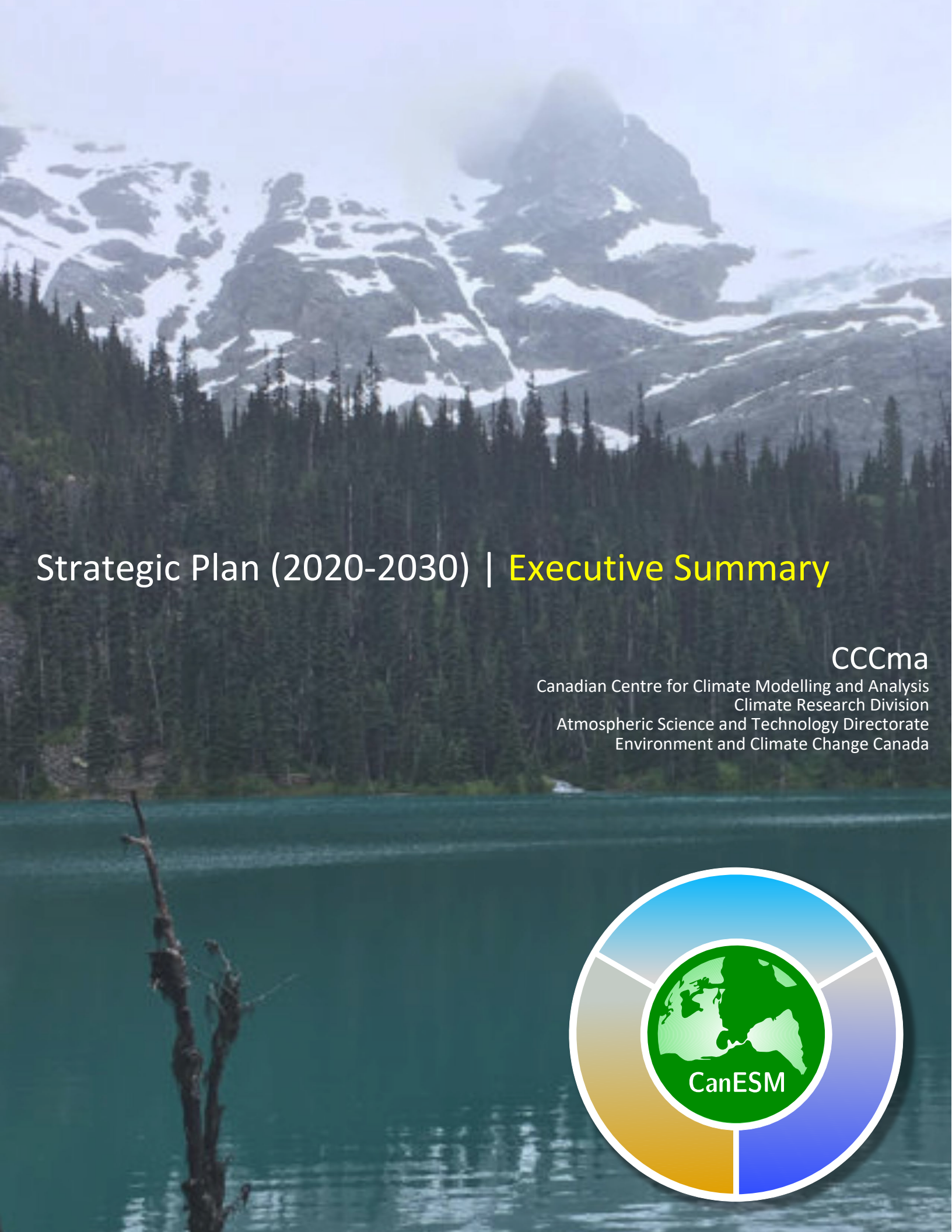


Strategic Plan (2020-2030) | Executive Summary

CCCma

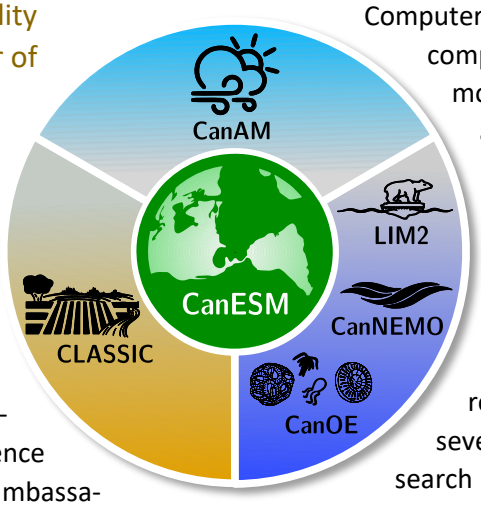
Canadian Centre for Climate Modelling and Analysis
Climate Research Division
Atmospheric Science and Technology Directorate
Environment and Climate Change Canada

Vision To serve as the national focal point for global-, continental- and regional-scale climate change projections, analyses, and scientific information for Canadians.

Mission To provide robust climate predictions on seasonal to decadal timescales and climate projections on centennial timescales over Canada and the globe through the continuous development and innovative application of Canada's suite of global and regional climate (Earth system) models and the expert analysis of their output. The Canadian Centre for Climate Modelling and Analysis (CCCma) is a world-leading centre for the development and application of Earth system models addressing key emerging scientific questions that provide timely, relevant knowledge and information to Canadians and others striving to mitigate and adapt to climate change. Our work responds to the growing need for climate information by those engaged in domestic and global efforts to combat climate change and manage the associated risks. In addition, this research fulfills Canada's international commitments to promote further scientific understanding of climate change and to exchange climate information.

Impact Over the past four decades, CCCma has developed a state-of-the-science, global-scale, climate modelling capability and is the sole Canadian provider of comprehensive Earth system modelling capacity. Our scientific leadership in the field of Earth system modelling means that the Climate Research Division's (CRD's) research scientists are an integral part of the international research community spearheading ongoing developments, influencing international science research strategies, and acting as ambassadors for Canadian climate science. Such deep international connections allow our scientists to integrate scientific and technological advances of the international community into Canada's model development, applications and analysis efforts, thereby improving the quality and robustness of climate information products. The development of such expertise within the Canadian government means that Canadian decision-makers have the highest level of expert scientific advice available to them to support policy and regulatory deliberations, decisions and actions related to climate change.

