Stations: Staffed – NAV CANADA (flight operations): Temp, Precip, Precip Type, Visibility, Clouds, Pressure
- Volunteer Climate Stations: Volunteer observers – sensors from MSC: Temp, Precip

Source: Mekis et.al (2018): An Overview of Surface-Based Precipitation Observations at Environment and Climate Change Canada; *Atmosphere-Ocean*

Limitations of gauging stations

- Low density
- Reliability of Automated & Manual Stations: Operate in challenging conditions especially in the North – Precip and especially snow difficult to measure accurately: Wind undercatch (>50%), icing, evaporation, etc.; Data gaps
- Changes in instrumentation; Need to be adjusted for long time series.
- No radar in the North.
- Length and consistency of time series to provide historical context is an issue.

Hydrology – RHBN Stations



- The Reference Hydrometric Basin Network (RHBN) is a sub-set of stations from the national WSC network (mostly rivers; some have headwaters outside the North).
- Characterized by near-pristine or stable hydrological conditions and have been active for at least 20 years.
- Low density in North; environment is frozen throughout much of the year, hydrologic gauges provide useful data for only limited durations.

How is Drought Defined in the North?

Drought: *A deficiency of precipitation from expected or "normal" over a season or longer period of time that results in insufficient water to meet the demands of human activities and the environment.*

Wilhite et al. 2014

- Low precipitation: Drought versus aridity. Lack of historical records in the north make understanding drought in a historical context difficult.
- Rapidly changing; What do we consider as the baseline for assessing current conditions?
- Determining meteorological drought in a cold climate is possible, but determining the impacts of drought is more difficult because some to all of the landscape is frozen during much of the year.

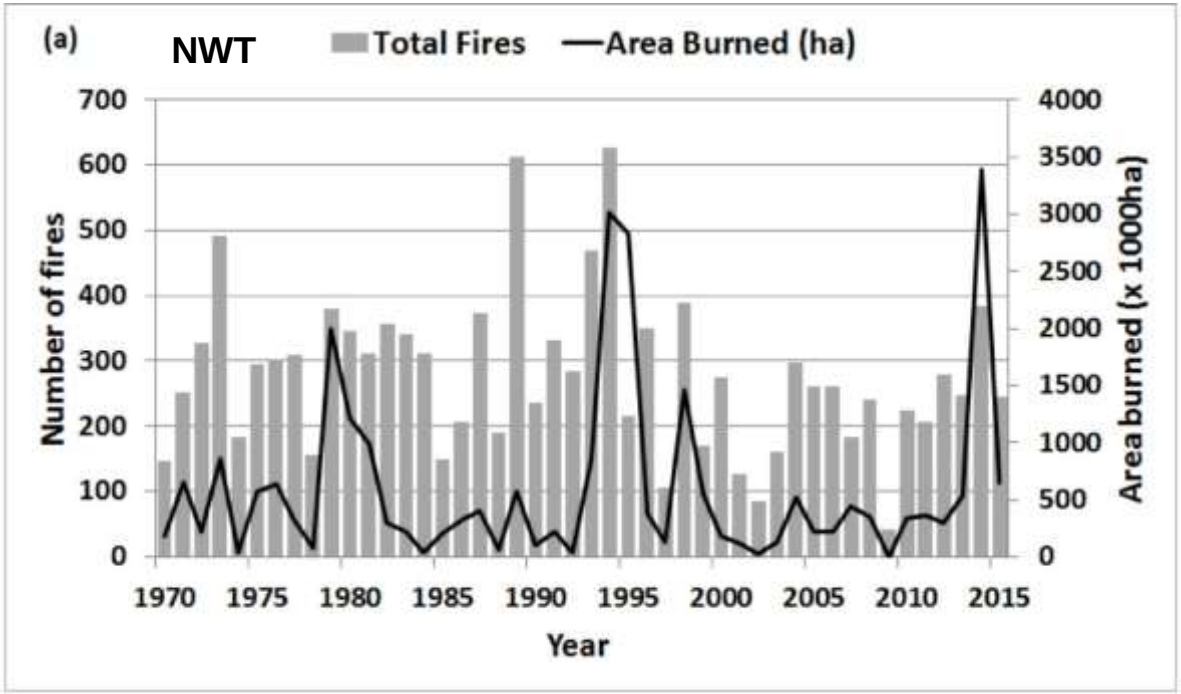
How is Drought Defined in the North?

