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Graphical Representation of Primary Outputs from Energy Balance Computations Conducted on Lake Ontario (1953-1997)

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Graphical Representation of Primary Outputs from Energy Balance Computations Conducted on Lake Ontario (1953-1997)

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Abstract

As a contribution to the Canada Climate Program, a major research effort was undertaken to examine the long-term heat balance for the lower Great Lakes (Sawchuk and Schertzer, 1988). A new model for evaluating the radiation and surface energy balance components for Lake Ontario and Lake Erie was developed. Improvements included the evaluation of solar radiation from a true radiative transfer model that treats multiple scattering effects explicitly and the evaluation of incoming longwave radiation that incorporated effects of aerosols and clouds. The model derived lake evaporation from a mass transfer formulation that includes dependency on wind speed and atmospheric stability. Accurate evaluation of the lake evaporation component is particularly important since it is a major term in the lake hydrology and longer-term variability in lake levels. A major difficulty in all energy budget studies of lakes over historical periods is the lack of water surface temperatures which is an important variable in evaluation of many of the radiative fluxes and turbulent exchanges at the air-water interface. In this model, a method for estimating surface temperature based on a hysteresis with lake heat content was applied. The relationship represents a strong negative feedback mechanism and provides a constraint that prevents numerical instabilities from amplifying (see Sawchuk and Schertzer, 1988). The model was applied to estimate daily surface radiation and energy balance components for Lake Erie and Lake Ontario over the period 1953 – 1997. This report provides graphical representations of the primary radiative and turbulent exchanges and selected meteorological/limnological components at the daily time scale (1953-1997) for Lake Ontario. The graphical output is particularly relevant for current and future comparisons of the magnitude, variability and interannual variability of key computed variables derived in a consistent method over the 45 year period. In particular, the graphical output documents the limitations in deriving the energy balance of large deep lakes without directly observed water temperatures.

Résumé

En tant que contribution au Programme sur le climat du Canada, un important effort de recherche a été entrepris pour examiner le bilan thermique à long terme des Grands Lacs inférieurs (Sawchuk et Schertzer, 1988). Un nouveau modèle a été créé pour évaluer les éléments du bilan radiatif et du bilan énergétique de surface des lacs Ontario et Érié. Les améliorations comprennent l'évaluation du rayonnement solaire à partir d'un modèle de transfert radiatif vrai qui traite explicitement les effets de diffusion multiple et l'évaluation du rayonnement incident de grandes longueurs d'onde qui a intégré les effets des aérosols et des nuages. Le modèle a calculé l'évaporation des lacs à partir d'une formule de transfert de masse qui inclut la dépendance de la vitesse du vent et de la stabilité atmosphérique. L'évaluation exacte de la composante d'évaporation des lacs est particulièrement importante puisqu'il s'agit d'un élément essentiel de l'hydrologie des lacs et de la variabilité à plus long terme des niveaux des lacs. Une grande difficulté dans toutes les études des bilans énergétiques des lacs sur des périodes historiques est le manque de données sur la température de l'eau de surface, qui est une variable importante dans l'évaluation de nombreux flux radiatifs et échanges turbulents à l'interface air-eau. Le présent modèle a utilisé une méthode d'estimation de la température de surface à partir de l'hystérésis du contenu en chaleur des lacs. La relation représente un solide mécanisme de rétroaction négative et constitue une contrainte qui empêche les instabilités numériques d'augmenter (voir Sawchuk et Schertzer, 1988). Le modèle a servi à estimer les éléments du rayonnement de surface quotidien et du bilan énergétique des lacs Érié et Ontario au cours de la période de 1953 à 1997. Le présent rapport fournit des représentations graphiques des échanges radiatifs et turbulents primaires et de composantes météorologiques et limnologiques sélectionnées sur une échelle quotidienne (1953-1997) pour le lac Ontario. Les produits graphiques sont particulièrement pertinents pour les comparaisons courantes et futures de l'ampleur, des variations et de la variabilité interannuelle des principaux paramètres calculés par une méthode constante sur la période de 45 ans. Plus particulièrement, les produits graphiques documentent les limites du calcul du bilan énergétique de grands lacs profonds en l'absence de températures de l'eau directement observées.

