www.ouranos.ca

Climate observations and projections for the Eeyou Marine Region

Ross Brown[1], Carl Barrette[2], Diane Chaumont[3], Patrick Grenier[3], Anne Frigon[3], René Roy[3], Jean-Pierre Savard[3]

1. Climate Research Division, Environment Canada @ Ouranos
2. ArcticNet, Centre d ’études nordiques, Université Laval, Quebec
3. Ouranos Consortium, Montreal, QC

Environment Canada Environnement Canada

ArcticNet

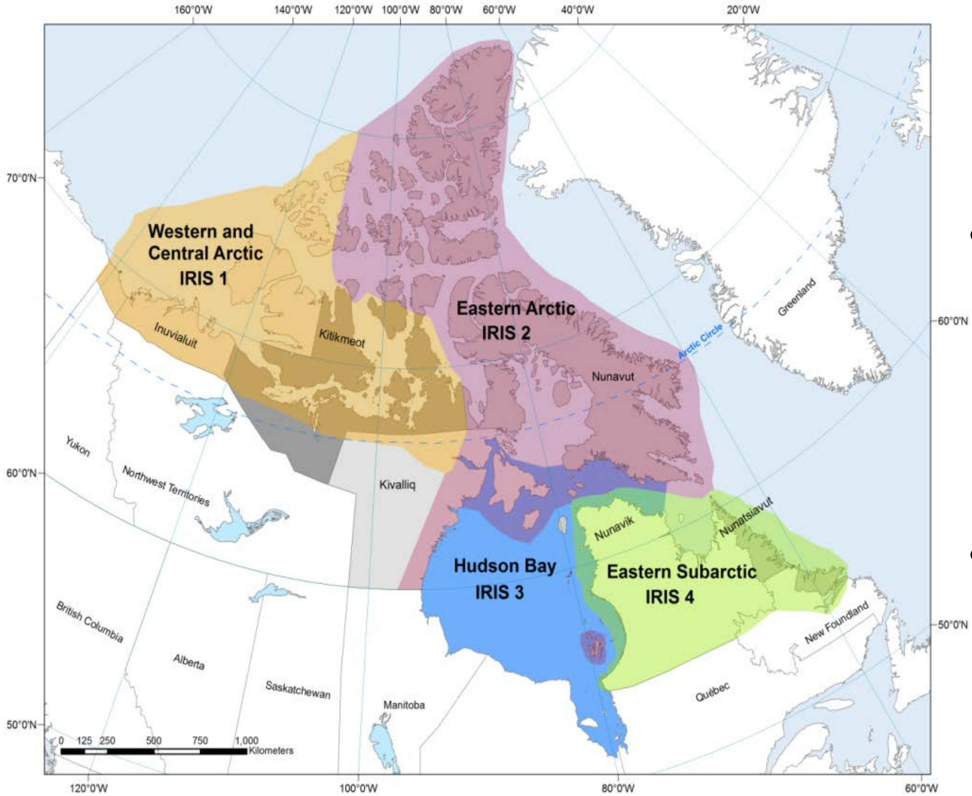
ᐅᑭᐅᖅᑕᖅᑐᒥᒃ ᑐᑭᓯᓂᐊᖅᑏᑦ

UNIVERSITÉ LAVAL

OURANOS

Outline

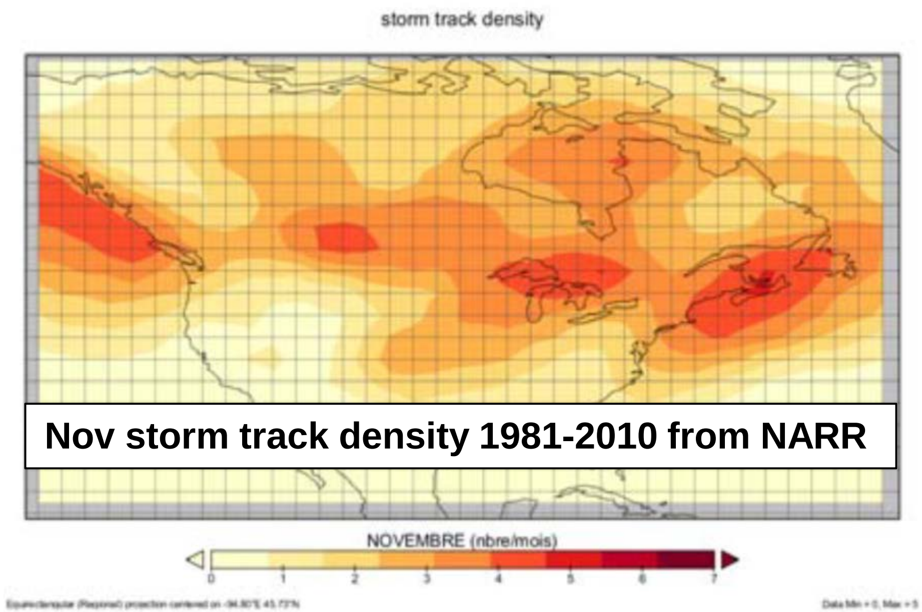
1. Background / Climate context
2. Climate observations
3. Observed trends
4. Construction of Climate Change Scenarios
5. Conclusions



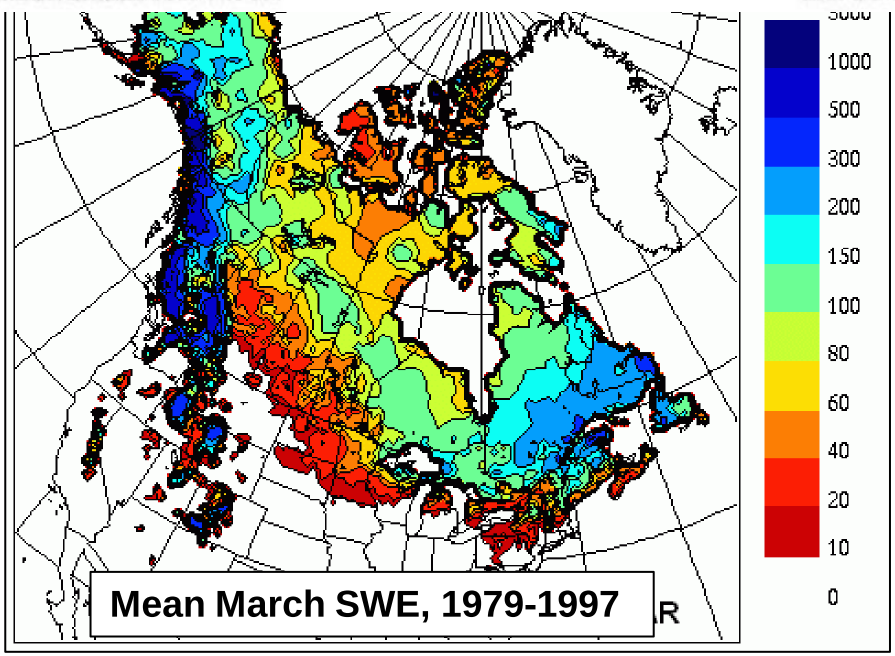
1. Background

- The Eeyou marine region is a “hot spot” in climate change scenarios – projected to have the largest winter warming in Canada
- Observations indicate the region has experienced warming of 2-3°C and rapid reductions in sea ice over the past 35 years
- Decision-makers need to have some idea of how fast the current climate system is changing and how the climate will respond to global warming for planning and adapting
- Ouranos working with ArcticNet in developing climate changes scenarios for four IRIS regions
- Scenarios developed for IRIS-4 Nunavik and Nunatsiavut (north of 55°N) and published in 2013 mainly focussed on the terrestrial environment
- Scenarios currently being developed for IRIS-3 region that includes Eeyou Marine Region

The Eeyou region has a unique climate regime



Nov storm track density 1981-2010 from NARR



Mean March SWE, 1979-1997

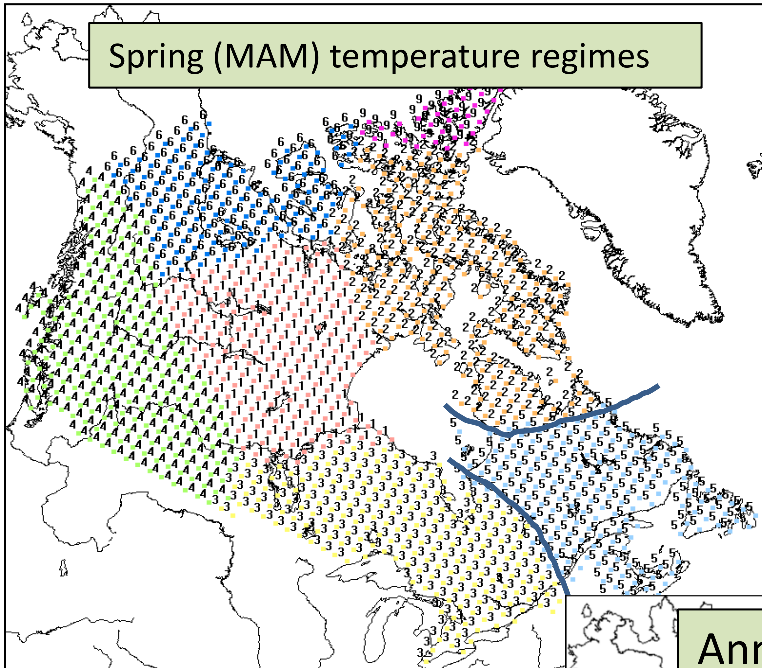
- Continental location next to a large body of water with seasonal sea ice and large inflow of relatively warm fresh water from large river systems
- Hudson Bay sea ice cover in winter allows cold Arctic air masses to easily penetrate to James Bay region
- Presence of ice and water has cooling effect in spring/summer and warming influence in fall-early winter
- Hudson Bay FW circulation maintains late sea ice formation in the Eeyou marine region in the fall period
- Thermal contrasts between land, ice and water affects atmospheric stability, winds, air temperature, fog, precipitation – is a truly Arctic climate regime at 55°N!