Snow Drought:

- What are the most effective definitions of meteorological and hydrological snow drought?
- What are the temporal features or indicators for snow drought?
- How crucial is the gap between how well we measure snow at gauges (meteorological snow drought) and snowpack conditions (hydrological snow drought)?
- What changes in snowpack and snow drought susceptibility are potentially due to changes in cover or terrain?

Drought Impacts in the North

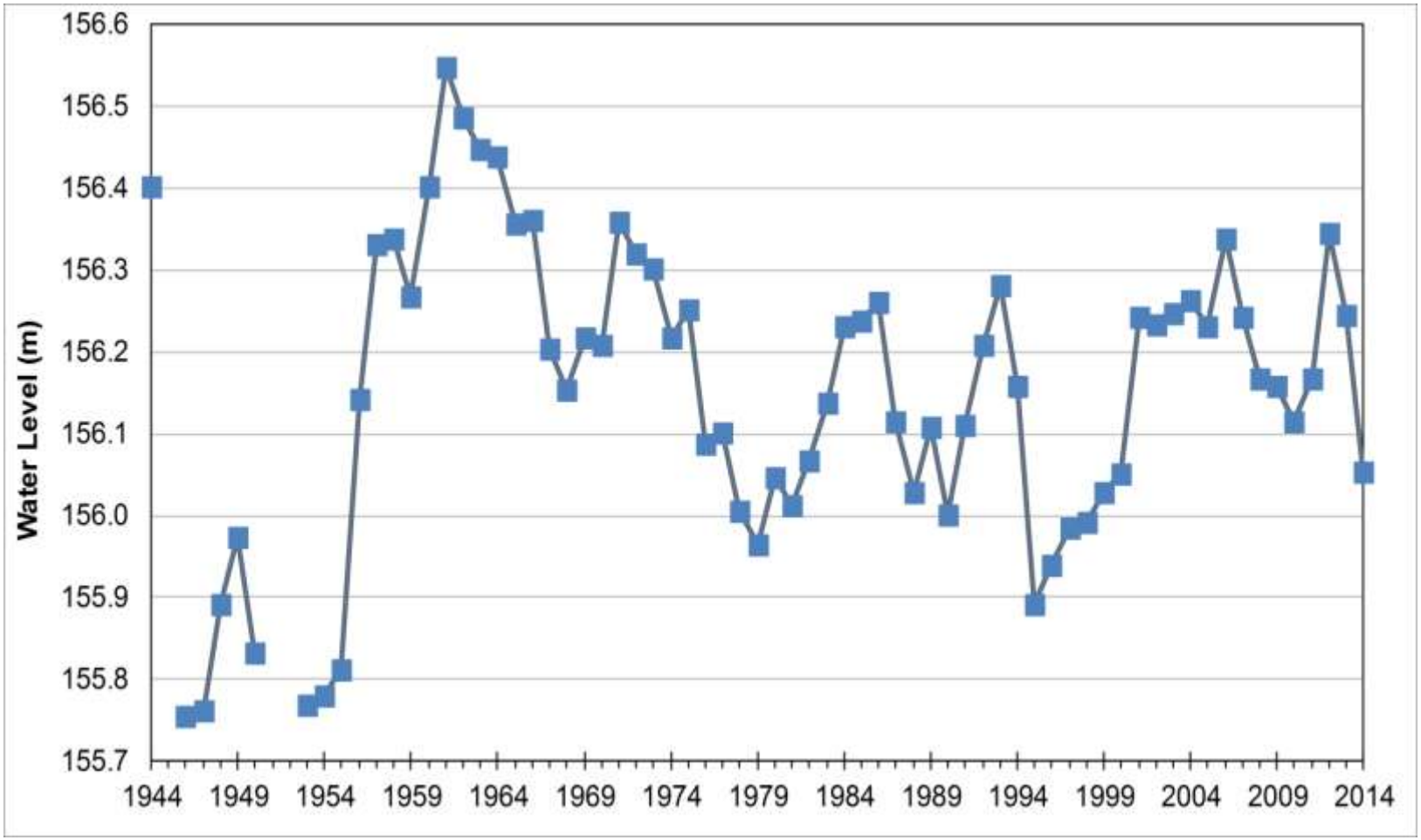
- Ecological drought: Forest Fires (and even tundra fires)
- Water availability: Hydro-electricity; Aquatic and Terrestrial Ecosystem health; Municipalities
- Agriculture (limited)
- Accelerated permafrost thaw?



