

Measuring and Modelling Evaporation from Crean Lake, PANP: Interim report, 2005 field season

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Introduction

A research permit has been granted to the researchers at the National Water Research Institute of Environment Canada for the purpose of conducting a study of evaporation from Crean Lake within the Prince Albert National Park.

The objective of this project is to develop and demonstrate a technique to estimate lake evaporation at regional scales and in remote areas; the technique involves a combination of boundary layer modeling and remote sensing of lake surface conditions.

Evaporation from open water bodies is an important component of the hydrologic cycle for many watersheds. This is particularly true for boreal and northern regions. In the Western Canadian Boreal region open water can represent from 10% to 15% of the surface area. They appear in sizes ranging from small ponds to “great lakes”. Many of these Boreal lakes act as storage features in complex drainage basins; they can in fact become disconnected and isolated during extended periods of drought (as was the case in the previous two years). The correct representation of the hydrological function of these water bodies is important to the correct hydrological modeling of these systems. As well, the effect of these water bodies on the regional climate needs to be correctly incorporated into the atmospheric and climate models. A reliable approach to the calculation of lake evaporation is necessary to both objectives.

Yet evaporation from open water remains a difficult process to measure or estimate. The major source of difficulty is the fact that the required meteorological parameters are rarely measured over the water surfaces, and the thermal lag between the water and land surfaces renders the land-based measurements ineffective in the parameterization of open water evaporation. The use of remotely-sensed data provides a means of obtaining useful information about the evaporating water surface; however, an appropriate formulation of the transfer processes occurring in the advective boundary layer are required.

Granger (2000) showed that lake evaporation is largely uncoupled from (or unsynchronized with) the land surface evapotranspiration. The land surface processes follow closely the pattern of energy supply, the partitioning of the net radiation is straightforward; the soil heat flux tends to be relatively small for most situations and the turbulent fluxes of sensible and latent heat, for the most part, behave in a similar manner.

The partitioning of energy at a lake surface, on the other hand, is more complex. Because of radiation penetration, heat storage effects can be significant. The turbulent fluxes of sensible and latent heat are not necessarily in phase with the energy supply, but are governed by the gradients of temperature and humidity in the boundary layer. These gradients are controlled both by water surface temperatures (affected by radiation and intermittent mixing of the water) and by the processes occurring at the upwind land surface (heating of the air and evapotranspiration). For these reasons, land surface data alone are insufficient to parameterize the lake evaporation. Information about the lake surface is also required. A combined approach of using remotely-sensed data along with an appropriate model of the advective boundary layer above the lake represents a more promising approach to estimating lake evaporation.

Granger (2000), using lake evaporation observations made over Big Quill Lake, in Saskatchewan, showed that the analytical solutions to the advection problem developed by Weisman and Brutsaert (1973) can be applied when the boundary layer over the lake is unstable (temperature decreasing with height). For stable conditions, however, these did not work well; and an analysis of the advection under stable boundary layer conditions, such as those encountered over a lake during daytime heating, is required.

To further the development of advection theory in general, Granger (2002) developed a boundary layer integration approach for the calculation of the sensible heat transfer to a patchy snow cover. This analysis included both stable and unstable situations for the very small-scale advection involved in snow melt. The study pointed to the need to better define the rate of growth of the internal boundary layer in advective situations. The boundary layer integration approach was used in the HEATMEX study of Quill Lake, and would also be incorporated into a field study of lake evaporation.

Bussi eres and Granger (2001) showed that at a larger scale, lake temperatures obtained from satellite can be combined with fluctuations in station temperature to obtain signature time series of lake water temperature. These can be used in the description of the sub-grid variability within regional and global climate model grid-cells. These lake signatures can also be used in conjunction with remote sensing to provide estimates of lake evaporation at a larger scale, that is, from a large number of water bodies for which little information is available.