Capacity The Climate Research Division leads the development and application of a tightly integrated suite of models designed to realistically simulate the Earth system, to make initialized climate predictions and forced climate projections, and to provide high-resolution downscaling of global results to the regional level to support a range of climate impact assessment outcomes. The ongoing development of Canada's modelling system underpins many of the Climate Research Division's key climate research activities. At the heart of the integrated modelling system is the global, fully coupled Canadian Earth System Model (CanESM), and the information technology (IT) infrastructure used to execute the model and process its output on High Performance Computer (HPC) systems. CanESM is comprised of an atmospheric model, CanAM; land surface and terrestrial ecosystem model, CLASSIC; ocean model, CanNEMO; sea-ice model, LIM2; and biogeochemistry ocean ecosystem model, CanOE. The current version of CanESM represents the culmination of several decades of active research involving collaborators within the Climate Research Division, the Atmospheric Science and Technology Directorate,



other government departments (notably Fisheries and Oceans Canada), and the academic community. Built around CanESM is a family of model components that initialize climate predictions for seasonal to decadal forecasts, enable regional downscaling, and support a range of climate process studies.

Challenges

As the consequences of human-induced climate change become increasingly evident, the Earth system modelling community is being called upon to answer more diverse science-policy questions with greater specificity. Meeting this urgent need requires physical processes to be modelled more realistically and in ever-increasing detail. The concomitant increase in model complexity necessitates improved model efficiency and enhanced scientific capacity.

Continued development and maintenance of Canada's Earth system model presents two key scientific challenges for the program. The first is maintaining a state-of-the-science representation of the climate system, which requires continuous development of existing model components and the introduction of representations of new processes that are important to understanding environmental changes relevant to adaptation and mitigation. The second is modernizing the existing model code to take full advantage of new high performance computing systems that will be installed and are essential to running efficient simulations.