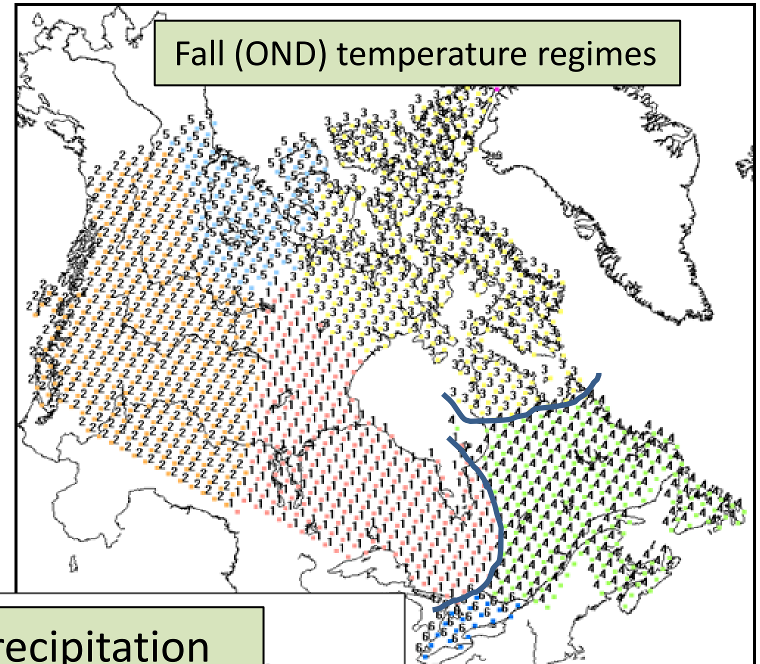
Portrait of mean climate conditions observed at Kuujjuarapik, 1957-2012

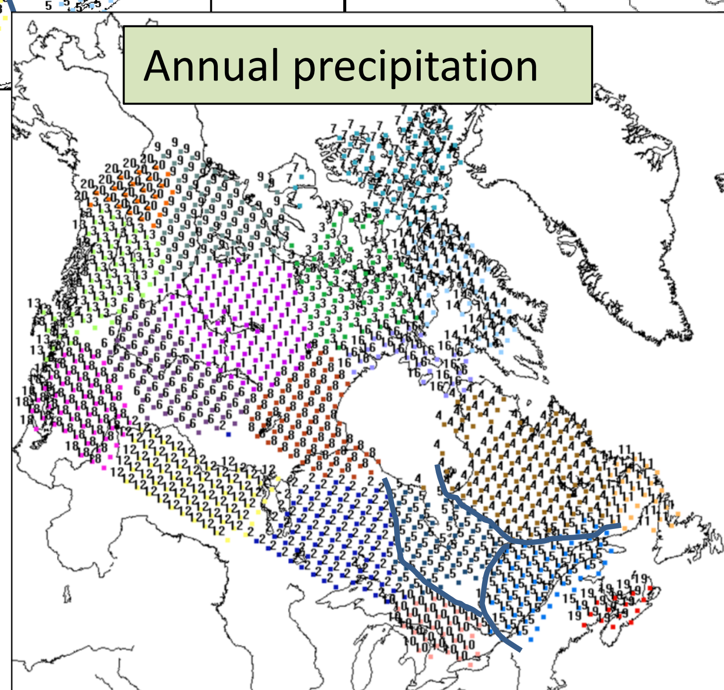
Variable	Average (1957-2012)	Interannual Variability (1 stdev)	Trend (1957-2012)
Annual total precipitation	780 mm	86.6 mm (11.1%)	No change
Annual total snowfall	337 mm WE	71.0 mm (21.0%)	**Sig decrease**
Air temperature	-22.3°C (Feb) to 11.5 °C (Aug)	3.2°C (Feb), 1.9°C (Aug)	**Sig warming from June to Dec**
Freeze period	Oct 30 - May 9	14 days (7%)	**Sig decrease**
Snow cover season	6-7 months (Oct - May)	19 days (10%)	**Sig decrease**
Maximum snow depth	60 cm in early March	26 cm (43%)	**Sig decrease**
Ice safe for traffic*	Dec 10 (1957-1987)	12 days	n/a
Ice unsafe for traffic*	May 15 (1956-1991)	19 days	n/a
Maximum ice thickness*	144 cm (1956-1991)	23.3 cm (16%)	n/a

*From Cdn Ice Service summaries of fu/bu data and weekly ice thickness observations

Evidence of 2 distinct climate zones in the region…







Results from Principal Components analysis of CANGRD data over 1950-2005 period, R. Brown, EC/CPS

2. Climate Data Sources:

Climate data for the region are available from a multitude of sources and organizations:

- Sfce climate observations (EC, MDDEFP, RMCQ, CEN, H-Q, University researchers, local communities)
- Ice/ocean observations (Cdn Ice Service, DFO-MEDS, satellite, models)
- Satellite data (NOAA-AVHRR, MODIS, passive m/w…)
- Paleoclimatic data (CEN – tree rings, pollen etc)
- Reanalyses (ERA-interim, CFSR, MERRA, NCEP…)
- Traditional knowledge

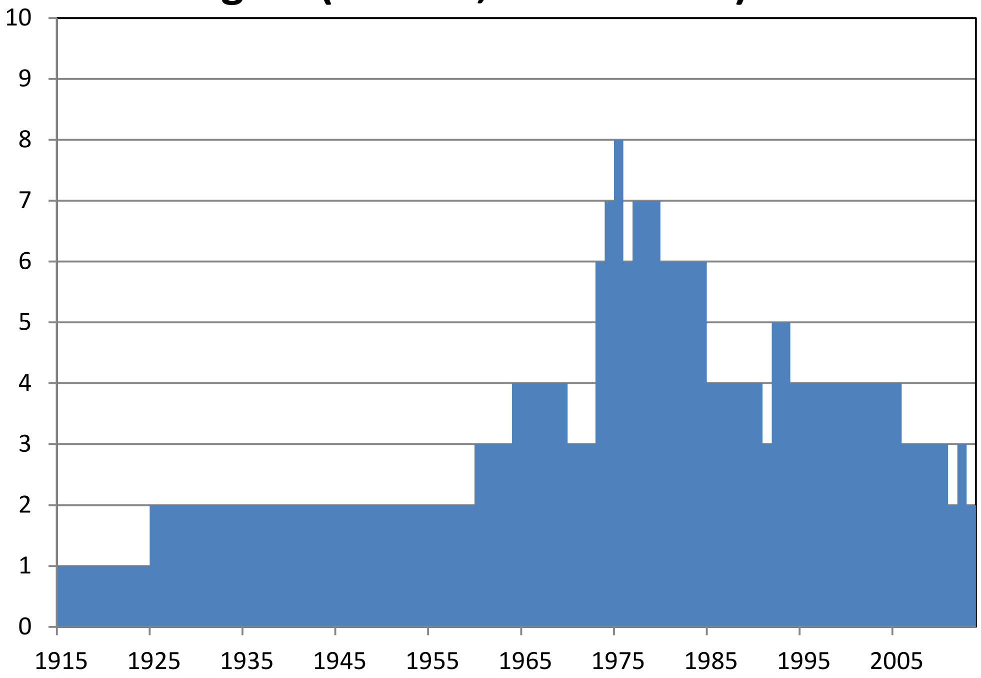
Datasets cover different time periods, have different spatial resolutions, and have particular issues related to their use

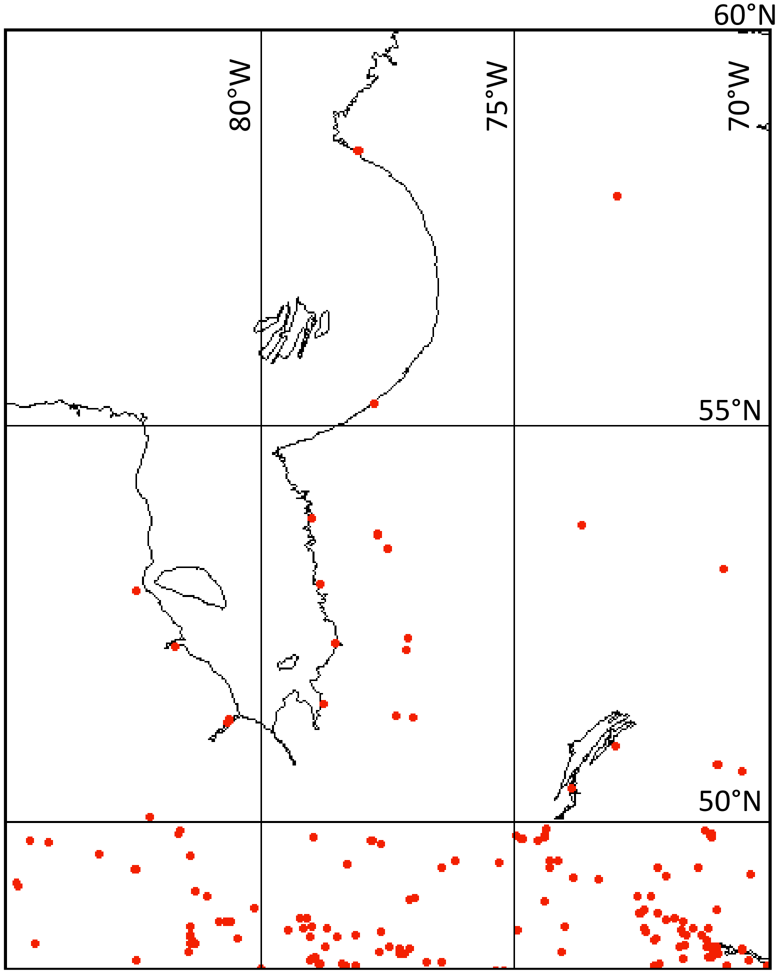
- Homogeneity issues (e.g. station shifts, changes in observing practices, changing source of information in reanalyses over time)
- Sampling issues (e.g. representativeness of point observations of snow depth)

<u>Action Item</u>: Inventory needed of climate data sources in the Eeyou region to determine data availability and suitability to document observed changes in key variables and climate indicators

Historical climate data over the region is limited and fragmentary

Number of EC climate stations with historical daily climate data in Eeyou Region (52-58N, -75 to -80W)