Table of Contents

Introduction

Accurate quantification of the energy exchange across the air-water interface of a lake is crucial for understanding processes such as thermal stratification and the potential impacts of climate / climate change on the lake and aquatic ecosystem components (Schertzer and Sawchuk, 1990). The surface heat exchange can be defined as the following:

$$Q^* - Q_H - Q_{LE} - Q_t - Q_i - Q_M = 0$$

where, Q^* is net radiation, Q_H is sensible heat flux, Q_{LE} is latent heat flux, Q_t is the surface heat flux, Q_I is ice heat flux, and Q_M represents minor heat flux terms such as exchanges resulting from hydrological exchanges. The surface heat flux may then be evaluated as a residual. Details of the component formulations and computational techniques can be found in Sawchuk and Schertzer (1988), Schertzer and Sawchuk (1990).

Evaluation of the energy balance components for a large lake requires measurement of individual components at representative locations over the lake. However, other than for specialized research studies, such data is not usually available and recourse is to model mean meteorological conditions at the lake surface using meteorological stations at the lake periphery. Computational techniques can then be applied to estimate radiation and energy balance components. Such approaches have been applied to long-term studies conducted on the lower Great Lakes.

Derecki (1975) estimated monthly totals of energy budget components for Lake Erie (1950-1968) using shoreline meteorology and water intake temperatures to estimate lake surface temperature. Schertzer (1987) computed daily heat flux components, and heat storage of Lake Erie (lakewide and for the west, central and east basins) which formed boundary conditions for Lake Erie water quality model development (Lam et al., 1983, Lam and Schertzer, 1987). Few comparable long-term studies exist for Lake Ontario, although intensive measurements and calculations of energy balance components were performed during the international Field Year for the Great Lakes (IFYGL) from April 1972 to March 1973 (Pinsak and Rodgers, 1981). Quinn and den Hartog (1983) compared latent and sensible heat fluxes evaluated from solving the energy balance components with other methods such as estimates from the water balance equation and mass transfer models with values recommended by the IFYGL Energy Balance Panel.

This report is focused on the model results of Sawchuk and Schertzer (1998), who developed and applied a new energy budget model approach to Lake Erie and Lake Ontario. The objective here is to provide detailed graphical output of the primary input and output variables from the Sawchuk and Schertzer (1988) investigation.

Elements of the Energy Budget Model Approach

Sawchuk and Schertzer (1988) conducted an investigation to develop a model for evaluating daily values of surface radiation and energy balance components for large deep lakes. The focus of the study was to replace empirical and site specific formulations of the energy budget technique with physical models (where possible) in an effort to develop a numerical algorithm with general application. Considerable effort was expended in ensuring the algorithm was numerically stable, provided accurate flux estimates, required little computer time and performed in all environmental conditions. The model was applied to Lake Erie and it's three sub-basins and Lake Ontario for the climatological period 1953 to 1983 to evaluate the magnitude and variability of surface energy

balance components and to compare these estimates, where possible, with estimates from other long-term studies.

Model development focused on three aspects: radiation receipt, evaporation rates and ice cover. Net radiation was estimated from the sum of net shortwave and net longwave radiation fluxes. The shortwave model is a true radiative transfer model and marked the first time that such a model was applied to evaluate shortwave radiation receipts in a boundary layer study. Comparison of model estimates with measured values showed that the model could estimate daily totals of incoming shortwave radiation within, or close to, the range of values measured during IFYGL. Largest differences between model estimates and measured values were observed on days with predominately thin, high-altitude clouds, e.g. cirro-stratus combinations with maximum differences up to 30 percent of measured values. The impact of high altitude clouds on surface radiation receipt was much less when low clouds were also present.