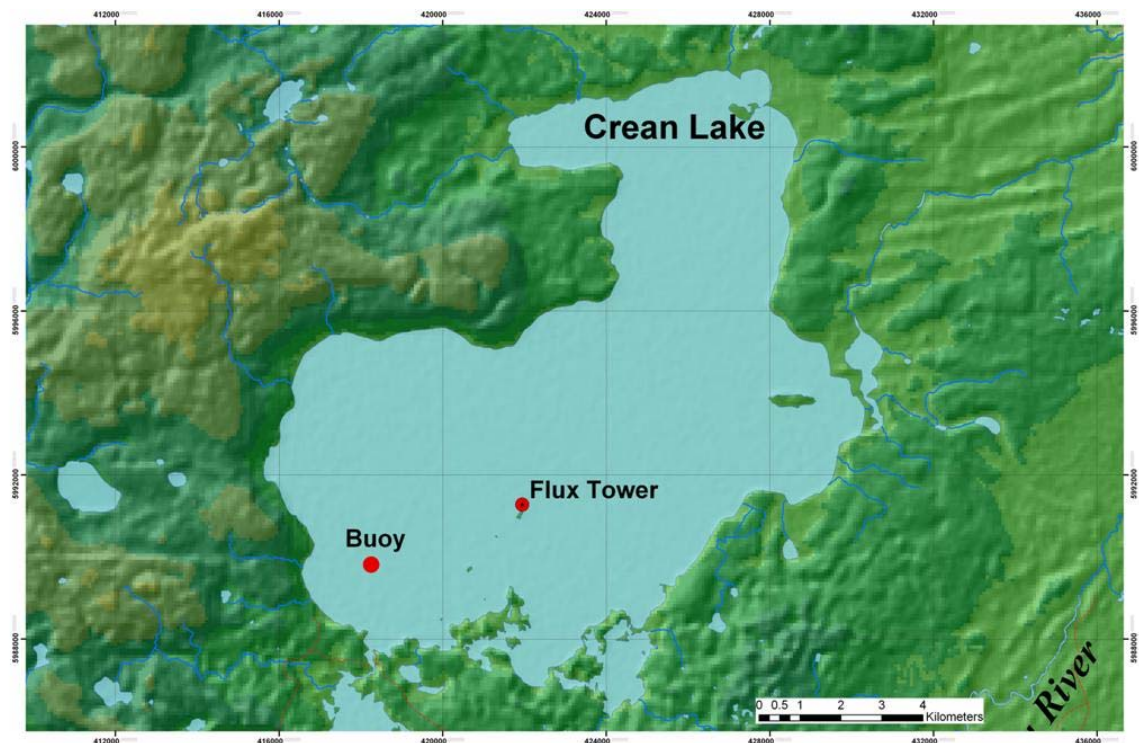
The need for improved estimates of lake evaporation and the logistic difficulties associated with direct measure of these processes in remote areas is widely recognized. The application of remote sensing data to this issue will greatly improve our understanding of the hydrology in Canadian watersheds, will make an contribution to the development of regional climate models (RCMs) and will better enable us to predict the impacts of climate change on Canadian land-surfaces.

Field campaign 2005

For the initial field season, 2005, the following equipment was deployed on Crean Lake:

- 1) An instrumented buoy was set out over the deepest portion of the west bay of Crean Lake (see Fig.1); instrumentation included air temperature and humidity, 3m above the surface, infrared surface temperature, and a chain of 10 precision thermistors for the water temperature profile to a depth of 28m. Data collection began on July 27 and continued to September 19 (on which date the buoy overturned, rendering the data collection system inoperative).
- 2) An instrumented micrometeorological tower was set up at the north end of the northernmost island in Crean Lake; instrumentation included a direct measurement of evaporation, short-wave and net all-wave radiation, 2 levels of air temperature, humidity and wind speed, wind direction, infrared water surface temperature. Data collection began on August 3 and continued to October 27.
- 3) A water level recorder was set out next to the staff gauge near the dock at the Warden Cabin. This recorder remains in operation.

Figure 1. *Crean Lake showing the measurement sites during the 2005 field season.*



b) Evaporation

Data from the meteorological tower at the north island allowed for two independent determinations of lake evaporation; a direct measurement using eddy covariance equipment, and a calculation from the profiles of temperature, humidity and wind speed. Figure 3 shows the cumulative evaporation from these two methods for the observation period; the figure also shows the net all-wave radiation, expressed as an equivalent evaporation. The two methods are in excellent agreement. For the period August to October, Crean Lake lost approximately 220mm to evaporation. Even when the radiant energy supply diminished in the Fall, the rate of evaporation from the water surface remained relatively constant at approximately 2.7mm/d.