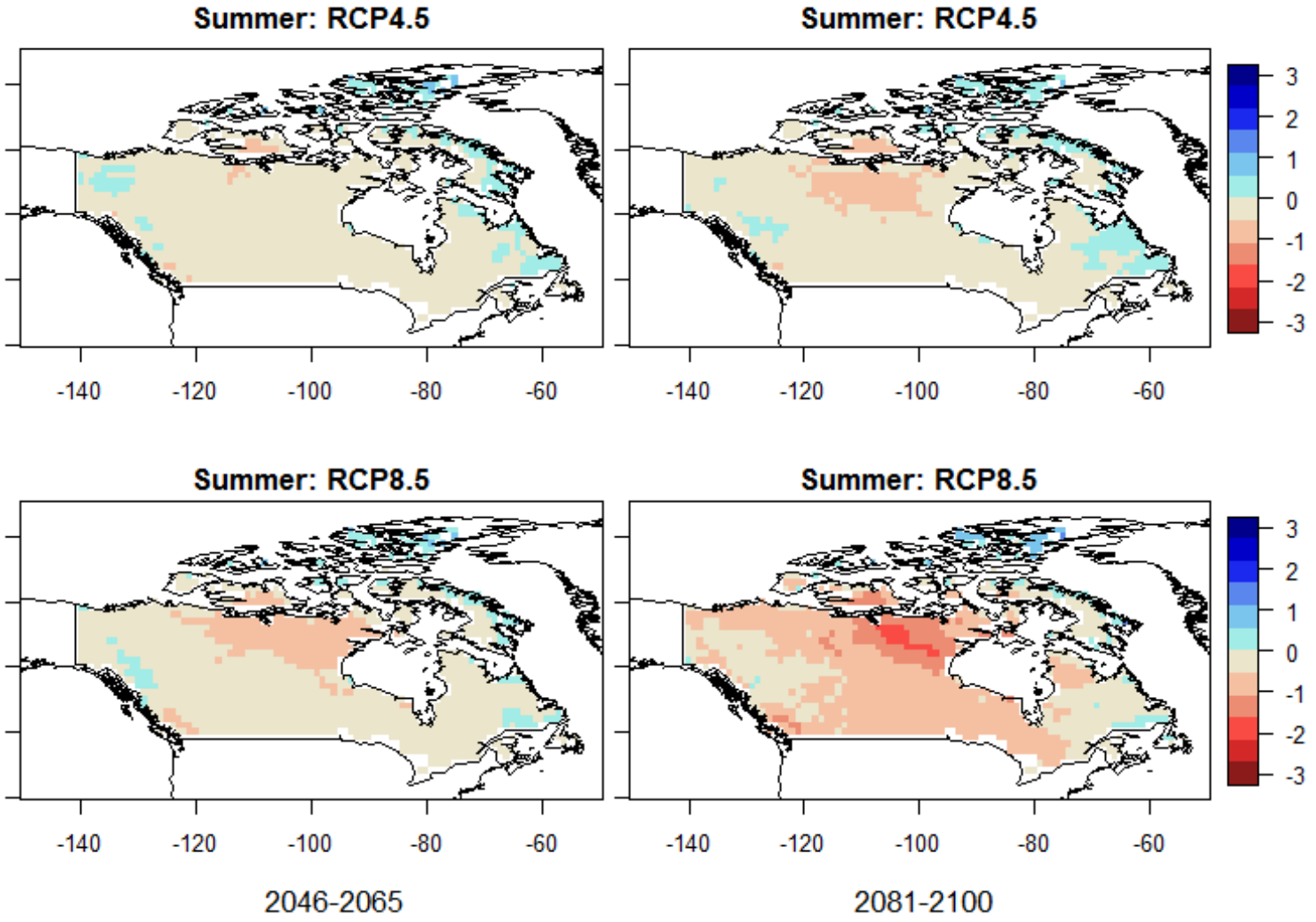
Potential Indices

- **Standardized Precipitation Index** (SPI)
- **Palmer Drought Index** (PDSI, Palmer Z – Moisture Anomaly)
- **Soil Moisture** (% Average, Difference from Normal, Total Soil Moisture)
- **Standardized Precipitation Evapotranspiration Index** (SPEI)
- **Drought Code & Fire Weather Index** (NRCan)
- **Surface Water** (Streamflow, Lake Levels, others?)
- **PET:** Difficult to estimate and depending on formula, data intensive.