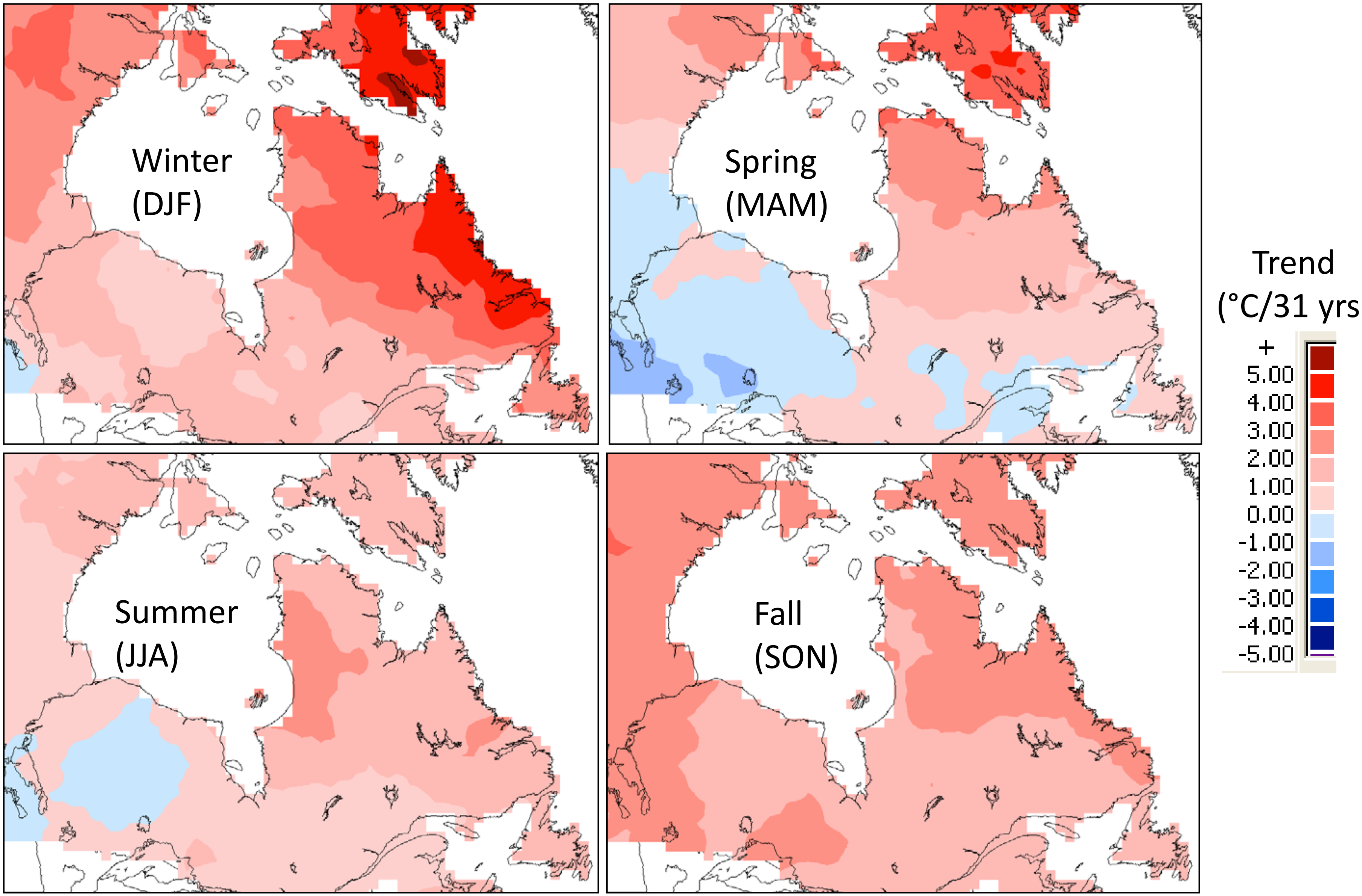




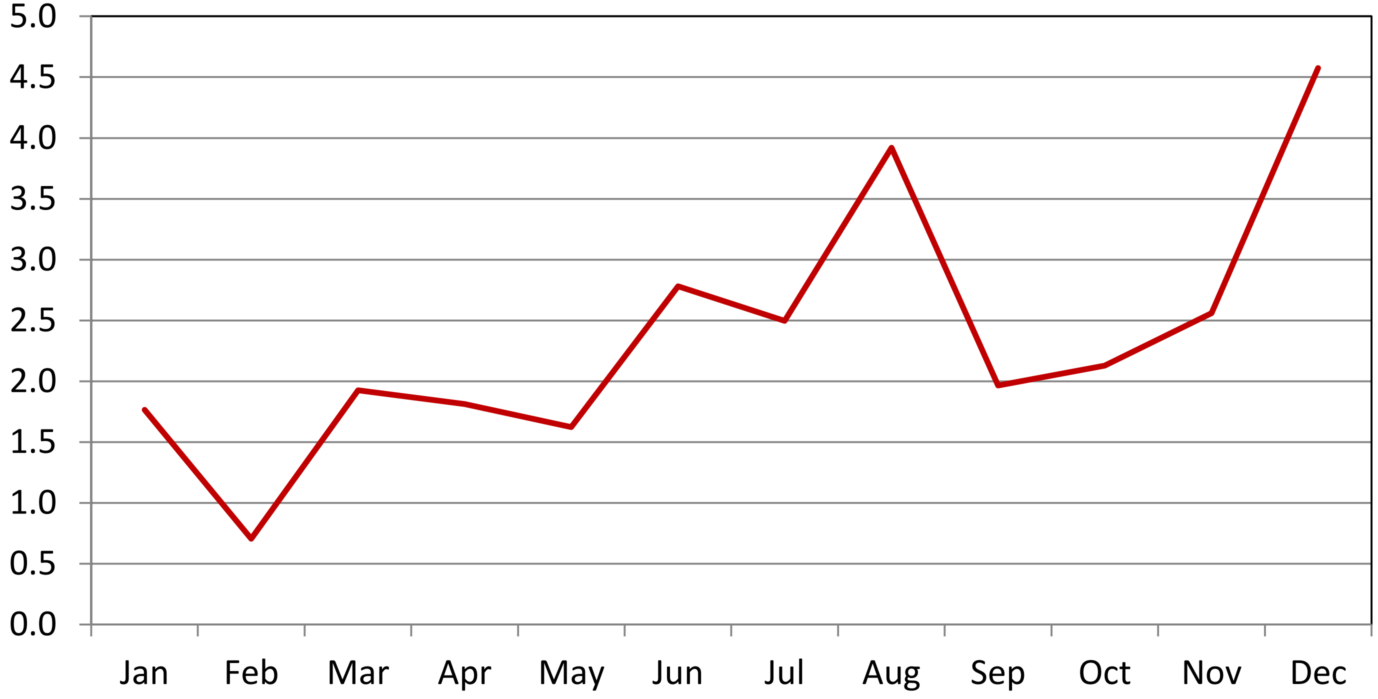
Note: Locations such as Umiujaq and Sanikiluaq have hourly climate observation during daylight hours but this is insufficient for defining daily climate variables such as Tmax, Tmin

3. Observed trends

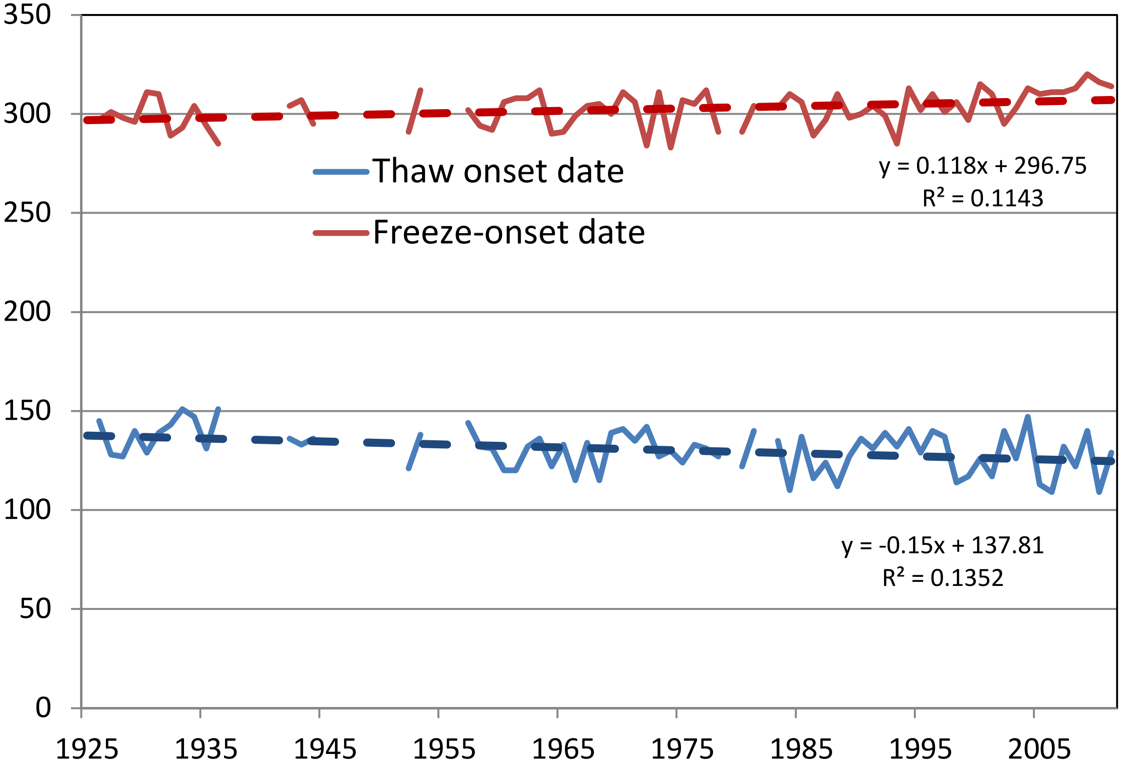
Observed warming (°C) over the 1980-2010 period from the CANGRD dataset