Estimates of longwave radiation were obtained from a variant of Beer's law that incorporated effects of clouds, aerosols, and atmospheric gases on incoming longwave radiation. Estimates of daily totals of incoming longwave radiation were usually within 2 to 3 MJ m^{-2} day^{-1} of measured values which is within the uncertainty of incoming longwave radiation measurements on most days. In general, largest errors in estimates of incoming longwave radiation were observed for mostly clear days resulting in model underestimates. These underestimates may have resulted from several causes, (a) underestimated over-lake air temperatures, (b) inaccurate specification of reference heights for mean atmospheric temperature for emission of radiation and/or inaccurate specification of vertical temperature profile for a mostly clear atmospheres, and (c) neglect of multiple scattering effects. Specification of reference height and vertical temperature profile are likely the most important considerations. Sawchuk and Schertzer (1988) assumed a reference height ranging from 200 m (winter) to 300 m (summer) as recommended by Paltridge and Platt (1976). If the reference height was changed to 50 m as recommended by Ulden and Holtslag (1985), mean atmospheric temperature for emission would increase by approximately 2.5 °C. This temperature increase would be sufficient to bring clear sky longwave radiation estimates to within instrumental uncertainty of measured values on most days.

The evaporation model used in Sawchuk and Schertzer (1988) is a variant of the mass transfer approach. The primary improvement is the replacement of the Lake Hefner value for the mass transfer coefficient with a formulation that includes a dependency on wind speed (Quinn, 1978; Quinn and den Hartog, 1981). Although this formulation was strictly applicable to neutral conditions, atmospheric stability is incorporated through scaling of over-lake wind speeds. This approach resulted in evaporation estimates for Lake Ontario during IFYGL that compared favourably with values recommended by the IFYGL Energy Balance Panel. Estimated Bowen ratios were found to compare favourably with values tabulated by Pinsak and Rodgers (1981).

A simple model of ice extent, based on the cumulative freezing day concept provided acceptable estimates of ice heat flux due to ice formation and decay. Although the heat transfer associated with ice formation and decay is small, ice extent is important because of the high albedo for shortwave radiation and the effect of ice in reducing evaporation rates. Comparison of mean ice extent derived from a 31 year simulation for Lake Ontario and Lake Erie with tabulated values of Assel et al. (1983) showed good agreement.

The model was applied to produce 31 year simulations of daily radiation and energy balance components for Lake Erie and Lake Ontario. Daily lake heat contents were obtained from the product of estimated surface heat flux and lake surface area. Heat content estimates were compared

with measured heat contents for both lakes for the period 1967-1982 (Schertzer and Sawchuk, 1985; Schertzer, 1987). Estimated and measured heat contents showed excellent agreement on most days, usually within the accuracy of heat content measurements.

Examination of annual surface heat flux values, obtained from summing daily estimates, reveals that annual surface heat fluxes are not balanced on an annual basis. For Lake Erie, surface heat flux appears to be balanced over periods ranging from three to six years. Lake Ontario appeared to be gaining heat, although gains were small and within the uncertainty of measured heat contents.

One of the important recommendations resulting from the Sawchuk and Schertzer (1988) study was that future research was required for improvement of estimates of surface water temperature. Surface water temperature is the crucial variable in energy balance studies over lakes. It arises in estimation of over-lake meteorology variables, Bowen ratio, and incoming and emitted longwave radiation, etc. Consequently, almost all components of the model require knowledge of surface water temperature. In this investigation, a first approximation was estimated as the hysteresis between surface temperature and lake / basin heat content.

The computations conducted by Sawchuk and Schertzer (1988) for Lake Erie, Lake Erie West, Central and East Basin and Lake Ontario resulted in an enormous input and output database. The final report summarized the results for the 1953 – 1983 period as monthly and annual means. This report provides a detailed graphical summary of primary variables of the lake / basin heat flux, meteorological components and computed evaporation. While the graphs and tables of Sawchuk and Schertzer (1988) served to provide the essential overview of the energy budget conducted over these lakes and basins, the detailed summary plots in this report document the magnitude and variability in the key components at a finer temporal scale. The figures in this report documents the results of the current stage of computations and provides a solid basis for future advanced research on the development of improved techniques and applications of energy budget research for climate change impacts research on large deep lakes.

Data File Processing

The detailed meteorological data supplied for Lake Ontario consisted of plain ASCII text files. Initial processing of the file was required to allow efficient processing by MATLAB and Excel. Two conditions need to be corrected before they could be processed.

Originally, these file were formatted for efficient processing by FORTRAN programs. At first glance, the files looked like they could be processed as space delimited files but, where missing data values occurred in adjacent columns the value "-999.99M" did not leave a separating space. These values were replace with the simpler "-999.99" along with a blank space.