Figure 3. *Crean Lake evaporation, summer 2005.*

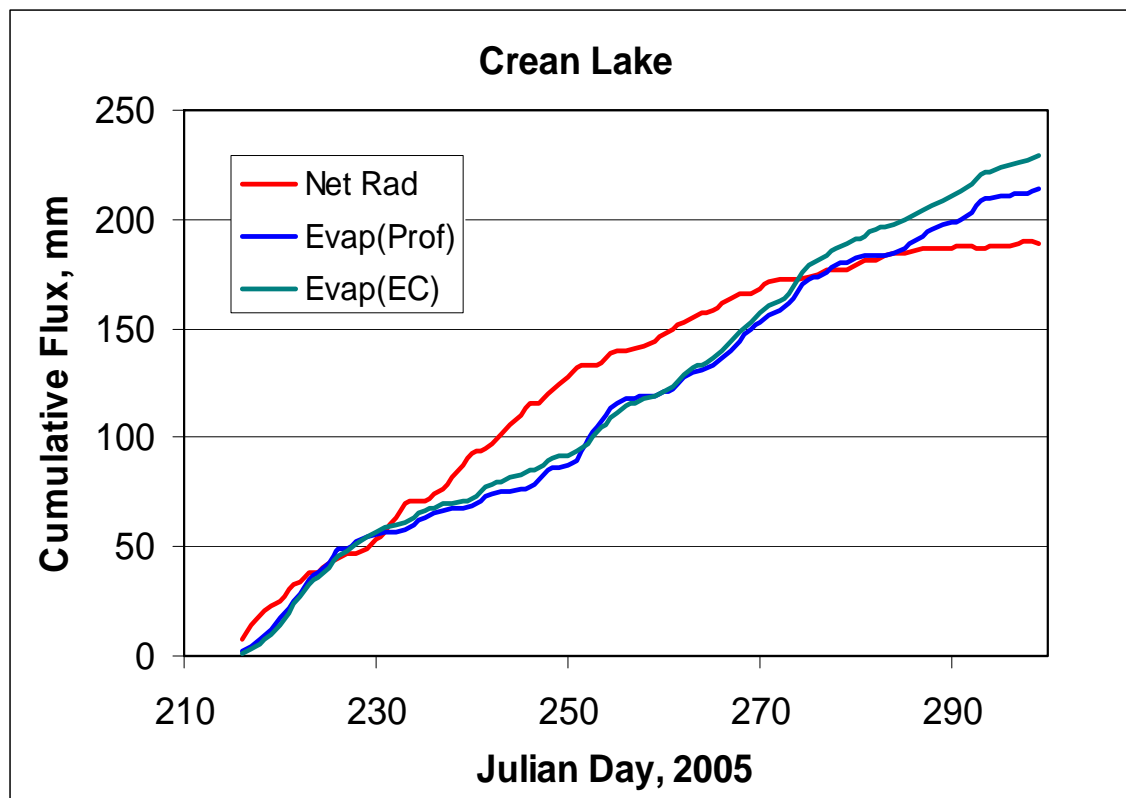
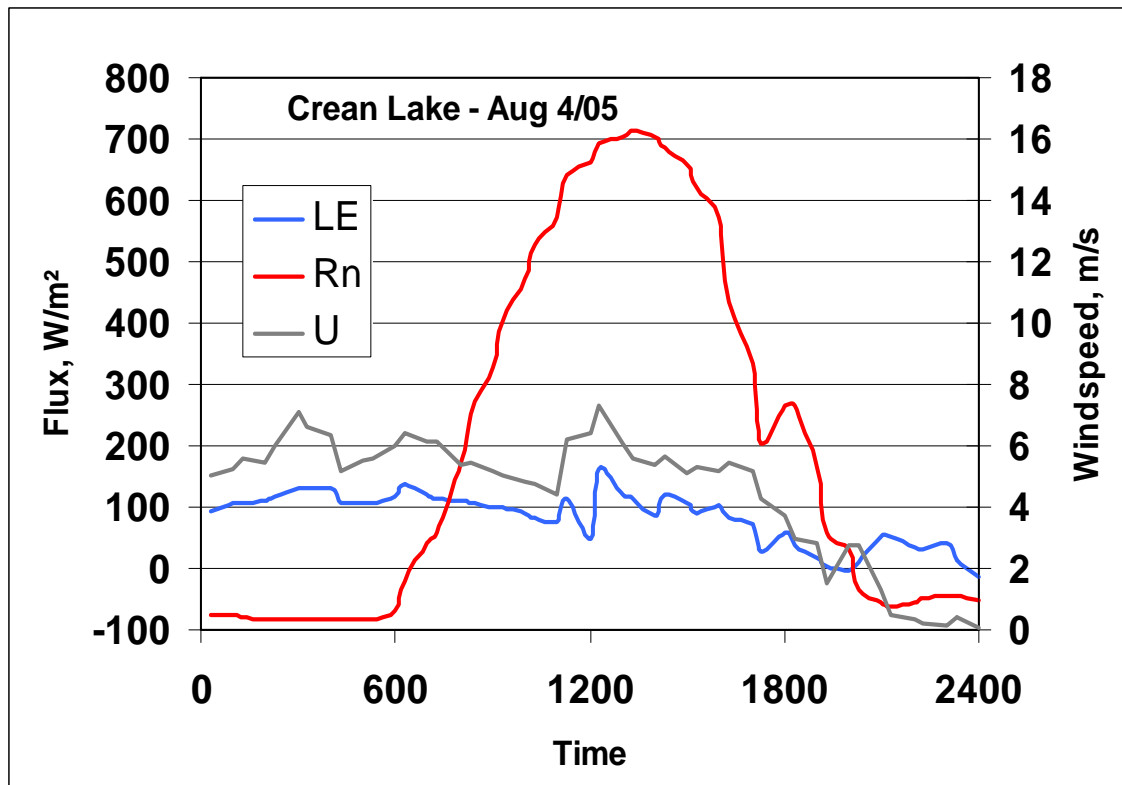