Observed warming (°C) of monthly air temperatures at Kuujjuarapik A, 1957-2012

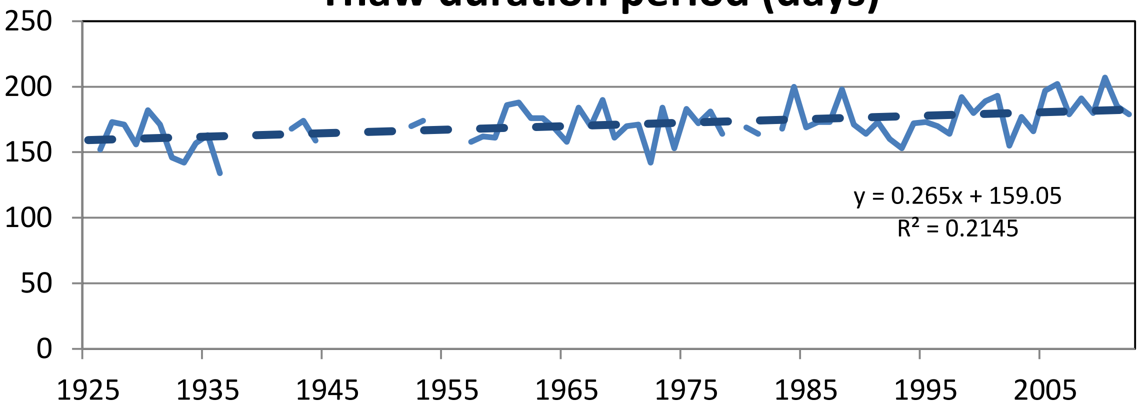


Historical variation in thaw-onset and freeze-onset dates at Kuujjuarapik A

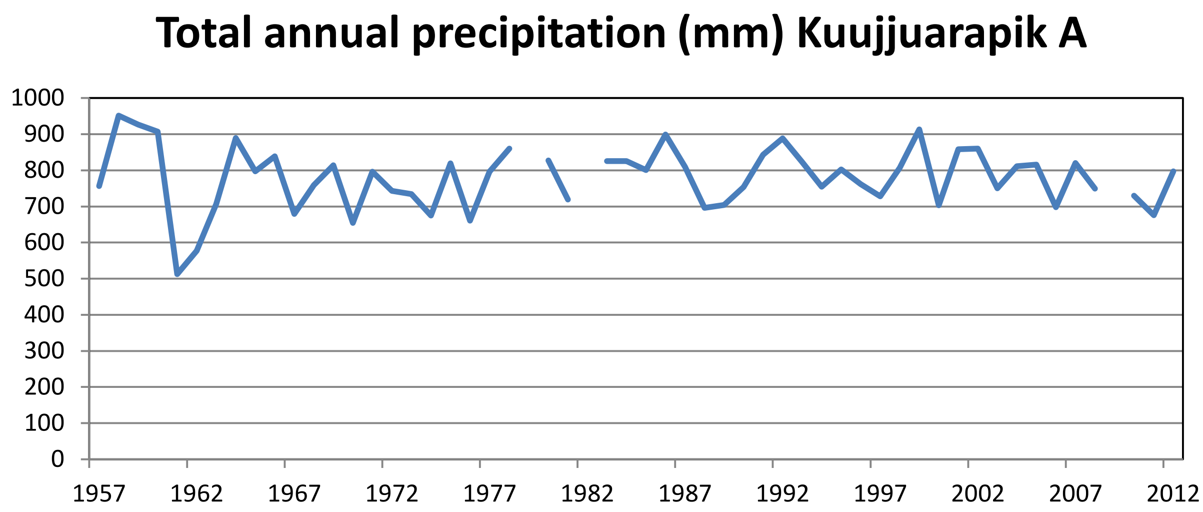


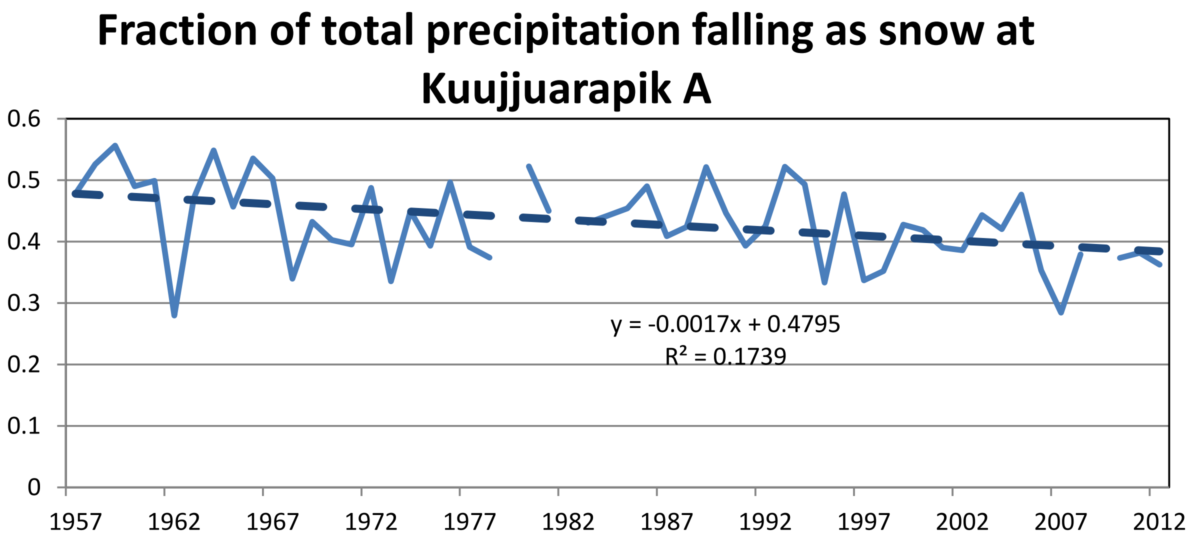
- Thaw-onset date is significantly earlier by > 10 days since 1925
- Freeze-onset data is significantly later by > 13 days since 1925
- The period with above-freezing air temperatures is now > 23 days longer than 1925

Thaw duration period (days)



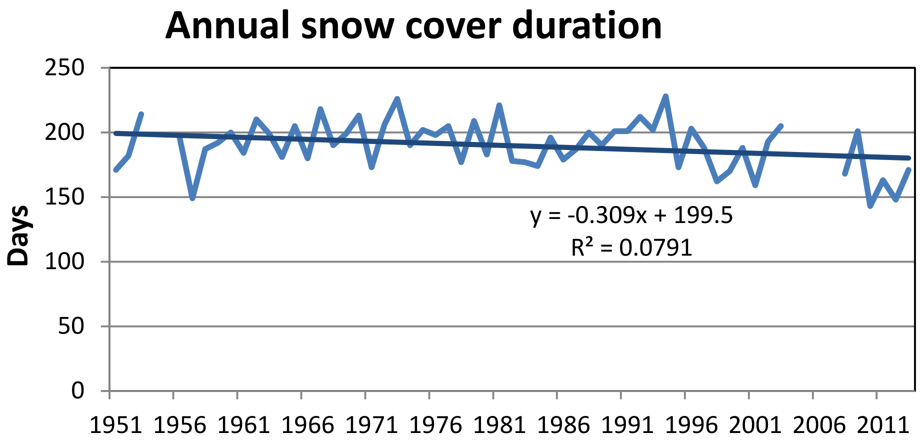
Precipitation at Kuujjuarapik A, 1957-2012

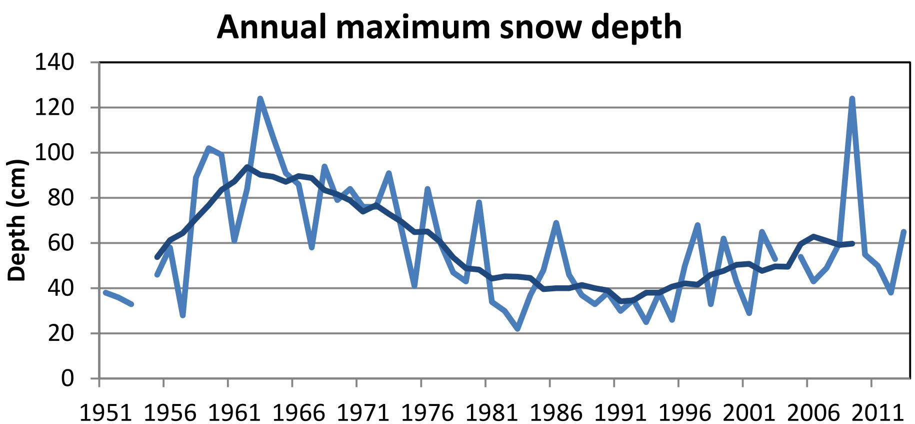


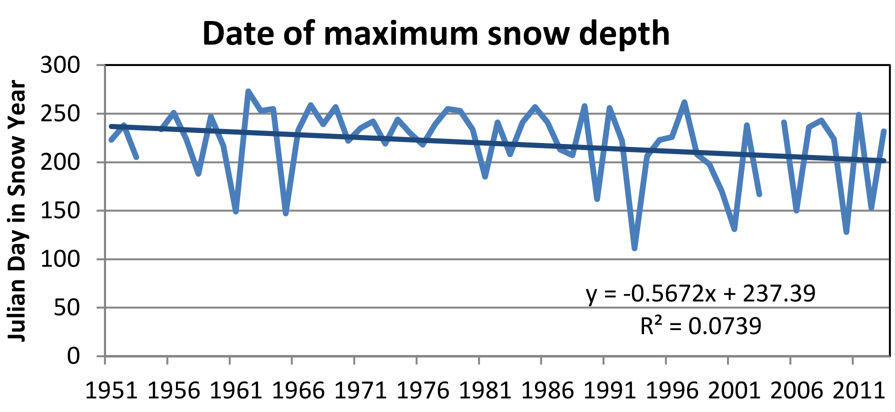


- No evidence of any changes in annual or seasonal total precipitation
- Significant decrease in the amount of precipitation falling as snow in response to warming