It was also found that some entries consisted of the character string "********". These would cause MATLAB to fail, expecting only numeric entries. Since no documentation existed as to the meaning of this string, they were also replaced with the generic "missing value" value.

The parameters present in these meteorological files (see table 1 for a detailed description) were grouped into five categories with detailed daily time series plots produced:

1. Heat Fluxes (Appendix 2),
2. Other Fluxes (Appendix 3),
3. Radiative (Appendix 4),

4. Meteorological (Appendix 5),
5. Evaporation (Appendix 6).

Plotting routines were written using MATLAB to generate detailed yearly plots and to produce some basic statistics. All routines used to process the data file are listed in Appendix 7.

Table 1: Lake Ontario Flux and Meteorological Output Parameters

Kd	MJ m^{-2} day^{-1}	incoming solar radiation
Ku	MJ m^{-2} day^{-1}	reflected solar radiation
Ld	MJ m^{-2} day^{-1}	incoming long wave radiation
Lu	MJ m^{-2} day^{-1}	emitted long wave radiation
Q*	MJ m^{-2} day^{-1}	net radiation
Uk	m/s	over-lake wind speed
Ta	°C	over-lake air temperature
Td	°C	over-lake dew point temperature
Rh	percent	over-lake relative humidity
Tw	°C	surface water temperature
As	fractional value	surface albedo
Qh	MJ m^{-2} day^{-1}	sensible heat flux
Qe	MJ m^{-2} day^{-1}	latent heat flux
Ev	Mm	daily evaporation
Qi	MJ m^{-2} day^{-1}	ice heat flux
Ic	fraction surface area	lake ice extent
Qm	MJ m^{-2} day^{-1}	minor heat flux terms
Qt	MJ m^{-2} day^{-1}	total surface heat flux
Qc	Exa Joules	lake heat content (computed)

In addition to the detailed plots, two types of summary plots were also produced (see Appendix 1 for the complete set of summary plots). The first averages the above listed parameters for each ordinal (also sometimes referred to as Julian) day over the study period, in this case 1953 through 1997. The Maximum, Mean and Minimum values are plotted.

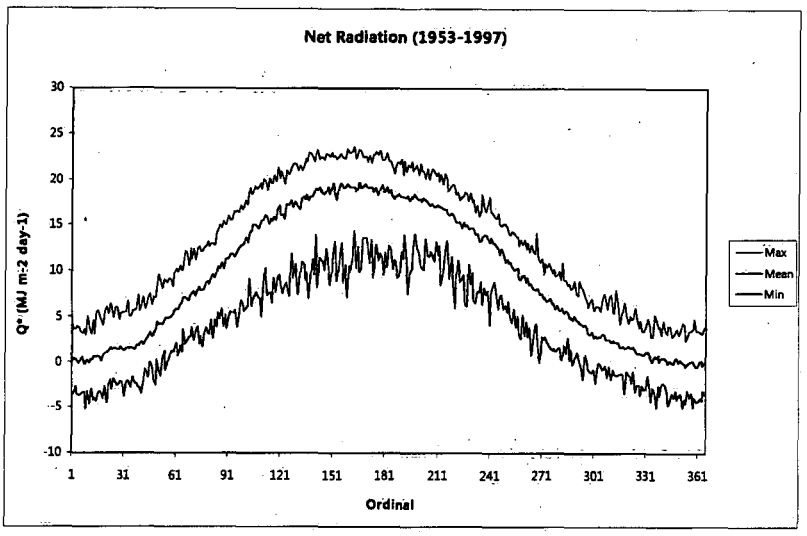

Figure 1: Sample Ordinal Summary

The second summary plot consists of simple yearly averages. Each year is represents by a vertical line, Maximum to Minimum (Absolute), along with a horizontal bar representing the Mean.