Goals

Based on the success of our Earth System modelling program, the expertise it has accrued, our on-going engagement with the larger climate and atmospheric research community, and our role as a convener of Canadian Earth system science, CanESM is well positioned to be the foundation of a comprehensive integrated modelling infrastructure within the Canadian community. With components that are adapted to interface with downstream modelling systems (e.g., biodiversity models, human health risk assessment models, highly resolved hydrological models), CanESM can provide the highest-quality of climate change information so that Canadian decision makers can adequately respond to the diverse and growing information needs of Canadian society.

Opportunity

The need to sustain Canada's state-of-the-science Earth system model underpins many of the information requirements identified by Canadian decision-makers and stakeholders in *Climate Science 2050: Advancing Science and Knowledge on Climate Change* (CS2050). These requirements include the advancement of our understanding of how weather and climate extremes are projected to change in a changing climate; the role of terrestrial and marine carbon cycle processes and feedbacks on the climate system; the potential for carbon sink enhancement; and the sensitivity of carbon stocks to climate warming, particularly in the Arctic. CS2050 also identifies the need for Earth system science to support mitigation including the climate response and co-benefits of reducing emissions of short-lived climate forcers and for developing insight into the climate response and potential unintended consequences of climate engineering. The CS2050 science priorities of developing more skillful climate predictions on near-term time scales and of further developing climate projection downscaling techniques are directly responsive to the information requirements of adaptation programs.

Planning

During the strategic planning process for CRD's Canadian Centre for Climate Modelling and Analysis, seven scientific priorities were identified to ensure that CanESM remains

well positioned to respond to the evolving climate information needs of Canadians. These scientific priorities address the two key scientific challenges for the program and align with the priorities identified by Canadian decision-makers and stakeholders in CS2050. These priorities necessitate that the Government of Canada continues to invest in Canada's core strength of developing and maintaining Canada's state-of-the-science Earth system model and in the application of the model to advance actionable science aligned with CS2050 priorities.

The first priority (1) addresses the two key scientific challenges of the program, namely, the maintenance and development of a state-of-the-science representation of the climate system; and, modernizing the existing model code to take full advantage of new high performance computing systems. The first priority also recognizes that a high-quality global model is the necessary starting point for subsequent downscaling which uses a regional climate model to provide more spatial detail over Canada as needed by users from a range of disciplines. Priorities two (2) to seven (7) address the priority needs of Canadian society for climate change projections as described in CS2050, namely, science to support the achievement of carbon neutrality in Canada, and to build healthy and resilient communities and ecosystems.

Priority Area Action Plan

1 **The Changing Earth System – Past and future:** We will modernize the existing CanESM code, further develop existing model components, and introduce representations of new processes to advance our fundamental understanding of the Earth system and improve simulations of the response of this system to changes in human and natural drivers.

2 **Detailed Regional Climate Information for Canadian Decision Makers:** In order to respond to the increasing demands for higher resolution projections of climate change, we will continue to further develop the Canadian Regional Climate Model (CanRCM) which takes global model output and refines it to include enhanced representation of the terrestrial ecosystem and regional topographical features (such as the Great Lakes and Rocky Mountains). We will also add new regional ocean modelling capabilities to CanESM to provide consistent, high resolution, ocean and sea-ice projections for Canada's three oceans. Our regional Earth system model, based on the coupling of the CanRCM to the Canada's Three Ocean's Downscaling System (CanTODS) will provide seasonal predictions for both atmospheric and ocean variables.

3 **Carbon Cycle Earth System Feedbacks:** We will advance our understanding of the role of biogeochemical feedbacks in the Earth system and will better quantify the sensitivity of the climate system, including Arctic ecosystems, to anthropogenic carbon emissions by improving the representation of terrestrial and marine ecosystem and carbon cycle components in the CanESM framework.

4 **Seasonal to Decadal (S2D) Climate Prediction:** We will improve Canada's seasonal to decadal (S2D) prediction system and expand the number of climate metrics forecasted by this system to allow development of products tailored to specific sectors, and eventually individual users.