Observed trends in snow cover at Kuujjuarapik A, 1950-2013

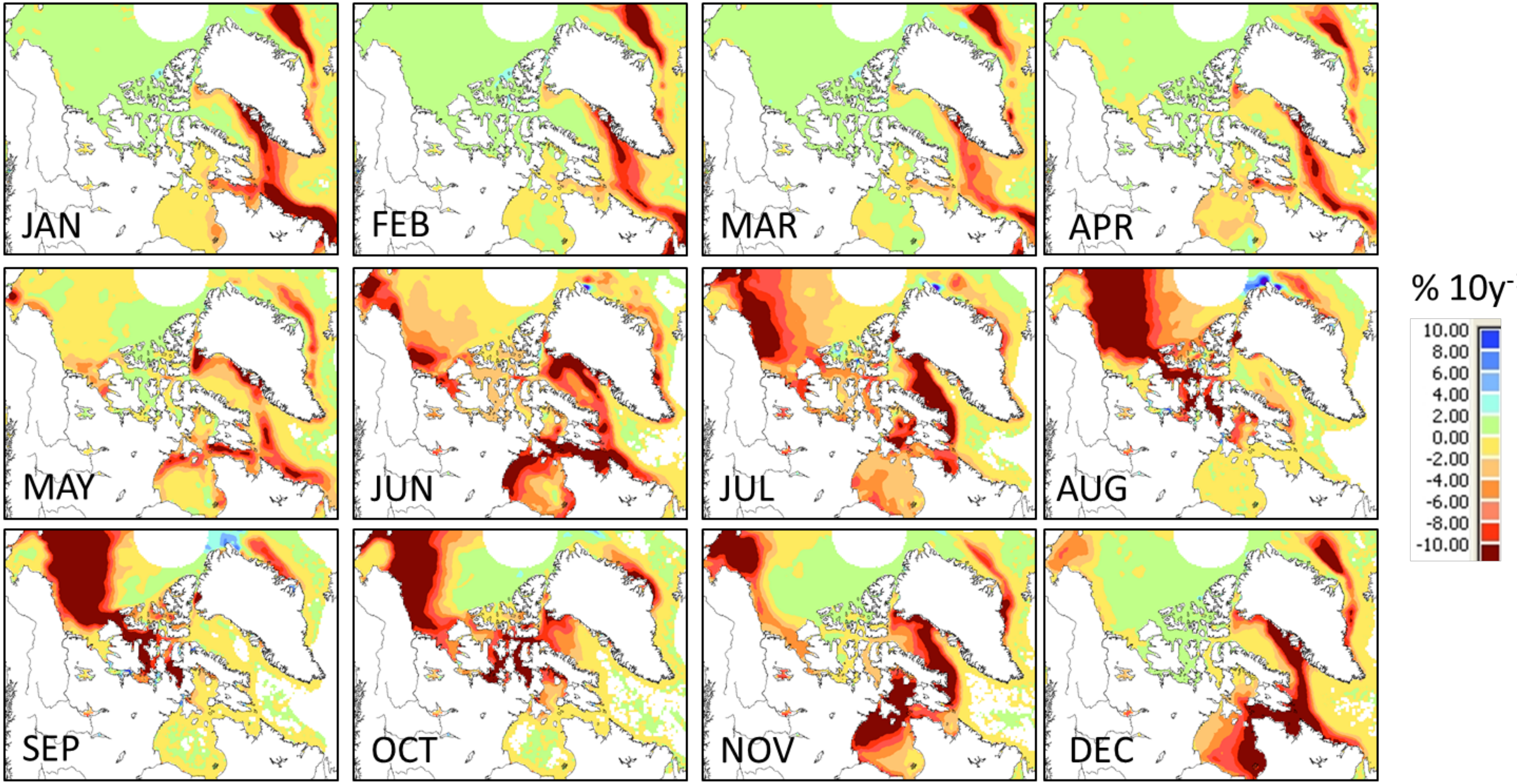






- Evidence that the snow season is becoming shorter (about 50 days less snow cover now than 1960s and 1970s)
- Annual maximum snow depths decreased ~40 cm between 1960s and 1990s but have rebounded in recent years (cyclical behaviour?)
- Maximum snow depths are occurring on average about 1 month earlier in the snow season; much greater variability in dates of maximum depth in period after ~1990

Observed trends in sea ice concentration from passive microwave satellite data 1979-2012



1979-2012 trend (% per decade) in monthly average ice concentration (%) over the Canadian Arctic and adjacent waters based on the passive microwave satellite dataset of Cavalieri et al. (1996, updated to 2012).

Shows local reductions in ice concentration > 10 % / decade over the Eeyou marine region in December and June

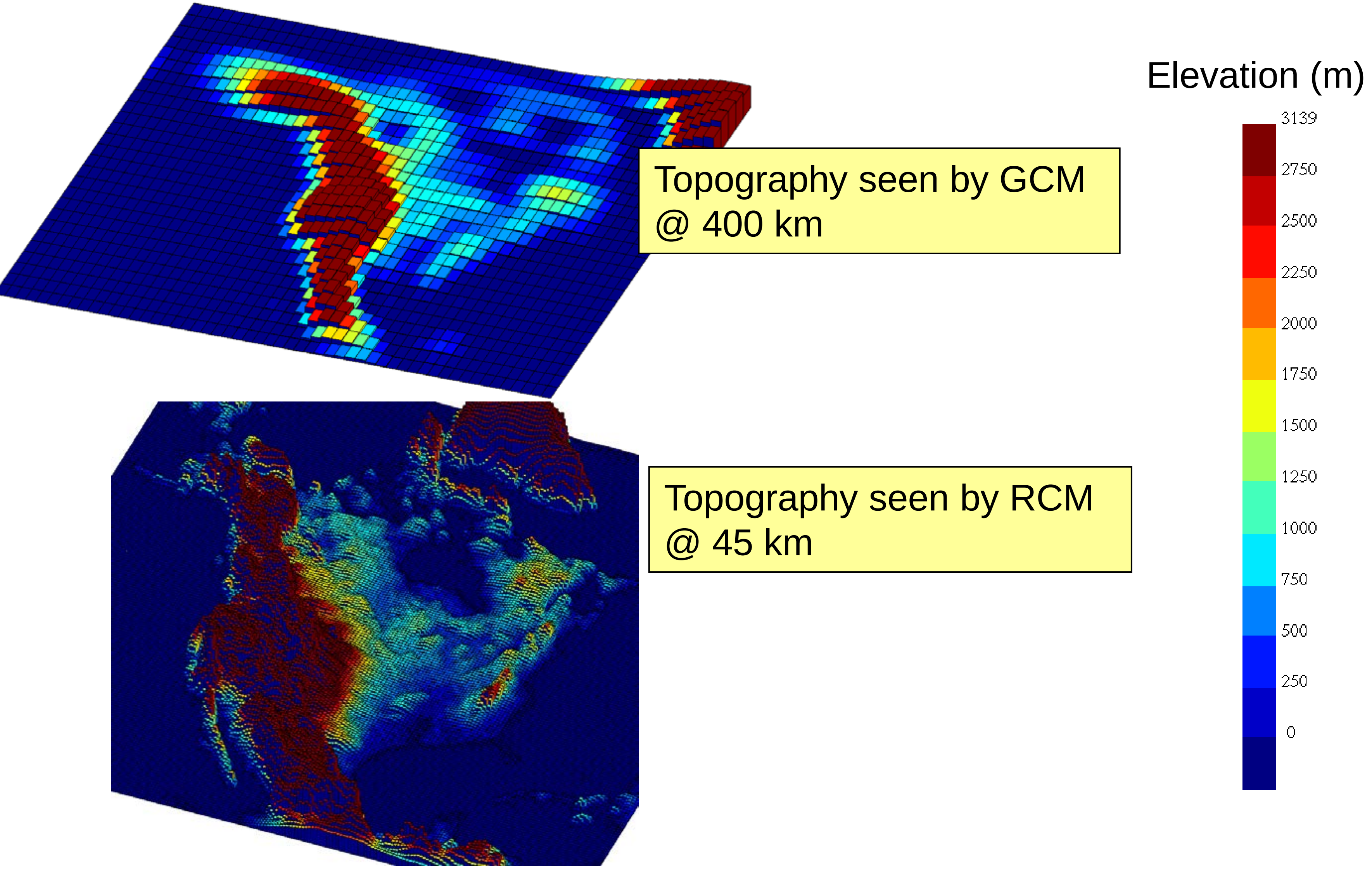
4. Construction of Climate Change Scenarios

Scenario: "*a plausible representation of future climate" (Mearns et al. 1997)*

A number of different methods can be used to construct climate scenarios…

- **Extrapolation of observed trends** (problematic when the observed series is strongly affected by multi-decadal climate variability)
- **Construct warm world analogues by comparing the local climate response in past warm and cold years** (no guarantee that the same conditions will exist in the future)
- **Simulate the climate response using Global Climate Models (GCMs)** (physically-based and internally consistent; coarse resolution ~200-300 km; many 100s of simulations available to examine the magnitude and robustness of projected changes; can statistically downscale output for local-regional scale applications
- **Use a Regional Climate Model (RCM) to dynamically downscale GCM climate simulations** (provides improved representation of topography and regional-scale processes like lake-effect snowfall)

Example of the improved representation of topography and land surface properties seen by a RCM (better representation of mountains, large lakes, coastlines, soil and vegetation types)



Source : D. Caya, Ouranos

Climate Scenario Construction Process used for ArcticNet

1. <u>Definition of Climate Indicators:</u>

Scenarios developed for a range of climate indicators in consultation with the IRIS collaborators e.g.