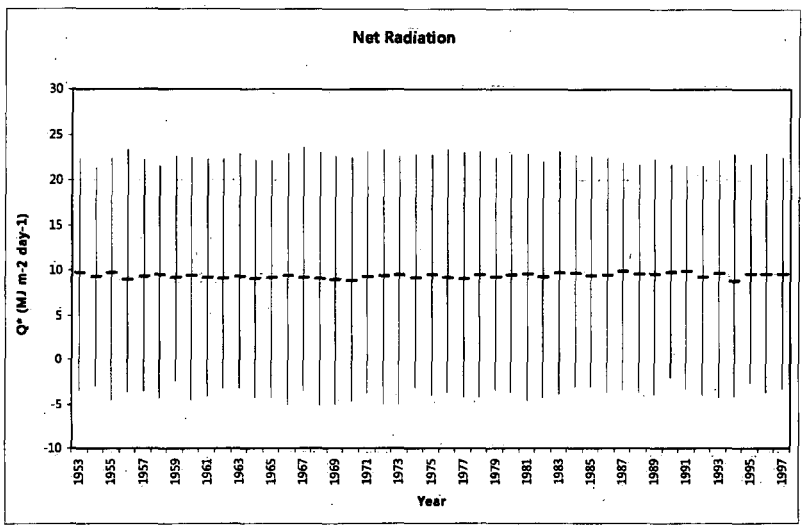

Figure 2: Sample Yearly Summary

Computations Involving Surface Water Temperature

Sawchuk and Schertzer (1988) modeled surface water temperature as surface temperatures were generally not available till 1966 and from then on there were different databases involving water intake temperatures, airborne radiometer measurements, lake surveillance observations and finally remote sensing from satellite observations. Schertzer and Sawchuk (1985) summarized all available water temperature measurements for the lower Great Lakes. Schertzer computed one dimensional temperature profiles for the lakes and estimated the lake and basin heat contents.

The algorithm used to estimate surface water temperature is based on the relationship between surface water temperature and the total heat content of the lake or basin. The relationships were derived by using paired surface water temperatures and heat content values. Figure 3 illustrates this "hysteresis" relationship for two periods of the year: a warming phase (15 March to 10 September) and a cooling phase (11 September to 14 March) (Sawchuk and Schertzer, 1988). The relationship between surface temperature and heat content was approximated by a linear combination of Legendre Polynomials of order 0 to 5 shown as dashed and solid curves on Figure 3. Higher order approximations did not appreciably reduce the root mean square error of the estimates or improve statistics of the fit (Table 2).

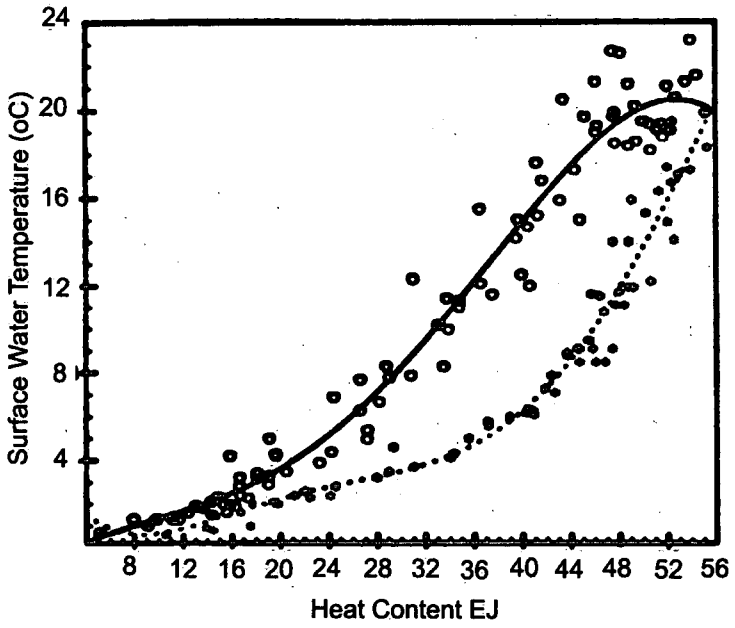

Figure 3: Relationship between surface water temperature and total lake heat content for Lake Ontario. Solid line represents warming period and dashed line represents cooling period (based on Sawchuk and Schertzer, 1988)

Table 2: Root mean square errors of differences between predicted and observed water surface temperatures for Lake Ontario (Sawchuk and Schertzer, 1988).

	Warming Phase	Cooling Phase
RMSE	1.32 °C	1.05 °C

As indicated in Table 2, the approximations to water surface temperature in the present approach perform better during the cooling phase of the lake. Figure 3 also illustrates that there is larger variability during the warming period of the year, especially during late summer especially when heat content is at or near the maximum. Procedures used to initialize the heat content for a particular year and the computation of the daily mean surface temperature is described in detail in Sawchuk and Schertzer (1988) and also applied in Schertzer and Sawchuk (1990).

