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PROGRESS REPORT OF THE PARTIES
CLIMATE CHANGE IMPACTS ANNEX CHAPTER

OVERVIEW

Climate change is an exacerbating stressor, which challenges the health of our Great Lakes ecosystems and the communities they support. Hundreds of scientists and experts from the Great Lakes community within Canada and the United States monitor the Great Lakes and over 125 of these experts are engaged in using their data to report on the state of the Great Lakes using science-based indicators, including indicators to track the impacts of climate change. These data programs and indicators perform trend analysis and change detection assessments for air temperature, water levels, and ice duration. Current climate change concerns relate to greater fluctuations and possibly lower water levels across the Great Lakes region, rising lake temperatures and associated impacts on existing aquatic species and historic land covers (i.e., wetland loss) as well as possible introductions of non-native species (SOLEC, 2011).

Recognizing that climate change has an impact on the quality of Waters of the Great Lakes, Canada and the United States incorporated a new annex in the 2012 GLWQA to address this issue, through which both governments commit to coordinate efforts to identify, quantify, understand, and predict the climate change impacts on the water quality of the Great Lakes and to share information broadly with Great Lakes resource managers to proactively address those impacts.

ACTIONS TAKEN TO MEET KEY COMMITMENTS

The United States and Canada have established the following Priorities for Science and Action, which helped focus the governments' efforts on key commitments from the Climate Change Impacts Annex that needed to be undertaken in the first three years (Table x).

Table x – Binational Priorities for Science and Action and Key Commitments

		KEY COMMITMENTS
NATIONAL PRIORITIES FOR SCIENCE	• Compile existing knowledge on Great Lakes climate change. • After compiling Great Lakes climate change knowledge, assess and identify critical information needs and develop strategies to address those gaps.	• Develop and Improve Regional Scale Climate Models to Predict Climate Change in the Great Lakes Basin at appropriate temporal and spatial scales. • Link the projected climate change outputs from the regional models to chemical, physical, biological models that are specific to the Great Lakes to better understand and predict the climate change impacts on the quality of the Waters of the Great Lakes. • Enhance monitoring of relevant climate and Great Lakes variables to validate model predictions and to
BINATIONAL PRIORI	• Address the needs of other GLWQA annexes for improved climate change science (e.g., understanding positive and negative impacts predicted under climate scenarios, monitoring of climate variables, improving tools for the analysis of climate change). • Communicate and share climate change information with key user groups throughout the Great Lakes basin. • Refine existing "Great Lakes Climate Summaries and Outlooks" factsheets with	

BINATIONAL PRIORITIES FOR ACTION	• Address the needs of other GLWQA annexes for improved climate change science (e.g., understanding positive and negative impacts predicted under climate scenarios, monitoring of climate variables, improving tools for the analysis of climate change). • Communicate and share climate change information with key user groups throughout the Great Lakes basin. • Refine existing "Great Lakes Climate Summaries and Outlooks" factsheets with enhanced binational collaboration to produce and deliver climate information on a regular basis.	understand current climate change impacts. • Develop and improve analytical tools to understand and predict the impacts and risks to, the vulnerabilities of, the quality of the Waters of the Great Lakes from anticipated climate change impacts. • Coordinate binational climate change science activities (including monitoring modeling and analysis) to quantify, understand, and share information that Great Lakes resource managers need to address climate change impacts on the quality of Waters of the Great Lakes and to achieve the objectives of this Agreement.

Binational Actions Taken

Information Sharing (Commitment A9/C5)

Significant progress has been made towards compiling knowledge on climate change impacts, documenting critical information gaps, and sharing information across the Great Lakes region. Actions taken include, but aren't limited to, the following examples:

In June 2013, Canada and the United States initiated the development of the first binational quarterly newsletter focusing on climate impacts and outlooks for the Great Lakes region. The "Great Lakes Quarterly Climate Summary" provides a quick and easy to understand binational overview of the latest season's weather and water level conditions, weather and water level-related impacts and an outlook for the upcoming quarter. These Quarterly Outlooks are produced by U.S. and Canadian experts for use by managers and practitioners at federal, state, provincial, regional, and local scales as well as stakeholders and the general public. Electronic copies of these Quarterly Outlooks are archived and posted at http://binational.net/annexes/a9/.

In May 2014, information on climate change in the Great Lakes, based on the best available peer-reviewed science, was conveyed to members of all the Annex Subcommittees through a webinar. The purpose of this webinar was to enhance broad understanding of climate information needs among the members of the Annex Subcommittees, who are responsible for considering climate change impacts, where applicable, in implementing actions related to the other issue annexes under the 2012 GLWQA. These webinar discussions were also an opportunity to initiate dialogue among the members of all of the Annex Subcommittees to determine the type of climate change information they would require and

assist to focusing the work under the Climate Change Impacts Annex to provide more tailored climate change information. In August 2014, a similar presentation was delivered to the Habitat and Species Annex Subcommittee upon their request. The Council for Great Lakes Industries also requested a briefing from the Annex 9 co-chairs to discuss the climate change information shared under the GLWQA.