5 **Climate Extremes and Extreme Event Attribution:** We will provide timely and credible information on the role of anthropogenic climate change in high impact climate events and on future changes in climate extremes in Canada

to support climate risk management by developing a system suitable for transfer to operations for extreme event attribution.

6 **Role of Short-lived Climate Forcers:** We will provide improved estimates of the climate and air quality co-benefits of mitigation of short-lived climate forcers by improving representation of aerosols and chemistry in CanESM.

7 **Implications of Climate Engineering and Response to Mitigation Options:** We will analyse the potential global, regional and Canadian climate impacts of solar radiation management (SRM) and carbon dioxide removal (CDR) scenarios by simulating and analysing climate impacts of SRM, CDR and other mitigation options.

Requirements

To realize the goals of this plan, the following actions are required:

1) ***Sustained investments in key technical and scientific human resource capacity within the Climate Research Division.*** The nature of these investments has been defined through a human resources challenge function that was part of the process to develop the strategic plan;

2) ***Enhanced external collaborations to further the development and analysis of CanESM as the foundation of a comprehensive integrated modelling system, with components that are designed to support downstream modelling systems (e.g., climate impact models).*** This will be achieved by first developing the model in a manner that lowers the technical barriers to using the model for partner organizations and the academic community; followed by developing a clear governance framework to support an expansion in the scope of collaboration ; and

3) ***The establishment of a standard modelling framework and shared coding standards to support effective collaborations with partner organizations.***

Summary

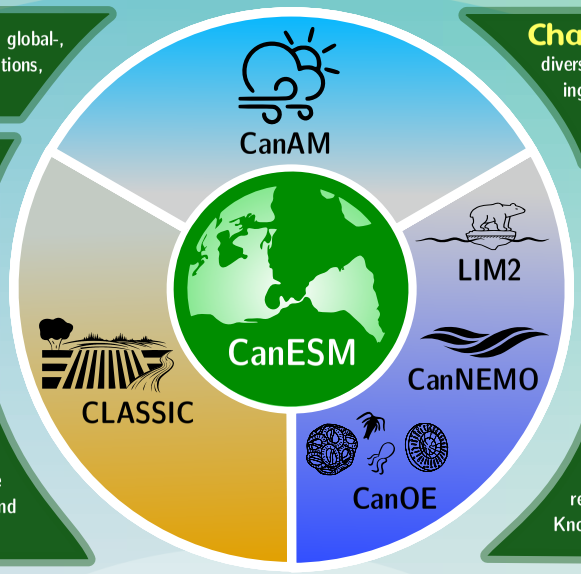
As a northern nation, Canada has experienced a rate of environmental change more pronounced than that of many nations, which has had significant and wide-ranging impacts on almost every facet of our society, economy and infra-structure. We know that this will continue into the future. This summary highlights the scientific priorities for Canada's Earth system modelling research program. Research and development focused on these priorities are required to deliver timely, relevant knowledge and information to Canadians and others striving to mitigate and adapt to climate change over the next decade. These priorities, and the accompanying implementation plan, build on CRD's strong scientific leadership and foundational capacity in this scientific domain and leverage the scientific computing and monitoring technology advances of the past decade to enable Environment and Climate Change Canada to maximize its contribution to informing responses to Canada's current adaptation and mitigation challenges.

CCCma Strategic Plan (2020-2030) | Overview

Vision To serve as the national focal point for global-, continental-, and regional-scale climate change projections, analyses, and scientific information for Canadians

Mission To provide robust climate predictions and projections over Canada and the globe through the continuous development and innovative application of Canada's suite of Earth System models and scientific analysis of their output

Capacity CRD leads the development and application of a tightly integrated suite of Earth System models. At the heart of this system is the global, fully-coupled Canadian Earth System Model, CanESM, which is comprised of models for the atmosphere, CanAM; ocean, CanNEMO; land surface and terrestrial ecosystem, CLASSIC; sea ice, LIM2; and ocean biogeochemistry ecosystem, CanOE