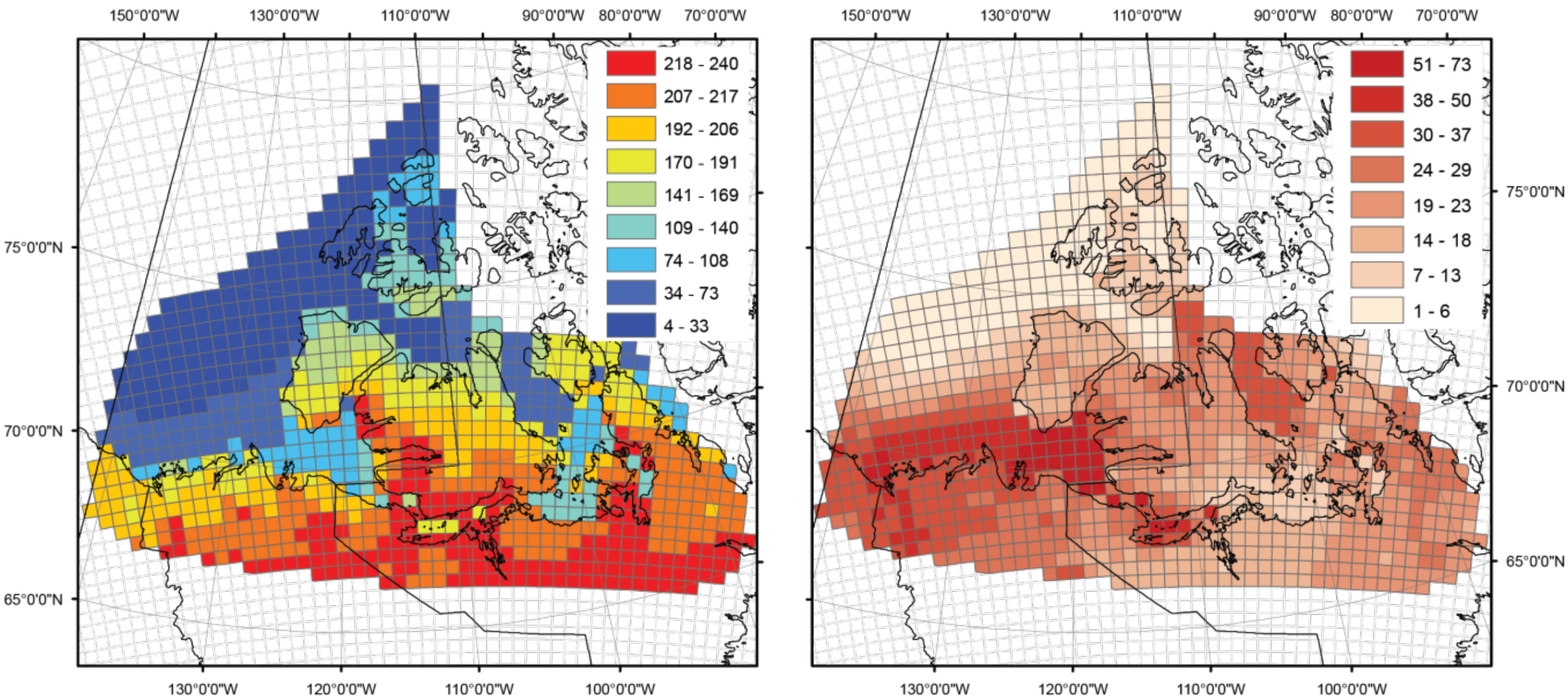
- Berry production (growing degree-days, length of growing season)
- Caribou (maximum snow depth, rain-on-snow frequency, winter thaw frequency)
- Water resources (solid/liquid precipitation)
- Hunting (freeze-up/break-up dates, snow cover)

2. <u>Period and Resolution</u>: 2050 period requested for planning purposes; CRCM4 resolution of 45 km considered adequate for most needs



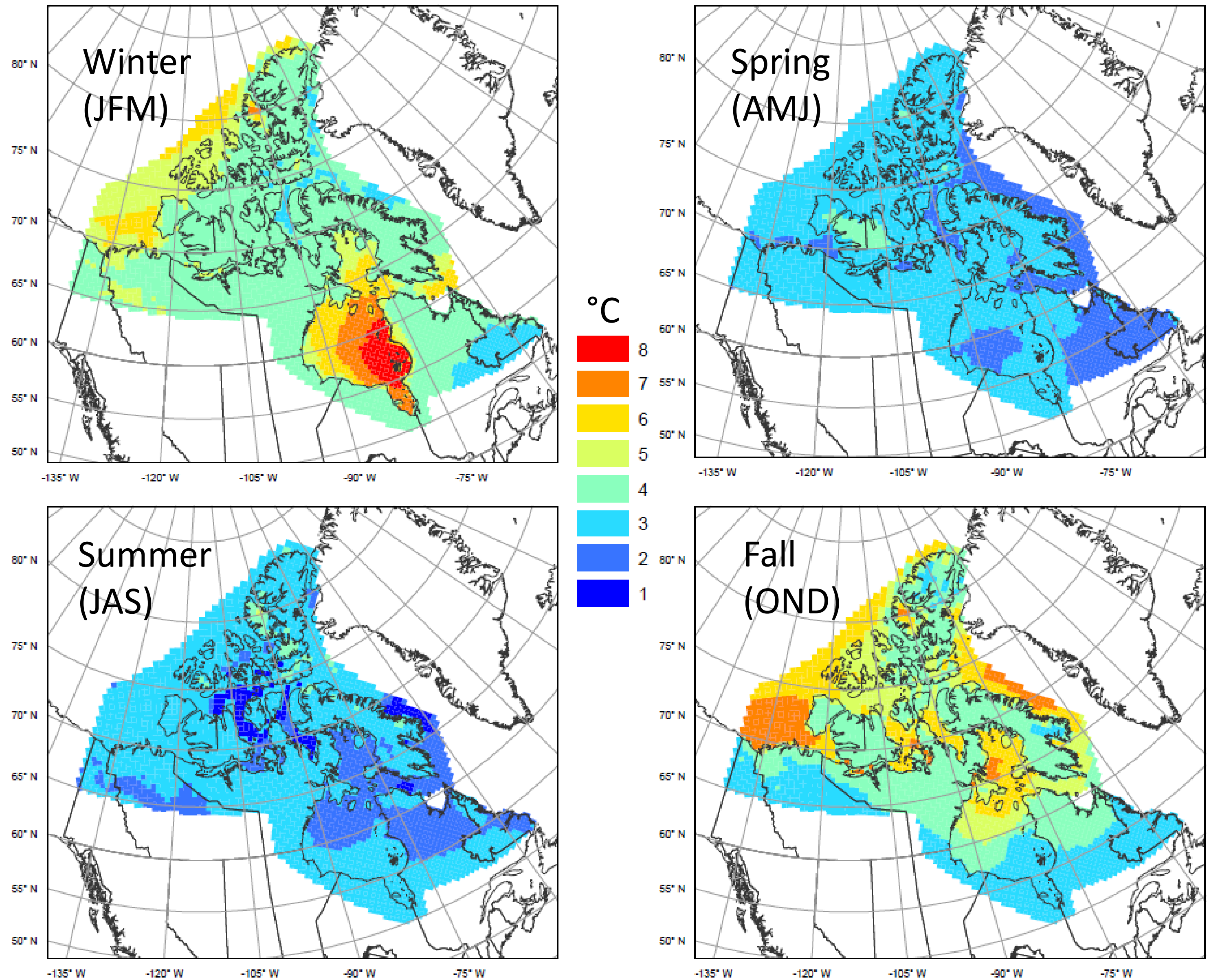

3. <u>Scenario construction</u>: - 8 different model runs, SRES A2 emission scenario

Projected changes presented as maps along with variability in the projected change (stdev of model runs) and regionally-average summary tables



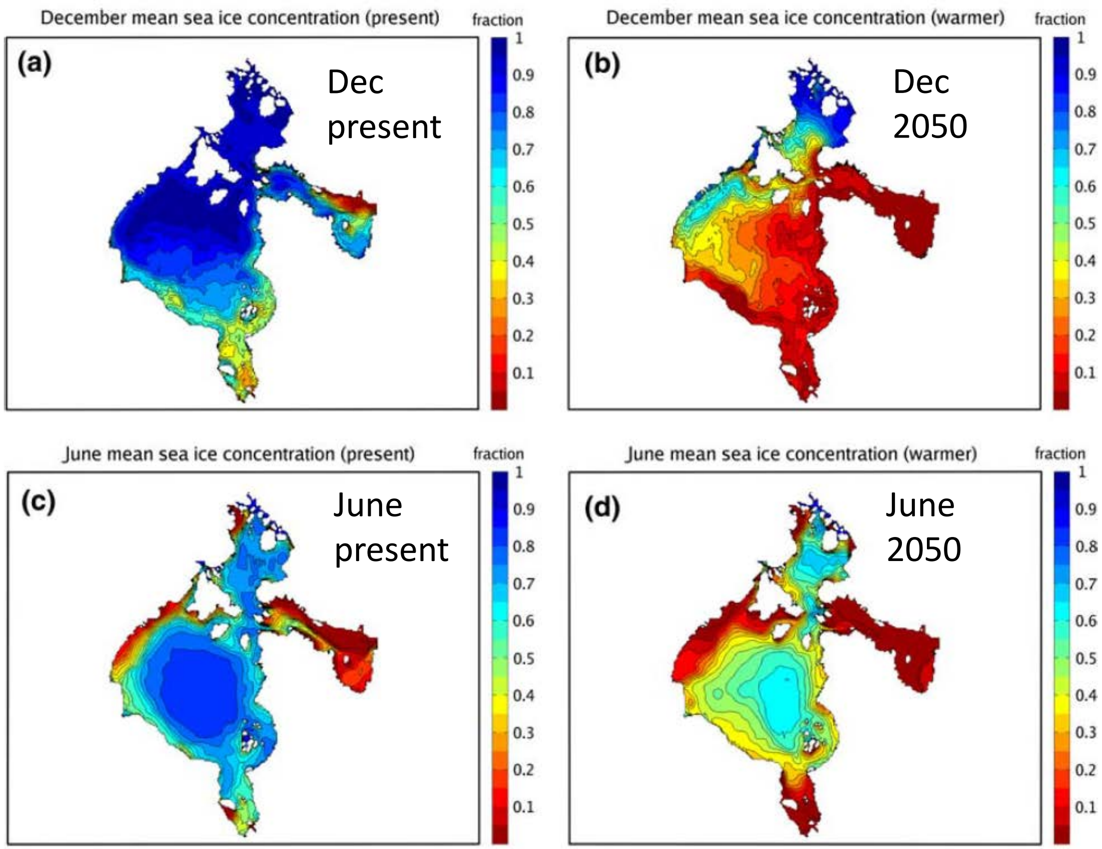
2050 projected change in thawing degree days (TDD) (Celsius) from eight CRCM runs (left panel) and the between-run standard deviation (right panel).

