Climate analysis and scenario development in support of ArcticNet IRIS

Project Leader

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Abstract

Building climate projection scenarios for the Canadian Arctic and Subarctic regions is more challenging than for more southern regions due to the complex regional settings and interlocked physical processes. The main objectives of the project are: 1) to supply climate change (CC) information in support of the ongoing IRIS reports (IRIS 1-2-3), 2) to build a climate database and analyze its information to support impact and adaptation (I&A) studies and the production of climate projection scenarios, 3) to analyze the recent climate trends and the natural climate variability over the IRIS regions, and assess the potential of the climate model to capture the observed variability and physical processes and, 4) to track state-of-the-art developments in coupled cryosphere/atmosphere/ocean models to improve the reliability of climate scenarios. This project will provide researchers, stakeholders, decision-makers and communities with more accurate knowledge of current and anticipated climate changes and contribute to support sustainable development in this complex and rapidly changing environment.

Key Messages

- Understanding the dynamics of the arctic climate is challenging. This is mostly due to the lack of in situ observations along with their temporal coverage.
- Homogenized data for various climate indicators (air temperature, solid and liquid precipitation) show important interannual variability and allow for a suitable trend analysis despite the sparse distribution of climate stations across IRIS regions.
- Air temperature anomaly for period 2001 to 2011 (WRT 1981-2010) shows important differences ranging from +1.5 to +2°C over Baffin Island, Davis Strait, Baffin Bay and the southern Elsmere Island.
- Projected change in mean annual air temperature provided by the Canadian Regional Climate Model (CRCM) for horizon 2050 varies within the IRIS 1 region from 2 to 4 degree Celsius.
- Projected change in total monthly precipitation provided by the CRCM over the three IRIS regions show spatial differences ranging from 6 to 43% with higher increases in winter.

Objectives

The main objectives of this project are:

- To produce climate scenarios for the IRIS regions 1-2-3, and improve those already produced for IRIS 4 in sight of the publication of the report's second edition;
- To identify source of climate data series and analyze these observed climate data in support of impact and adaptation (I&A) studies and the production of climate scenarios;
- To analyze the recent climate trends and the natural climate variability over the IRIS regions, and assess the potential of the climate model to capture observed variability and physical processes;
- To track state-of-the-art developments in coupled cryosphere/atmosphere/ocean models to improve the reliability of climate scenarios.

Introduction

This special project is the direct continuation of the collaboration initiated in 2008 between Ouranos and ArcticNet in developing climate scenarios for the IRIS 4 region (Integrated Regional Impact Study of the Nunavik and Nunatsiavut region). The main objectives of the project range from supplying climate change (CC) information in support of the ongoing IRIS projects (IRIS 1-2-3) to more fundamental research on observed and modeled climate phenomena. Achieving a thorough knowledge of recent climate trends in the Arctic is challenging considering the

sparse distribution of climate stations and the lack of consistencies between available data sets. In this context, it is crucial to use multiple existing data bases of observations and modeled data. In addition, building climate scenarios for the Canadian Arctic and Subarctic regions is more challenging than for southern regions due to the complex regional settings and physical parameters that are not included in some climate models such as the topography, the influence of ocean circulation and sea ice, the snowdrift and permafrost. Obtaining observed data sets of high quality characterizing climate variability and trends, and validating climate models over the IRIS regions is also a challenge.

Activities

Analyses of past and recent climate trends

- Climate analyses already started to provide bases for the writing of the first draft of the IRIS 2 climate chapter. Climate information from multiple sources (i.e. from literature and databases) for air temperature, precipitation (solid and liquid) and sea ice cover were analyzed (e.g.: North American Regional Reanalysis (Messinger et al. 2006), Environment Canada, National Snow and Ice Data Center). The information is being compiled as a chapter assessing climate dynamics of the region by CEN/ArcticNet and Ouranos (C. Barrette, R. Brown, D. Chaumont and P. Grenier).

General analysis of biases and models' discrepancies in supplied CRCM outputs for IRIS projects

- A general analysis of biases and uncertainties of model outputs that will be used to produce climate scenarios of IRIS 1-2-3 regions was completed by Ouranos in January 2013. Discrepancies were highlighted and suitable model runs were selected. A report was produced by P. Grenier.