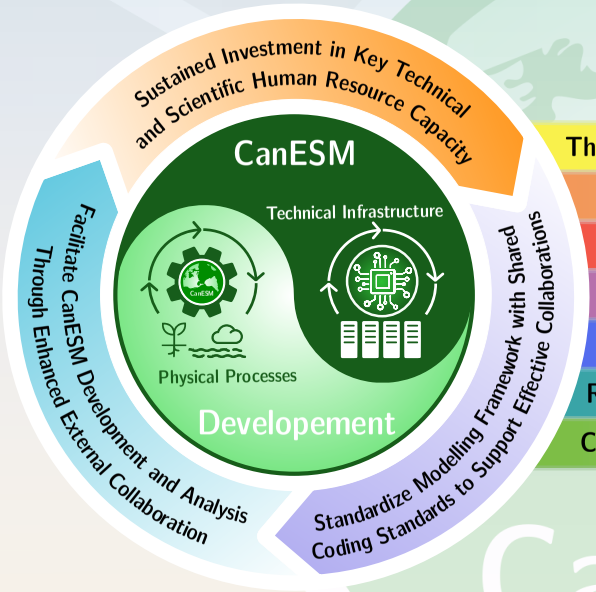
Challenges There is an urgent need to answer more diverse science-policy questions with greater specificity requiring physical processes to be modelled more realistically and in ever increasing detail. This has necessitated improved model efficiency and enhanced scientific capacity

Goals To be the foundation of a comprehensive, integrated, modelling infrastructure within the Canadian community, interfacing with downstream modelling systems and providing relevant climate change information to Canadian decision makers

Opportunity The need to sustain Canada's state-of-the-science Earth system model underpins many of the information requirements identified by Canadian decision makers and stakeholders in the GOC report, Climate Science 2050: Advancing Science and Knowledge on Climate Change

History/Impact Over the past four decades, CCCma has developed a state-of-the-science, global-scale, climate modelling capability and is the sole Canadian provider of comprehensive Earth system modelling capacity. Our scientific leadership in the field of Earth system modelling means that CRD's research scientists are an integral part of the international research community's efforts to understand and project climate change by spearheading ongoing developments, influencing international science research strategies, and acting as ambassadors for Canadian climate science. Such deep international connections allow our scientists to integrate scientific and technological advances of the international community into Canada's model development, applications and analysis efforts, thereby improving the quality and robustness of climate information products. The development of such expertise within the Canadian government means that Canadian decision-makers have the highest level of expert scientific advice available to them to support policy and regulatory deliberations related to climate change

Investment



Priority Areas

- The Earth System - Past and Future
- Regional Climate Information
- Carbon Cycle Feedbacks
- Seasonal to Decadal Prediction
- Extreme Event Attribution
- Role of Short-lived Climate Forcers
- Climate Engineering and Mitigation

Action Plan

Modernize the existing CanESM codebase; further develop existing model components; introduce representations of new processes to advance our understanding of the Earth system and improve the response of the system to human drivers

Further develop the Canadian Regional Climate Model to meet the increasing demand for higher-resolution projections of climate change; add new regional ocean modelling capacity to CanESM to provide high-resolution, sea-ice projections for Canada's three oceans

Improve the representation of terrestrial and marine ecosystem, and carbon cycle components in CanESM to advance our understanding of the role of biogeochemical feedbacks and to better quantify the sensitivity of the climate system to anthropogenic carbon emissions

Improve Canada's seasonal to decadal prediction system and expand the number of climate metrics forecasted to allow the development of products tailored to specific sectors and eventually individual users

Provide timely and credible information on the role of anthropogenic climate change in high-impact climate events and on future changes in climate extremes in Canada to support climate risk management; ultimately develop an operational system for extreme event attribution

Provide improved estimates of the climate and air quality co-benefits of mitigation of short-lived climate forcers by improving representation of aerosols and chemistry in CanESM

Use CanESM to perform geoengineering experiments employing solar radiation management, carbon dioxide removal scenarios and other mitigation strategies to evaluate the potential global, continental and Canadian climate impacts

CanESM