Projected warming (°C) over ArcticNet IRIS Regions for 2050 (SRES A2)

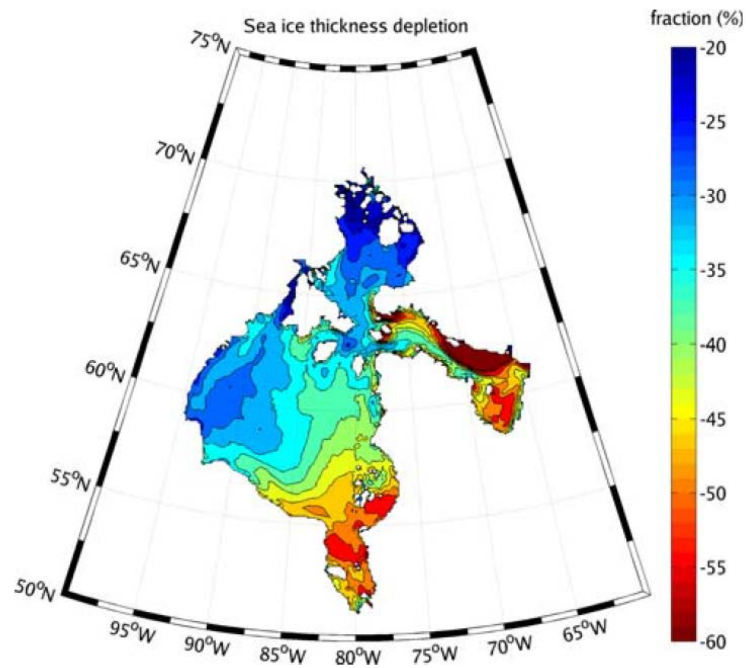


Projected change in sea ice concentration and thickness for 2050 from a regional sea-ice-ocean model of the Hudson Bay system

Present (left) and 2050 (right) mean sea ice conc

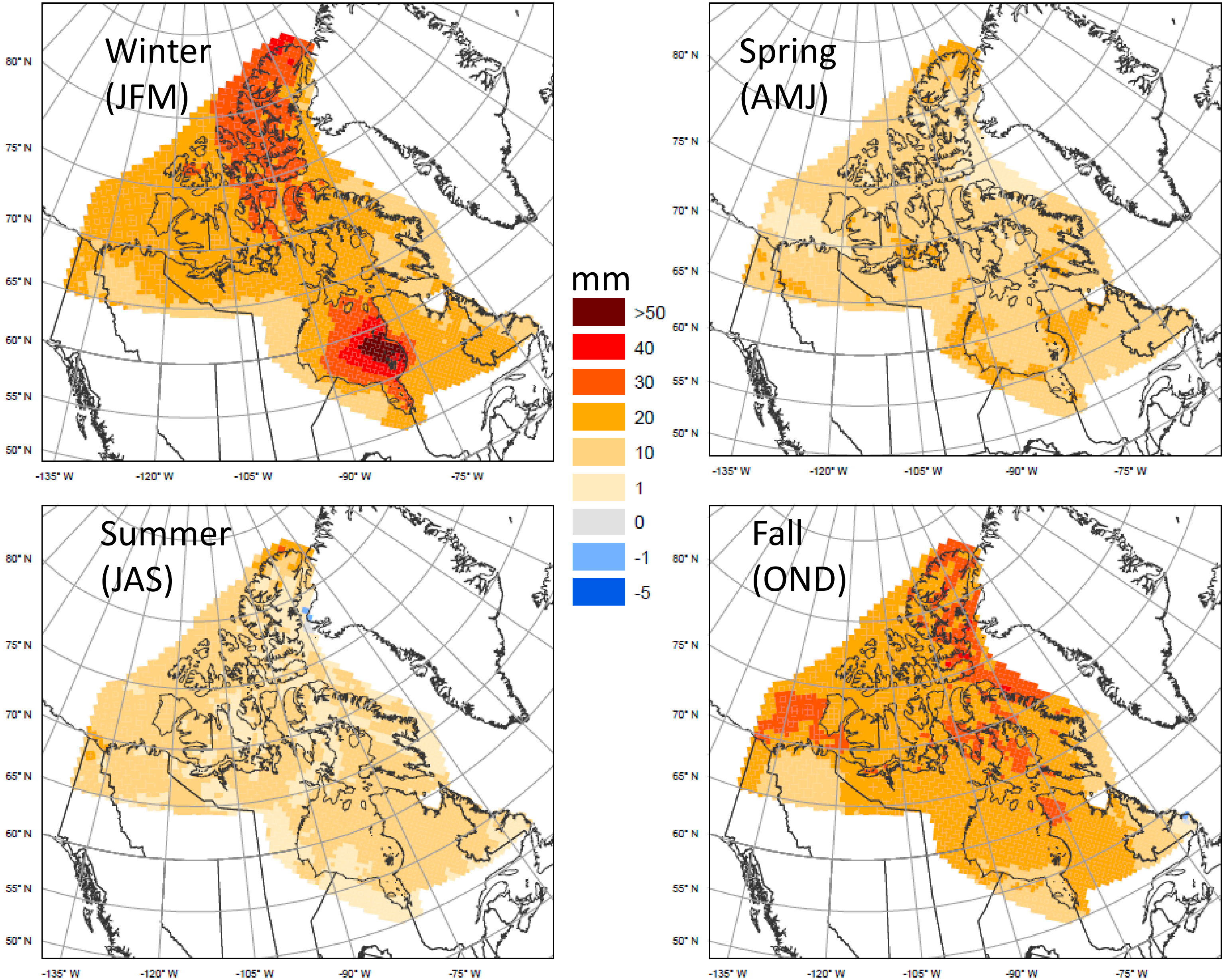


% change in mean winter sea-ice thickness for 2050

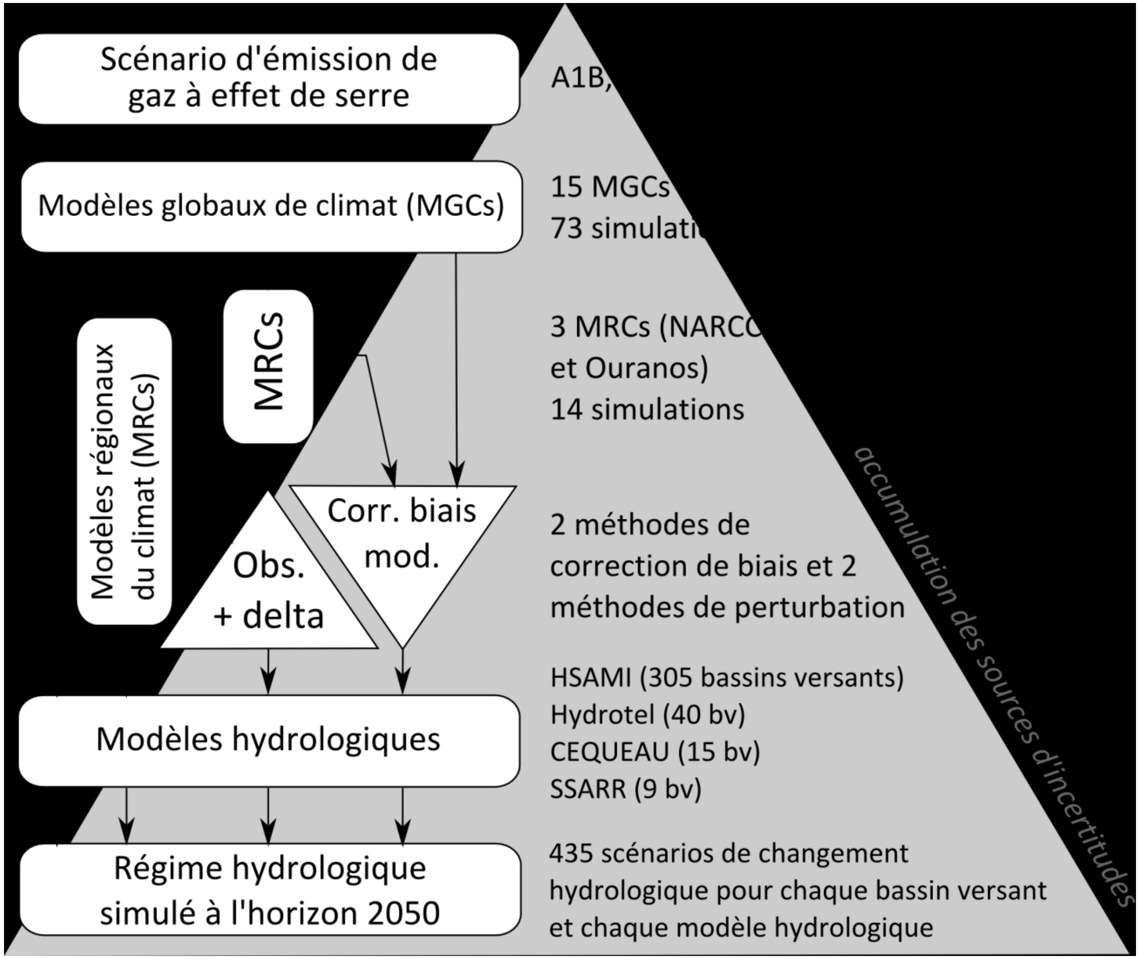


"The model indicates that the greatest changes in both sea-ice climate and heat content would occur in southeastern Hudson Bay, James Bay, and Hudson Strait"
Joly et al. *Climate Dynamics*, 2010

Projected change in total precipitation (mm) over ArcticNet IRIS Regions for 2050 (SRES A2)



Projected changes in Hydrology (Hydro-Québec and Ouranos)



Extensive work is being done at Hydro-Québec and Ouranos to understand how hydraulic regimes in Québec will respond to a changing climate