Implications Regarding Surface Temperature

Appendix 1 shows a summary of the magnitude and variability of the long-term (45 year) daily computations of the radiative and turbulent fluxes and selected meteorological and limnological variables and succeeding Appendices show the detailed computations for each year. Many of the variables are dependent on the accuracy of water surface temperature; however, water temperature is not often available in historical databases. The application of hysteresis functions, in this case, the relation between surface temperature and lake heat content has advantages and limitations. The advantage is that root mean square errors in the overall temperature approximations are not dissimilar to comparisons between surface temperature observations from different measurement types (e.g. ART vs. satellite vs. buoy observations). However, there are times of the year when variability is larger as noted during the warming phase and, in particular, at the period of maximum heat content. The effect of this variability can be seen in examination of the summary graphs for the surface water temperature in Appendix 1 and also in the Detailed Appendices. In particular, surface water temperature in many cases is constrained at the time of peak heat content. The inaccuracy in the surface water temperature at this time of year will affect computation of the temperature dependent radiative flux and turbulent exchange components.

Future research is required in order to develop new algorithms / approaches that can be applied to approximate water surface temperature in this lake as well as many lakes in Canada that do not have detailed water temperature observations, especially over climatologically significant periods. Such research is required especially in developing baseline conditions for future climate impacts analyses on lakes.

