PFRECaN

Predicting the Future(s) of Renewable Energy in Canada's North

Principal investigator

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Areas of contribution

User-aspects and verification
Polar atmospheric processes
Modelling and forecasting
Observations
Land processes
Data archiving
Policy-relevant / cultural aspects
Economic aspects
Societal and/or behavioural aspects

Summary

The proposed research has three key objectives: (1) assessment and development of regional climate modelling capacity for the Canadian Arctic, with an emphasis on improving boundary layer process representation in numerical models; (2) assessment of wind and solar energy resources in the Canadian Arctic over the next 20-50 years, with a focus on natural variability and anthropogenically forced change; and (3) an engineering/economic
assessment of the integration of renewables into electricity generation in communities in the Canadian Arctic, taking into account projected changes. This research program involves partnerships and multidisciplinary interactions among Hydro Quebec, the World Wildlife Fund, climate modellers, field-based atmospheric observationalists, and engineers. We have also reached out to the community of Sachs Harbour and the Government of the Northwest Territories.

Description

The recent World Wildlife Fund report “Renewable Energy Deployment in Canadian Arctic” (Das and Cañizares, 2016) found extensive opportunities for the integration of renewables into electricity generation in Canada's North. The present reliance on diesel-powered generators results in a large expense (and vulnerability) for Northern communities as well strong point sources of pollution. Using a 25-year planning horizon, Das and Cañizares (2016) found that both cost savings and pollution reductions (including greenhouse gases) could be realized through the generation of electricity by wind and solar energy. However, these analyses were based on past climate data and assumed a stationary climate into the future. Polar amplification of climate change and the related reductions of Arctic summertime sea-ice extent result in changes of Arctic climate larger and faster than those elsewhere in the world (e.g., Kirtman et al., 2013). Furthermore, even in the absence of anthropogenic change, atmospheric quantities (and associated renewable energy resources) display substantial variability from decade to decade (Deser et al., 2014). We propose a modelling approach to predict opportunities and vulnerabilities of renewable energy generation over the next several decades, using a work plan split into four linked sub-projects.

1. A study of how wind power and solar irradiance in Canada's Arctic will change in the future (due to anthropogenically forced change and natural variability), and to what degree future variations in these two resources might complement each other. An ensemble of simulations using the 5th generation Canadian Regional Climate Model (CRCM5) driven by realizations from the CanESM and CESM large ensembles will be used for this analysis. Having such an ensemble of RCM simulations will allow us to explicitly quantify the magnitudes of forced and internal variability. As well, it will allow a more robust estimate of co-variability between surface irradiance and near-surface winds, and of how variations in one of these renewable energy sources may be compensated (or compounded) by variations in the other.

2. Detailed observations of near-surface atmospheric variability using an instrumented tower in Sachs Harbour. These observations will allow us to understand the relationship of wind and solar power in this area to larger-scale weather variations; to ground-truth our prediction models; and to provide essential information regarding the physical operation of wind turbines in this climate (e.g. mechanical stresses and ice loading). Co-PIs Atkinson and Fochesatto will instrument a 20 m tower with a suite of sensors to measure profiles of temperature, humidity, pressure, and the three-dimensional wind field. These data will allow an assessment of the relationship between the large-scale synoptic setting and boundary-layer profiles of the mean state (wind and temperature) and turbulence (intensity and fluxes).

3. Further developing CRCM5 for high-latitude applications. While CRCM5 provides the best tool we have for predictions of future climates in Canada's North, relatively little work has been done so far in determining how well it simulates near-surface processes in this environment. The representation of stably stratified boundary layers, common in high latitudes, continues to pose a challenge to weather and climate models. Recent advances (both observational and using idealized process models) have demonstrated the existence of distinct regimes of the stably stratified boundary layer in a broad range of environments (including Dome C in Antarctica). We
propose to carry out detailed sensitivity studies of the representation of the boundary layer using CRCM5, the results of which will be used to guide model development. In particular, we will investigate the sensitivity of boundary layer representation to resolution (horizontal and vertical) as well as the representation of the underlying surface. We will also use the recently-included TKE scheme incorporating an explicitly stochastic representation of intermittent turbulence in the stable boundary layer to investigate the importance of intermittent turbulence for driving transitions between regimes. This work will result in a substantial increase in predictive capacity for environmental variability (and in particular wind and solar power) in Canada's Arctic. The data from Project 2 will play a central role in ground-truthing these simulations.

4. An extension of the engineering/economic analysis already undertaken by the WWF for the present climate, considering different energy system model formulations and different renewable energy systems (e.g., airborne gliders), and extending the analysis into the mid-21st century. Because of polar amplification of climate change, accounting for climate changes over the next few decades is an important next step complementing the feasibility studies which have already been done (and which assume a stationary climate). The simulations from Projects 1 and 3 will be combined with energy systems models to investigate how robust the economic assessments of renewable energy systems are to both forced change and natural variability. These analyses will also be informed by the data from project 2, which will allow an assessment of environmental stresses on devices such as turbines. Finally, the energy systems analyses will be extended by considering a broader range of renewable energy systems.

This research program involves partnerships and multidisciplinary interactions among Hydro Quebec, the World Wildlife Fund, climate modellers, field-based atmospheric observationalists, and engineers. We have also reached out to the community of Sachs Harbour and the Government of the Northwest Territories. In order to contribute to the Special Observing Period (SOP) NH1 and NH2, we intend to instrument a tower in Sachs Harbour in summer 2018, with observations continuing at least until mid 2019.

**Timeline**

2017-04-01 - 2020-03-31

**User relevant aspects**

Support for this proposal has come from both the World Wildlife Fund and Hydro-Quebec. To quote its website, the WWF is working with northern communities, governments, and power generation companies with the "goal to deploy low-impact, community-wide habitat friendly renewable energy technologies in at least three northern communities by 2020." We have committed to provide the WWF with a synthesis report at the end of the project to inform its present and ongoing commitment to renewable energy in Canada's north. Similarly, Hydro-Quebec faces the challenge of providing electricity to remote northern communities and industries. In its letter of support for the proposal, Hydro-Quebec states that the information provided by this research "will be much valuable in planning the new generating installations that will eventually provide energy to remote areas".

We have also reached out to the community of Sachs Harbour and the Government of the Northwest Territories for support of this project, and have received positive responses.
The policy relevance of this proposal comes through these connections to governments, NGOs, and power companies that are currently working together to make planning decisions regarding the incorporation of renewables into energy systems in Canada's Arctic.

**Regional emphasis**

Northern hemisphere: Yes  
Southern hemisphere: No

**Key project deliverables**

1. Predictions of future renewable energy resources (wind and solar), including their forced change, natural internal variability, and potential compensation.

2. An instrumented tower in Sachs Harbour providing information about near-surface wind and irradiance conditions, and linking these to boundary layer turbulent processes and synoptic conditions. These data will also be used for addressing engineering issues such as mechanical load on wind turbines; ground-truthing long-term predictive models like CRCM5; and providing data for initializing short-term weather forecast models.

3. Improved prediction capacity by CRCM5 in the Arctic domain, based on new observational constraints; carefully constructed sensitivity analyses targeting the simulation of near-surface wind and solar irradiance; and continued development of fundamental physical understanding.

4. An extension of existing feasibility studies of integration of renewables into the electricity supply of Northern communities, extending the analysis from the recent past into the middle of the 21st century; investigation of the performance of generation systems in Arctic conditions; and investigation of novel wind power systems.

**Data management**

This is yet to be determined, but a Data Management Plan is required of MEOPAR-funded projects.

**Is data provided to WMO Global Telecommunication System**

No