Producing maps of CC and uncertainties

- 8 sets of CRCM (Caya and Laprise 1999; de Elia and Côté 2010) output data were extracted from Ouranos database for production and analysis of CC scenarios. Data were extracted by Ouranos and supplied in early January 2013 (P. Grenier).
- Projected climate change mapping is actually being produced at Centre d'études nordiques (C. Barrette).
- The climate projection section of the IRIS 1 climate chapter is being written in close collaboration between ArcticNet, Ouranos and the CEN (C. Barrette, D. Chaumont, R. Brown, R. de Ellia, A. Frigon and P. Grenier).

Identification of knowledge gaps and investigation of key processes of the Arctic climate

- A database of climate records is being compiled including various model reanalysis (e.g. ERA40, NARR, etc.), in situ observations of Environment Canada and SILA network (CEN) (M. Markovic, C. Barrette).
- Analysis of climate at meso and large scales of atmospheric processes is being done in order to increase scientific knowledge of Arctic climate phenomena. This research also focuses to better understand models' (GCMs and RCMs) performances with respect to the observational data (M. Markovic, R. Brown).

Supporting climate analysis and modeling initiatives of specific ArcticNet projects

- Scientific and technical support is given to specific climate related ArcticNet projects. For instance, meetings with ArcticNet researchers, especially with CEOS researchers, were held during the ASM 2012 (Vancouver) in order to coordinate research efforts and selection of adequate data sources to be used as forcing source for a sea-ice modeling initiative (M. Markovic, C. Barrette).

Results

Recent climate trends and uncertainty estimations analyses of the Canadian Arctic of CRCM model runs:

- The analysis of the Canadian Arctic climate is made using various data sets of observed and reanalysis products. The information is gathered and structured as a chapter assessing the climate trends of the past 60 years in the IRIS 2 region. Temperature and precipitation anomalies (Figure 1) were computed using Environment Canada's second generation of homogenized data (Vincent et al. 2012). Snowfall anomalies were calculated using Environment Canada's homogenized data (Mekis and Vincent 2011) (Figure 2).
- Using reanalysis products and 9 runs of output results for the recent past period of the CRCM, uncertainties and biases analyses were produced to assess discrepancies among the model's ensemble. Selected fields for different model runs were compared: minimum and maximum air temperature, precipitation and snowfall. Results showed important discrepancies for snow accumulation in the CRCM run piloted by GCM CNRM-CM v3 #1. These discrepancies occurred in some channels of the Canadian Arctic Archipelago, where there was surprisingly no snow accumulation all year round.

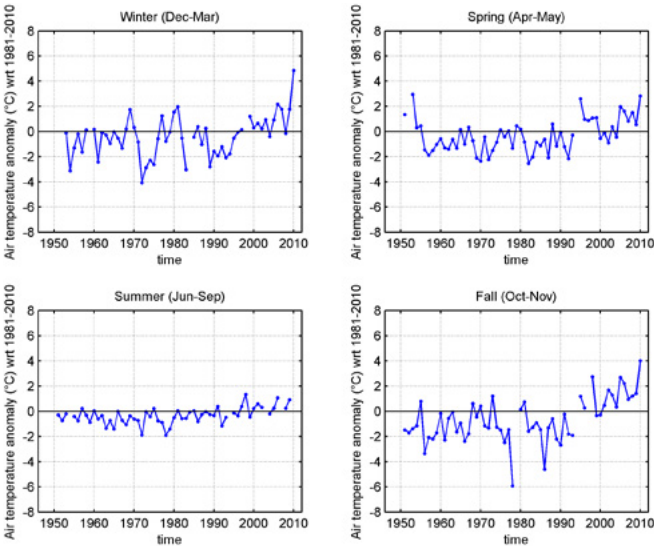

Figure 1. Regionally averaged seasonal air temperature anomalies with respect to 1981-2010 reference period. The average is calculated from four climate stations n the IRIS 2 region with at least 40 years of data in the period 1950-2011 based on homogenized data from Vincent et al. (2012).