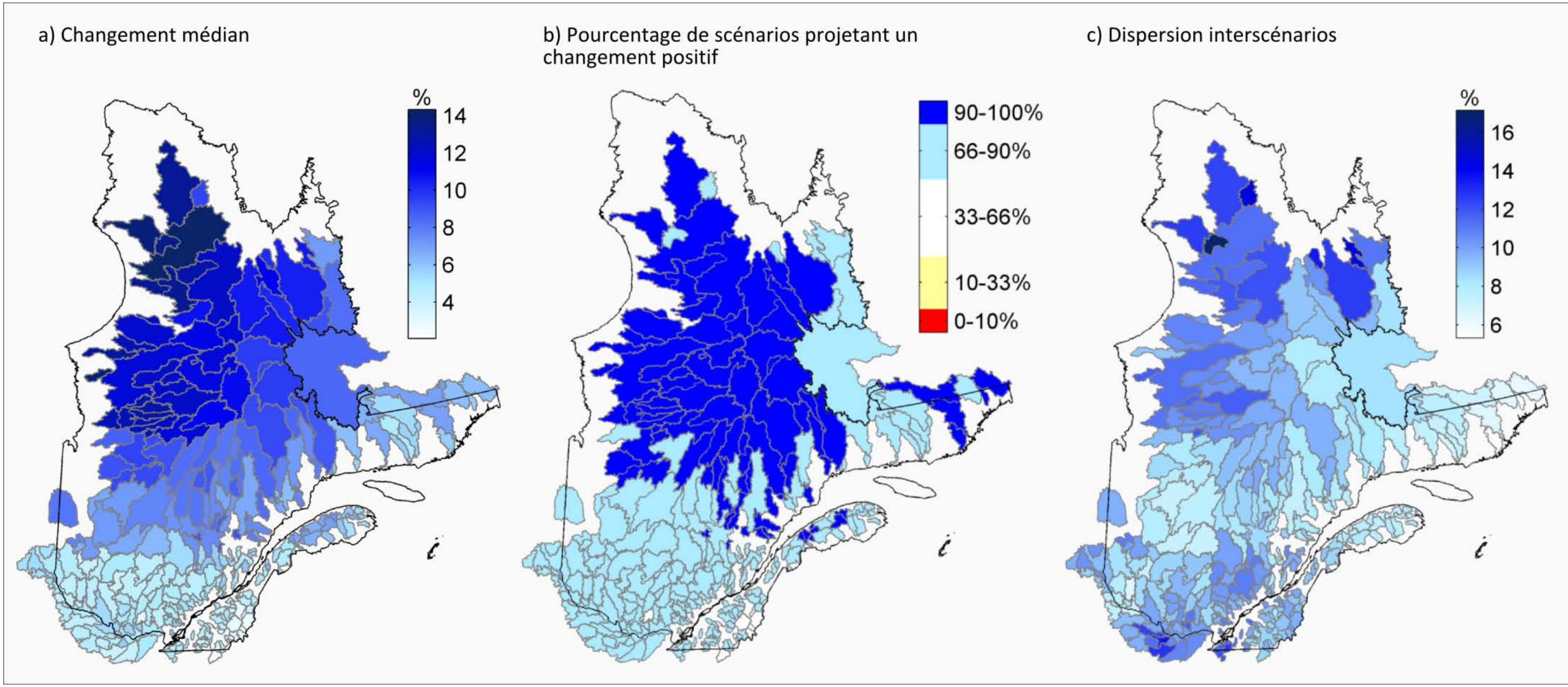
Scenarios have been developed for changes in snow cover and runoff using GCM and RCM output driving hydrological models

A probabilistic approach has been used to characterize the results of 100s of climate scenario simulations

Source: R. Roy, Hydro-Québec

Projected change in annual runoff for Québec river basins for 2050

(based on output from 435 GCMs for multiple emission scenarios)



Median runoff change (%)

% of scenarios showing an increase in runoff

Scenario dispersion (stdev as % of median)

Basins discharging into the Eeyou marine region are projected to have 5-15% increases in annual runoff

Source: R. Roy, Hydro-Québec

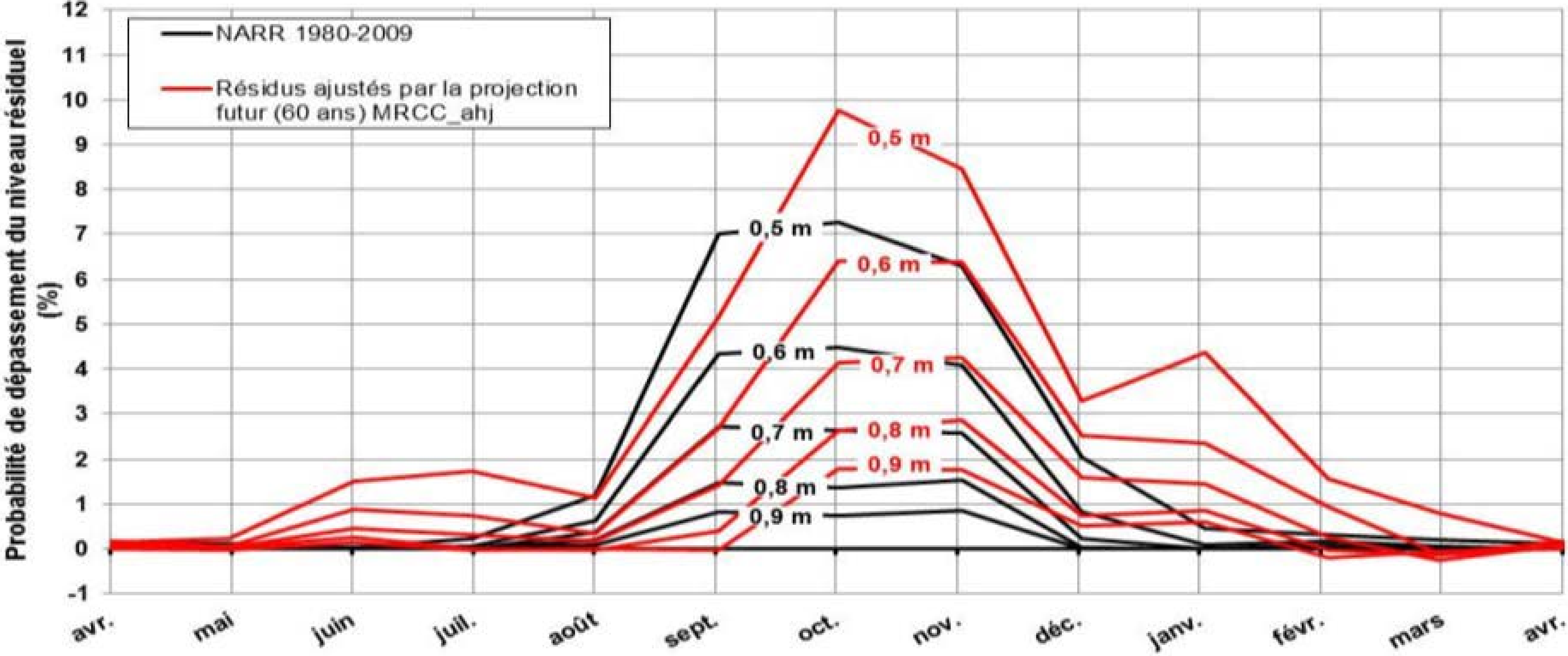
Projected changes in cyclones, waves and storm-surge flooding potential

Ouranos/EC/UQAM study (J-P Savard et al. 2013) carried out for MTQ to assess the potential for climate warming-induced changes in the cyclone climatology of Hudson Bay and the implications for coastal infrastructure. Umiujaq was the southernmost community included in the study

Key Findings:

- Warming increases the period with large thermal contrasts in the autumn and early-winter in Hudson Bay
- Increased thermal contrast favours the redevelopment of cyclones (projected 15-20% increase in storm frequency and duration)
- Less ice cover in the fall and early winter increases the potential for high waves and higher storm surge (increased potential for coastal erosion and increased risk of coastal flooding from storm surge)
- Increased cyclone frequency and duration are associated with increased precipitation amounts and extremes (increased flood risk)

Effect of climate change on the probability of exceeding non-tidal water level from storm surge at Umiujaq – **flood risk is increased with warming**



Source: Savard et al. (2013)

Merging TK and western climate monitoring information

- Matrix of TK observations of environmental change developed for IRIS-1 region by Stern and Gaden (2014)
- Can overlay trends from in situ obs, satellite data onto this matrix to provide a synthesis that is more relevant to local decision-makers

Table 1. Documented observations made by Inuit in the western and central Canadian Arctic

Observations	Inuvialuit Settlement Region						Kitikmeot Region						References
	Aklavik	Inuvik	Tuktoyaktuk	Paulatuk	Sachs Harbour	Ulukhaktok	Kugluktuk	Cambridge Bay	Bathurst Inlet & Umingmaktok	Gjoa Haven	Taloyoak	Kugaaruk	
Temperature													
Warmer summers or more extreme warm temperatures in summer	X	X	X		X	X	X	X	X	X			
More intense heat from the sun	X	X	X		X	X	X	X	X			X	
Cooler summers				X		X							
Longer summers, shorter winters	X	X	X		X			X		X	X		1-5, 7, 8, 14-16
Fewer winter extreme cold temperatures and/or generally milder winters	X	X	X	X	X	X						X	
Increase in temperature fluctuations					X	X						X	
Precipitation													
More rainfall			X	X	X	X							
More forceful rain	X				X	X							
More freezing rain		X	X	X			X					X	1, 2, 4, 6, 15, 16
Less snowfall or later snowfall	X	X	X	X		X	X	X		X	X		

Note: Sample only – the full table includes Snow and Ice, Landscape and Wildlife variables

Stern, G.A. and Gaden, A (2014). Navigating the north: a snapshot of the western and central Canadian Arctic (Chapter 1). In: Stern, G. and Gaden, A. (Eds). The Integrated Regional Assessment of the Canadian Western and Central Arctic. ArcticNet (in preparation).

5. Conclusions

- The EMR has a unique climate regime that is highly sensitive to projected warming
- Evidence that climate has changed significantly in the EMR over the period since 1950 (snow cover, sea ice, air temperature, snowfall)
- Available climate information for the Eeyou region is fragmentary - work needed to pull this together
- Need to work with users to define relevant climate indicators and to integrate local knowledge into results from western science climate monitoring
- CC projections show the Eeyou region as a “hot spot” for change related to the sea ice response – need to ensure that sea ice processes and Hudson Bay circulation are realistically simulated in CC projections
- A number of CC studies have been carried out in the Hudson Bay region that apply to the EMR (DFO, Ouranos-MTQ, Ouranos-Hydro-Québec) – a synthesis of existing studies would be useful to take stock of work done to date


Merci
Thank you
Kinanâskomitinâwâw
Naqurmiik
Environment Canada
Environnement Canada
ArcticNet
UNIVERSITÉ LAVAL
OURANOS