In 2015, Canada supported the development of a binational report documenting current climate change science and knowledge gaps across the Great Lakes basin. The 2015 State of Climate Change Science in the Great Lakes Basin report will inform the Annex 9 Subcommittee and support some of the commitments under Annex 9. The report was released in [December 2015] with a companion database that includes summaries of over 250 recent climate change studies. A binational Executive Summary of this report will be developed for posting on binational.net. In addition, a series of individual Annex-focussed webinars will be developed and hosted in the next cycle. It is anticipated that these webinars will lead to more fulsome discussions with the other Annexes on their understanding of climate change impacts and what their climate change information needs are. These discussions, along with a thorough review of the knowledge gaps identified in this report will also help the Annex 9 Subcommittee identify science and action priorities for the next cycle. .

A growing ensemble of in situ measurements – including offshore eddy flux towers, buoy-based sensors, and vessel-based platforms – are being deployed through an ongoing binational collaboration to reduce uncertainties in the Great Lakes water balance, provide a more robust basis for short- and long-term projections, and fill a significant gap in over-lake flux measurements, including evaporation and water temperatures, and related meteorological data. This initiative, known as the Great Lakes Evaporation Network (GLEN) is supported through a consortium of researchers from EC and NOAA, the University of Michigan, Northern Michigan University, the University of Colorado, Limno-Tech and the Great Lakes Observing System (GLOS).

In addition to binational actions taken jointly by Canada and the United States, numerous domestic actions in support of the key commitments of the Climate Change Impacts Annex were also undertaken. Table x and Table x briefly outline some examples of these domestic actions.

Table x – Domestic Canadian Actions Taken		
Climate and Ecosystem Models	Canada continues to support the development of Regional Climate Change models for the Great Lakes – St. Lawrence River system. A coordinated evaluation of the impacts of climate change on the levels and flows of the St. Lawrence River from 1961-2100 is being undertaken through a collaborative of agencies including Fisheries and Oceans Canada, Hydro-Quebec, Centre of Water Expertise of Quebec, OURANOS and Environment Canada. Climate change will modify the flow of water into the St. Lawrence River (from Lake Ontario, the Ottawa River, and tributaries) and the level of the Great Lakes. These two factors will lead to changes in both the average and extreme levels in the St. Lawrence River. The anticipated impacts include erosion or deposition along the river banks, navigation impacts, and impacts to drinking water intakes. A major focus of this project is improving the analyses of the routing of Ottawa River flows so that Great Lakes and St. Lawrence River models can be linked.	Commitment A9/C1 and C2

Climate Monitoring	EC collects data from a network of approximately 1300 surface weather and climate observing sites across the country. These sites include weather stations owned by Environment Canada, NAV CANADA, National Defence, along with volunteer climate stations. The majority of these sites are automated observing platforms which report year round, 7 days a week, 24 hours a day. The Water Survey of Canada (WSC) is the national authority responsible for the collection, interpretation and dissemination of standardized water resource data and information in Canada. In partnership with the Province of Ontario WSC operates approximately 440 active hydrometric gauges in the Canadian portion of the Great Lakes-St. Lawrence River Basin. The Science and Technology Branch of EC supports the operation of three evaporation stations at Stannard Rock on Lake Superior, Long Point on Lake Erie and Simcoe Island on Lake Ontario as part of the Great Lakes Evaporation Network.	Commitment A9/C3
Analytical Tools	The Canadian Precipitation Analysis (CaPA) is an operational near real-time gridded precipitation product from EC available since April 2011 for North America. CaPA has generated a lot of enthusiasm in the Great Lakes-St. Lawrence River area due to its unique capability of capturing some of the precipitation features that are specific to the Great Lakes-St. Lawrence River region, in particular the effects that the lakes have on the precipitation patterns, something that is very difficult to catch with the existing precipitation gauging network. A project was initiated in 2015 to provide the foundation for extending CaPA back to 1983.	Commitment A9/C4
	Multiple methods and estimates of Great Lakes runoff are now available from various federal agencies in the U.S. and Canada and a comprehensive evaluation and coordination of runoff estimates is necessary. The Great Lakes Runoff Inter-comparison Project (GRIP) was initiated as a binational collaboration that aims assess a variety of models currently used (or that could readily be adapted) to simulate basin-scale runoff to the Great Lakes. The Great Lakes Runoff Inter-comparison Project for Lake Ontario (GRIP-O) was initiated by EC in fall 2013. The project compared different hydrologic models in their ability to estimate Lake Ontario's direct incoming runoff. The results highlight the different models' weaknesses and strengths, in order to assess which model to use as a function of the targeted application and experiment settings, with the more general goal to improve Lake Ontario's runoff simulation by identifying and fixing some of the model weaknesses.	Commitment A9/C3