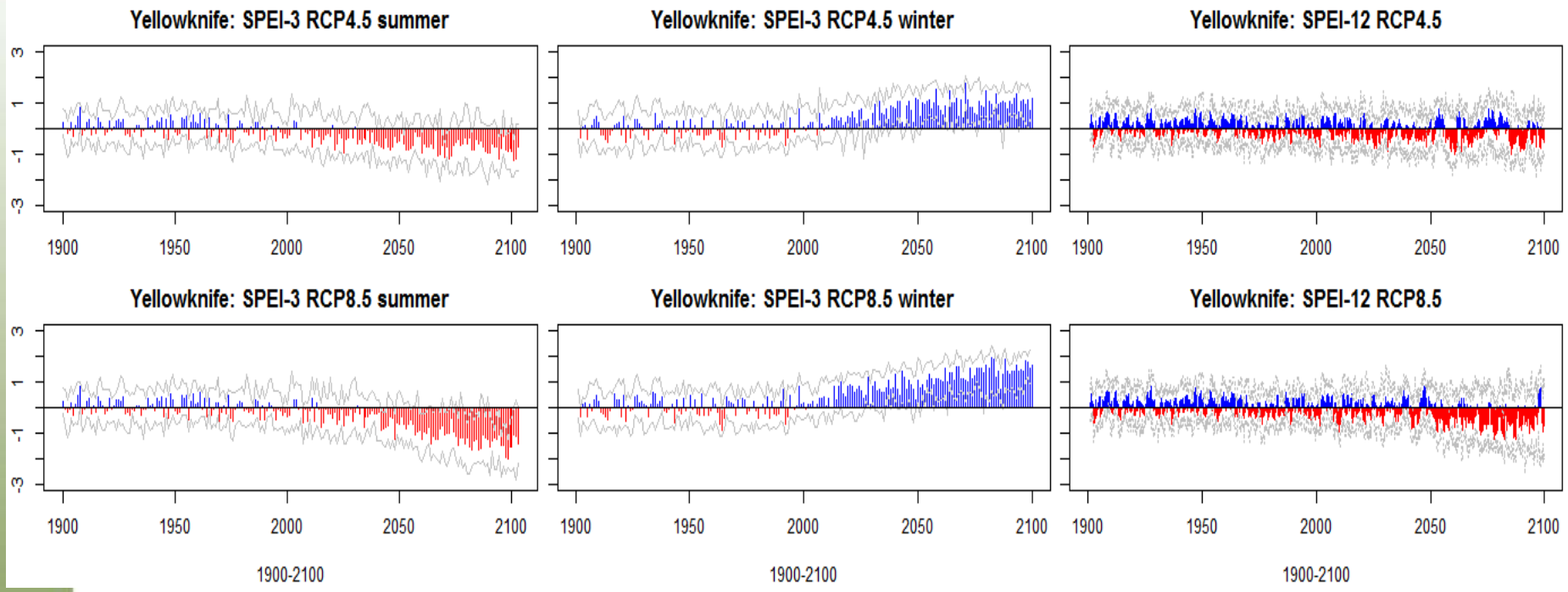
Great Bear Water Levels



Future Drought: SPEI



Future Drought: SPEI



Other Indicators

Canadian Precipitation Analysis (CaPa):

- Since 2011, ECCC produces objective estimates of precipitation amounts at any given location in Canada, even in regions with sparse precipitation gauges.
- Combines in near real time different sources of precipitation information along with a short term forecast provided by the Regional Deterministic Prediction System (RDPS) to produce a gridded analysis that covers all of North America.
- Resolution of 10 km; generated 4 times a day for 6 hour precipitation amounts and once a day for 24 hour amounts and it is available all year round.
- All reliable precipitation measurements from the networks available at the Canadian Meteorological Center (CMC) are assimilated in the system.

Other Indicators - Reanalysis

Strengths:

- Several products (e.g., NARR, ERA-Interim, JRA, WFDEI, etc.).