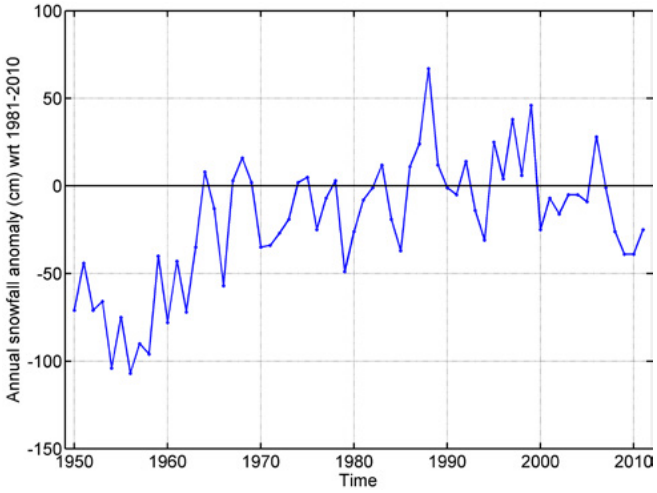

Figure 2: Annual regionalized snowfall anomaly with respect to 1981-2010 reference period for climate stations n the IRIS 2 region with at least 40 years of data in the period 1950-2011 based on homogenized data from Mekis and Vincent (2011).

Climate scenarios supporting I&A studies for the four IRIS regions:

- Using climate projection data from 8 CRCM runs piloted by 2 General Circulation Model (GCM) (Canadian General Circulation Models v3.1 and ECHAM v5) allowed for the development of CC scenarios for IRIS 1 and 2 regions. These scenarios are presented on maps of projected change for the 2050 (2041-2070) horizon compared to 1971-2000 and maps of uncertainty (standard deviation (STD) among the model ensemble) for a set of selected CC

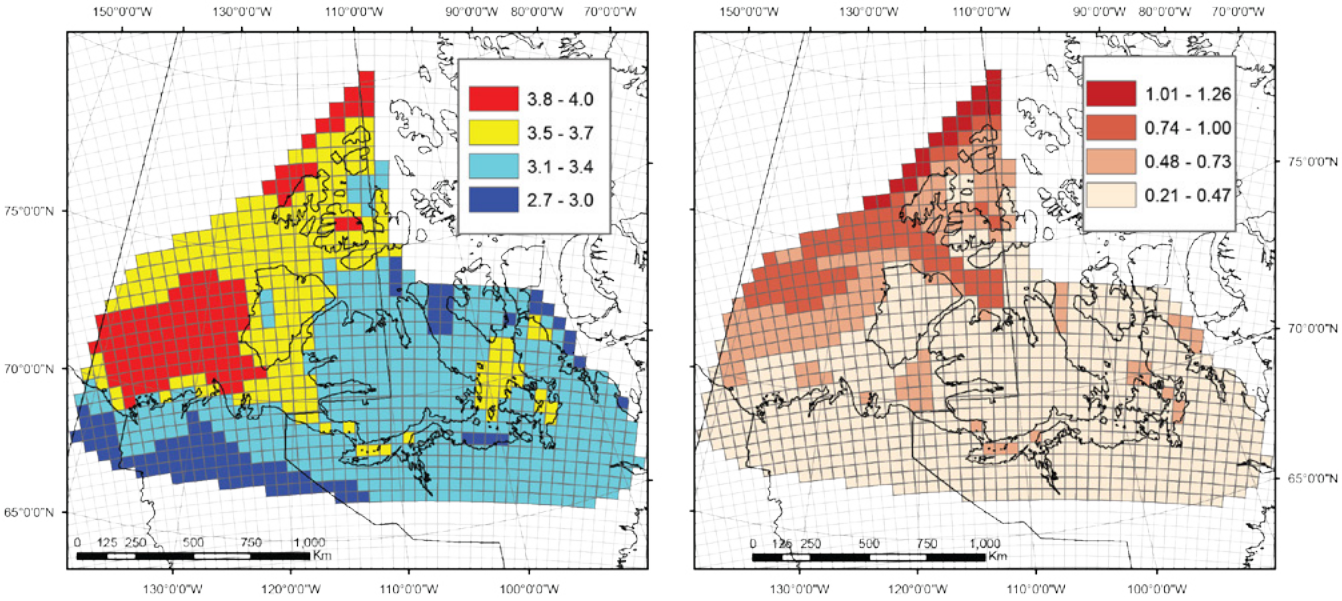

Figure 3: Air temperature projected change a) and standard deviation b) for 2050 from 8 CRCM runs n the IRIS 1 region.