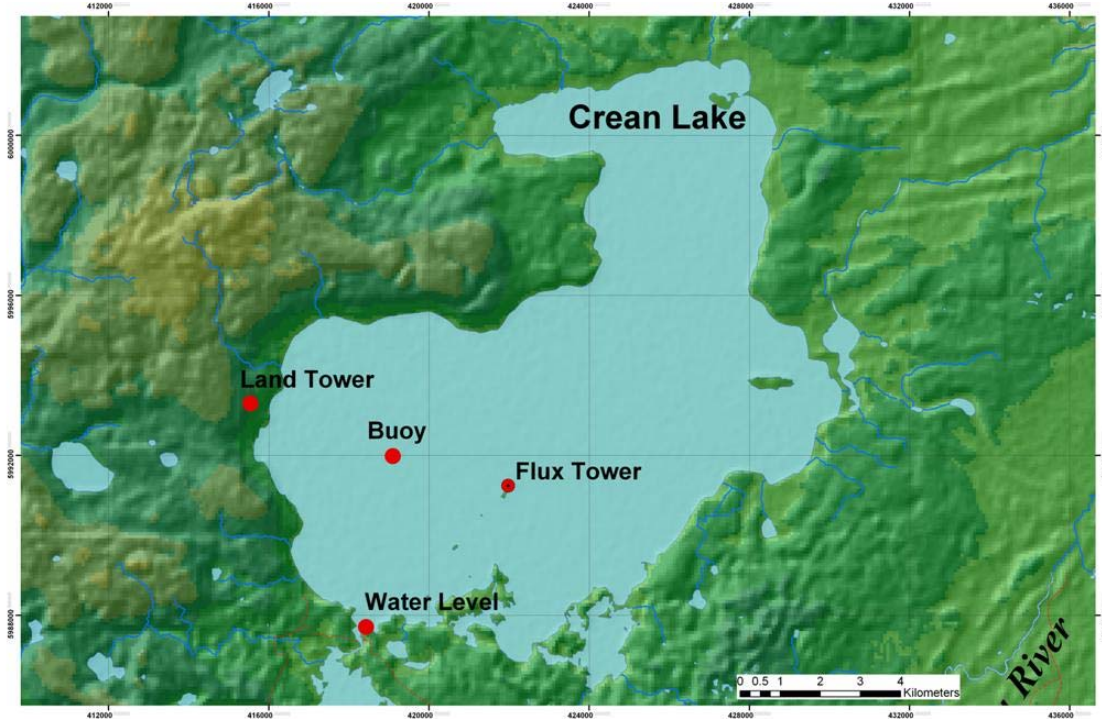
Figure 4 shows the variation of evaporation (expressed as a latent heat flux) during a typical day with bright sunshine. The figure shows that, unlike for land surfaces where the evaporation trace is synchronous with the net radiation, for an open water surface there is no apparent relationship between the supply of energy and the hourly evaporation rate. On the other hand, the evaporation rate follows the fluctuations in wind speed, U . This demonstrates rather convincingly that conventional evaporation models (which are for the most part extrapolations of terrestrial models based on the energy supply) do not work. It also demonstrates the need for an approach for which the air flow over the lake is considered.