Table x – Domestic U.S. Actions Taken		
Climate and Ecosystem Models	The National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Lab (GLERL) brought together several different modeling and observational approaches to study climate	Commitment A9/C1 and C2

	change in the Great Lakes basin. The modeling activity consisted of further development and application, specifically for our lake-dominated region, of three coupled atmosphere-lake-land regional climate models: the Coupled Hydrosphere-Atmosphere Research Model (CHARM, based on the Regional Atmospheric Modeling System, RAMS) at NOAA/Great Lakes Environmental Research Laboratory, the Regional Climate Model version 4 (RegCM4) at the University of Wisconsin, and the Weather Research and Forecasting Model (WRF) at the University of Maryland; along with development and testing of a version of the Finite Volume Coastal Ocean Model (FVCOM) with enhancements for simulation of ice (FVCOM-Ice) and lower trophic level ecology in the form of a nutrient-phytoplankton-zooplankton-detritus (NPZD) model component.	
Climate Monitoring	In 2013, the Lake Superior National Estuarine Research Reserve established a new Sentinel Site located in Pokegama Bay, Lake Superior. With funding support from NOAA, this Sentinel Site included weather/meteorological station, water quality sonde, surface elevation tables, permanent vegetation transects, geodetic vertical referencing benchmarks, and an acoustic doppler current profiler installation. This site is now recording monthly water quality sampling for nutrients and chlorophyll. The primary goal is to understand sediment movement and the consequence of sediment movement to marsh sustainably under the expectation of the increased frequency and intensity of storm events.	Commitment A9/C3
	NOAA-GLERL has been exploring the relationships between ice cover, lake thermal structure, and regional climate for over 30 years through development, maintenance, and analysis of historical model simulations and observations of ice cover, surface water temperature, and other variables. Weekly ice cover imaging products produced by the Canadian Ice Service started in 1973. Beginning in 1989, the U.S. National Ice Center produced Great Lakes ice cover charts that combined both Canadian and U.S. agency satellite imagery. These products are downloaded at GLERL by our Coastwatch program, a nationwide NOAA program within which the GLERL functions as the Great Lakes regional node.	
	Currently, there is year-round monitoring infrastructure dedicated to understanding off-shore processes that impact Great Lakes ecosystem health. Beginning in FY15, NOAA GLERL (with funding support from the NOAA Coastal Storms Program) is seeking to fill these data gaps through a two-phased approach. First, the team will deploy and manage data from vessel- and buoy-based sensors to improve understanding of over-water meteorology, evaporation, and water temperature in the Great Lakes. Second, the project will also focus on data analysis, system validation, and model assimilation to improve access to and understanding of the acquired data.	
Analytical	NOAA's Office for Coastal Management developed and released the Lake Level Viewer for the U.S. portion of the Great Lakes basin in 2014.	Commitment A9/C4

Tools	This tool helps users visualize lake level changes that range from six feet above to six feet below historical long-term average water levels in the Great Lakes, along with potential shoreline and coastal impacts. Communities can use this information to determine what preparations make the most sense in planning for water level change scenarios. Preparations might include zoning restrictions, infrastructure improvements, and habitat conservation. As a result of this work and product delivery, Digital Elevation Models are now available for each Lake Basin and the associated topographic and bathymetic data are being served on NOAA's Digital Coast.	
	NOAA GLERL developed and released a basin wide Water Level Dashboard in 2014. The Dashboard is a dynamic graphical interface for visualizing projected, measured, and reconstructed surface water elevations on the earth's largest lakes. This interface also reflects relationships between hydrology, climate, and water level fluctuations in the Great Lakes.	
Sharing Information	NOAA's National Center for Environmental Information produces an annual "State of the Climate" report. This report provides a collection of monthly summaries recapping climate-related occurrences on both a global and national scale.	Commitment A9/C5

Environmental Progress

The next State of the Great Lakes update will be in 2017, at which time we will likely have more climate change impacts information to share. The current State of the Great Lakes report from 2011 reviewed the trends for air temperature, water levels, and ice duration. The State of the Great Lakes 2011 indicator reports showed that annual average air temperatures were increasing in the Great Lakes region (with greater average increases being seen in overnight temperatures), and increasing surface water temperatures for the upper Great Lakes amongst other trends.

References

El Nino Impacts and Outlook - October/November 2015

State of Climate Change Science in the Great Lakes Basin report, 2015.

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Quarterly Outlook, Fall 2014.

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