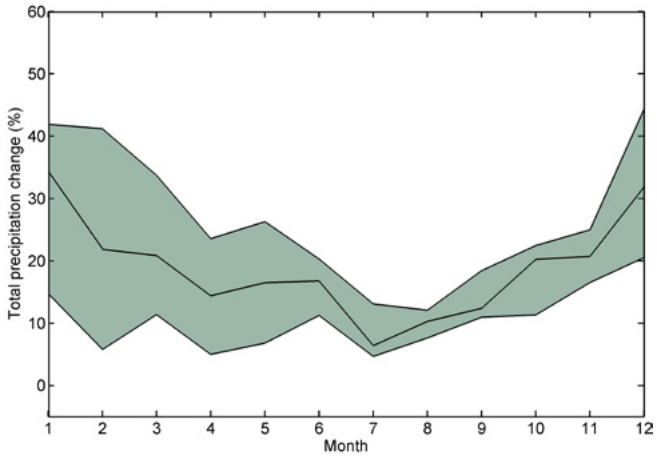

Figure 4: Monthly total precipitation change projected from 8 CRCM runs for IRIS 1-2-3 regions. The outer lines represent the range in the 8 simulations.

indicators. These scenarios are produced using specialized technical programming language and mapping tools. Figure 3 shows projected air temperature change and STD for the 2050 horizon over IRIS 1 region. Total monthly precipitation change for the 2050 horizon over IRIS 1-2-3 regions is presented in Figure 4.

Discussion

Recent climate trends and uncertainty estimations analyses of the Canadian Arctic of CRCM model runs:

- The chapter section on climate variability and changes has been drafted and is currently under revision by Ross Brown. Observation data show that despite important interannual variability, air temperatures have increased over the IRIS 2 region. This result agrees with other studies conducted in other Arctic regions. Precipitation is most important during summer period, especially in August, and this appears to be the case over the entire IRIS 2 region. High precipitation rates in August have important implications for various social and environmental services (e.g. water quality and infrastructures stability).
- Snow accumulation is one of the sensitive modeling fields. Important discrepancies were revealed in the CRCM run piloted by GCM CNRM-CM v3 #1. A more detailed analysis of this model run (CRCM and GCM pilot) is still needed to be able to better understand

the causes of these divergences, which often occurred in some channels of the Canadian Arctic Archipelago, where no snow accumulation was noticed all year round.

Climate scenarios supporting I&A studies for the four IRIS regions:

- The writing of the Climate Projection section to be included in the general *Climate Variability and Projections* chapter of IRIS-1 has progressed in parallel to the computing of the CC and STD indicator maps. Results from first CC indicator maps show that maximum change (~46%) in monthly total regional precipitation (IRIS 1-2-3) will likely occur during winter months, and minimum (~6%) projected changes in July and August. Maximum changes in mean monthly air temperature for IRIS regions 1-2-3 are anticipated in winter months. These preliminary results from CRCM outputs analysis correlate with GCM projections from other studies (ACIA 2005).

Conclusion

This climate/scenario project started in late November 2012 and has already provided crucial bases to support the progress of all IRISes. For instance, analyses of recent climate trends has already allowed for the production of a preliminary draft of the IRIS 2 climate chapter.

Analyses of climate trends and climate scenarios for both IRIS 1 and 2 are still under production and should be completed and delivered to IRIS leaders in late spring 2013. Methods and data sources will be detailed in a dedicated section within each IRIS climate chapter.

The analysis presented in Ouranos report *Climate Analysis and Scenario Development* in support of ArcticNet IRISes (IRIS 1, IRIS 2 and IRIS 3) by Grenier (2013) is a relevant step forward to address knowledge gaps in the domain of Arctic climate modeling. The results of this report provide a starting point to increase our knowledge of climate processes and improve climate models.

This project will allow us to compile a climate observation database covering the Canadian Arctic Region. Through the IRIS reports, this project will ultimately provide researchers, stakeholders, decision-makers and communities with more accurate knowledge of current and anticipated climate changes in order to help in developing adequate adaptation strategies and support sustainable development in this complex and rapidly changing environment.

Acknowledgements and References

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(All ArcticNet refereed publications are available on the ASTIS website (http://www.aina.ucalgary.ca/arcticnet/).

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