Figure 4. Crean Lake diurnal trace of evaporation, August 4 2005.



The 2005 field campaign did serve to show that the approach used for monitoring the evaporation over the lake is reliable. However, the complete analysis of the advective boundary layer over the lake, and the subsequent model development, requires that the upwind land surface boundary layer be measured as well as that over the lake. In 2005, the required “upwind” information was available. It is therefore proposed that a small tower be set up on the west edge of Crean Lake for the 2006 field campaign. The tower will provide the land surface evaporation and the required upwind temperature and humidity required for the analysis. Figure 5 shows the proposed locations of the instrumentation for the next field season. The island instrumentation will remain; the buoy will be relocated to the approximate centre of the west bay, and the land-based tower will be set up near the Portage camp site.

Figure 5. *Crean Lake* showing the proposed measurement sites for the 2006 field season.



Acknowledgments:

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References:

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Appendix A – Photographs of instrumentation at Crean Lake

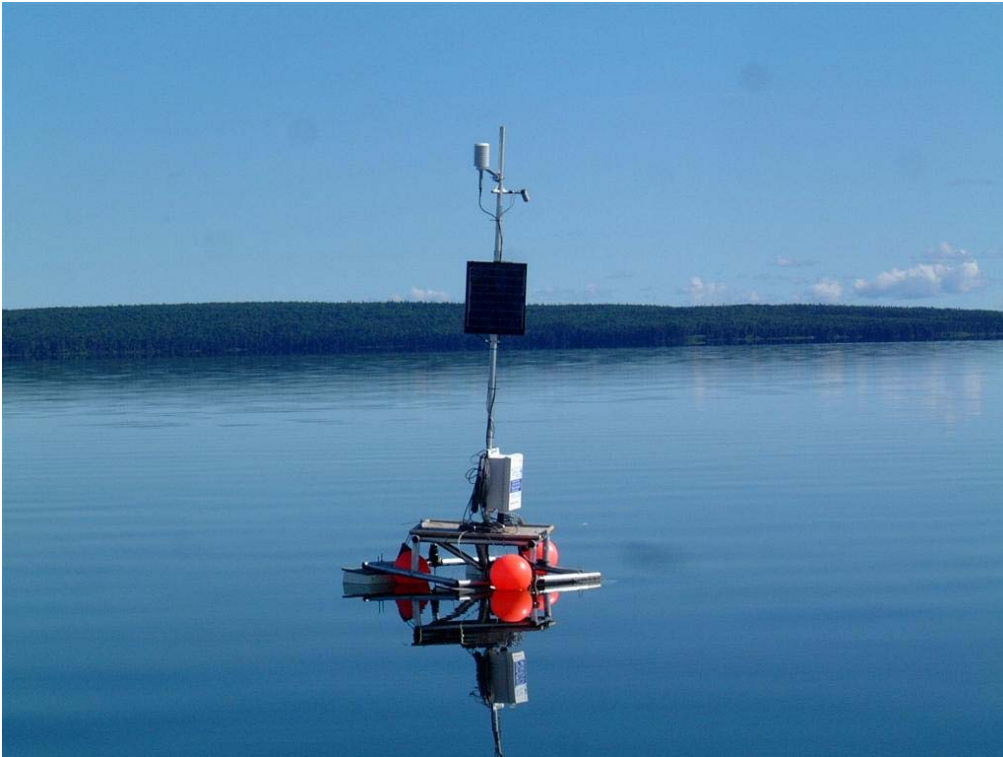


Photo A1. Instrument buoy on Crean Lake, 2005.



Photo A2. Flux tower at north island on Crean Lake, 2005.