- Global, consistent spatial and temporal resolution over 3 or more decades, hundreds of variables available; model resolution and biases have steadily improved.

Limitations:

- Observational constraints, and therefore reanalysis reliability, can considerably vary depending on the location, time period, and variable considered.
- Diagnostic variables relating to the hydrological cycle, such as precipitation and evaporation, should be used with extreme caution.

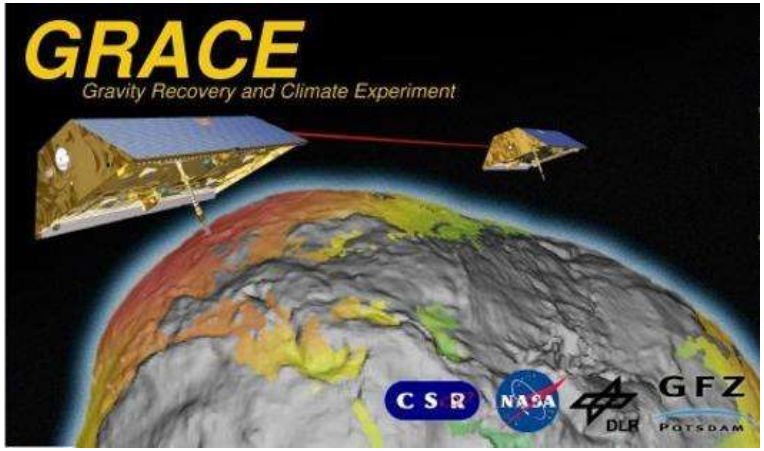
Sun et.al (2018): A Review of Global Precipitation Data Sets: Data Sources, Estimation, and Intercomparisons; *Reviews of Geophysics*

Other Indicators – Remote Sensing

Soil Moisture & Ocean Salinity (SMOS)

Gravity Recovery and Climate Experiment (GRACE)

Surface Water & Ocean Topography (SWOT)



Summary

- AAFC would like to improve and extend drought monitoring across the cold region of northern Canada.
- Key challenges are data availability, understanding of drought issues in northern areas, the ability to determine the impacts of drought, and a rapidly changing environment.
- Any suggestions are welcomed.