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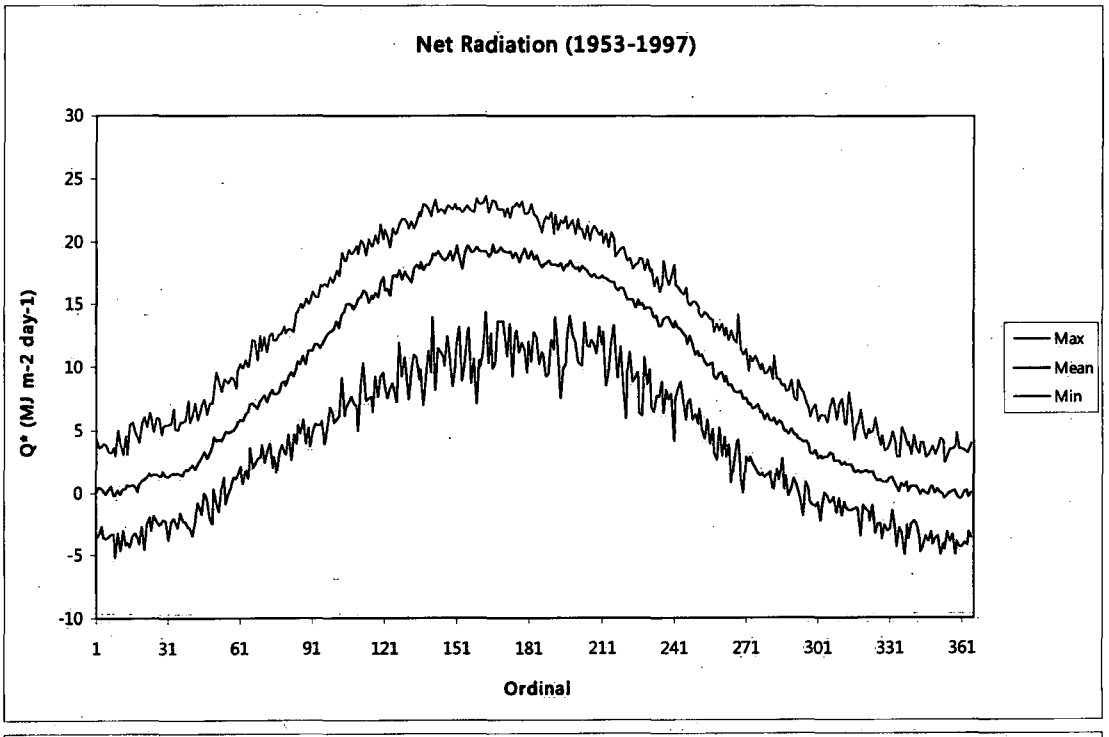
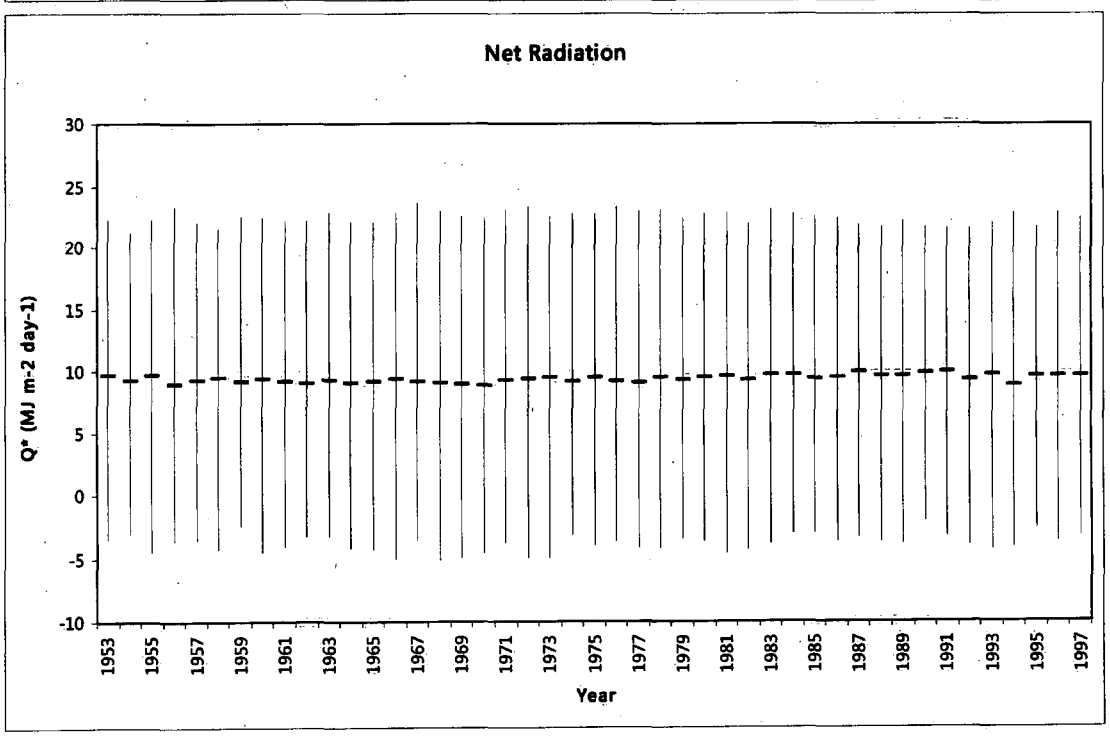
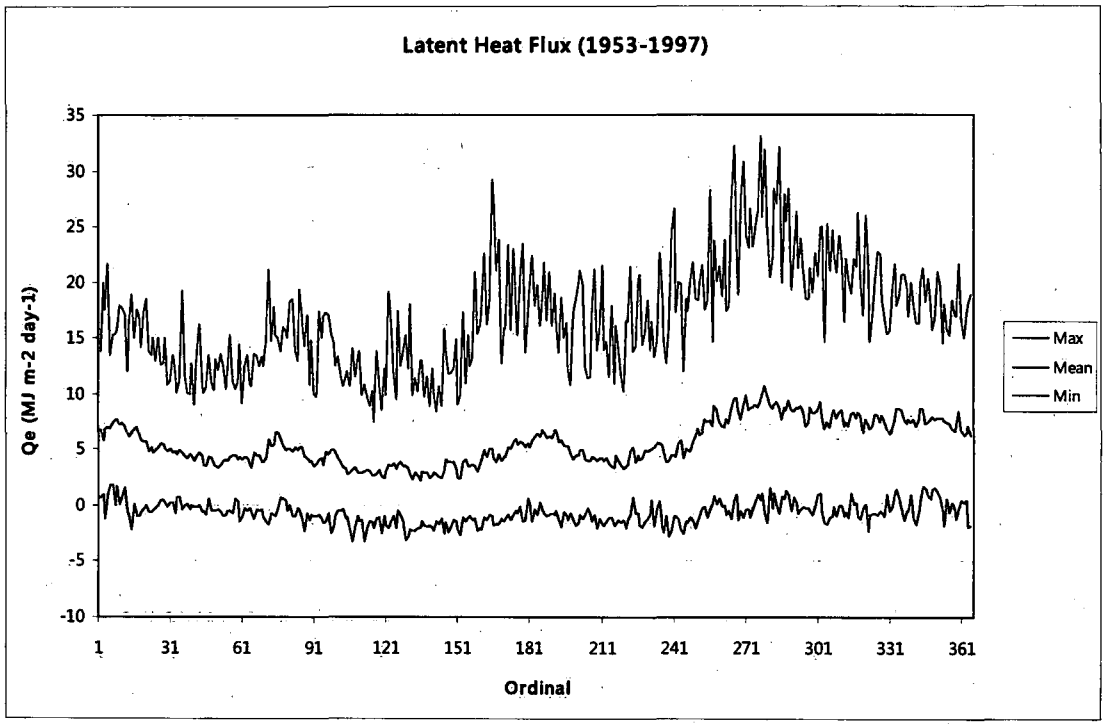
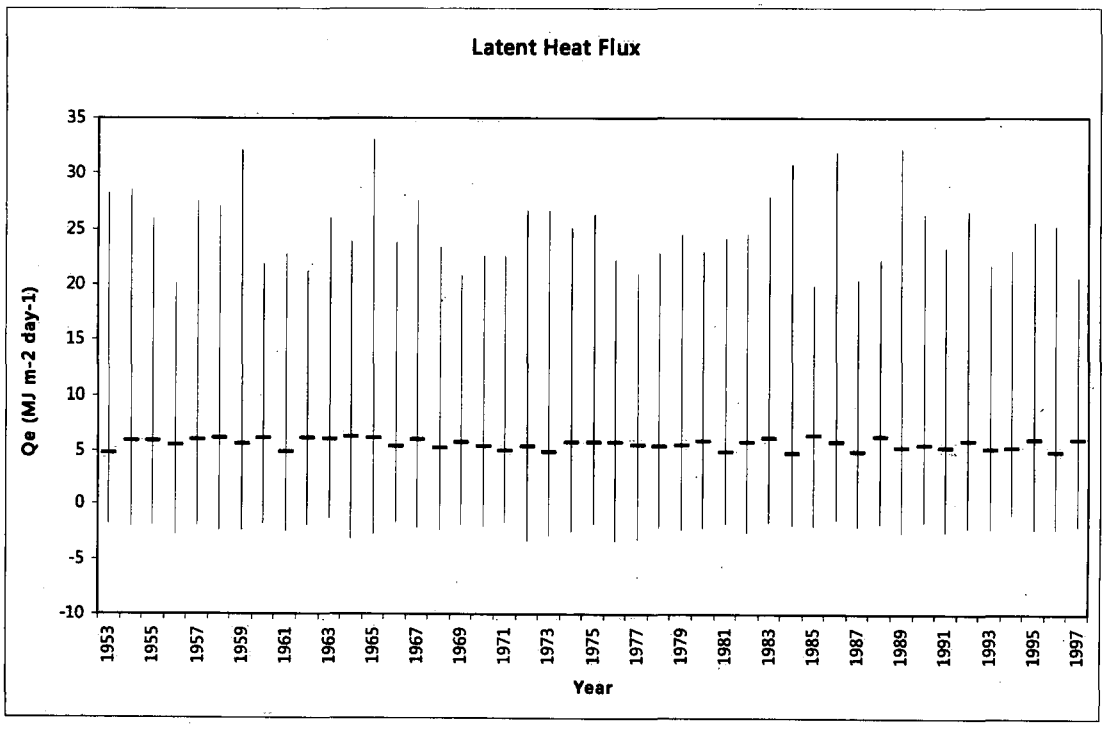
Appendix 1
Summary Plots






Latent Heat Flux (1953-1997)
Qe (MJ m-2 day-1)
35
30
25
20
15
10
5
0
-5
-10
1
31
61
91
121
151
181
211
241
271
301
331
361
Ordinal
Max
Mean
Min


Latent Heat Flux
Qe (MJ m-2 day-1)
35
30
25
20
15
10
5
0
-5
-10
1953
1955
1957
1959
1961
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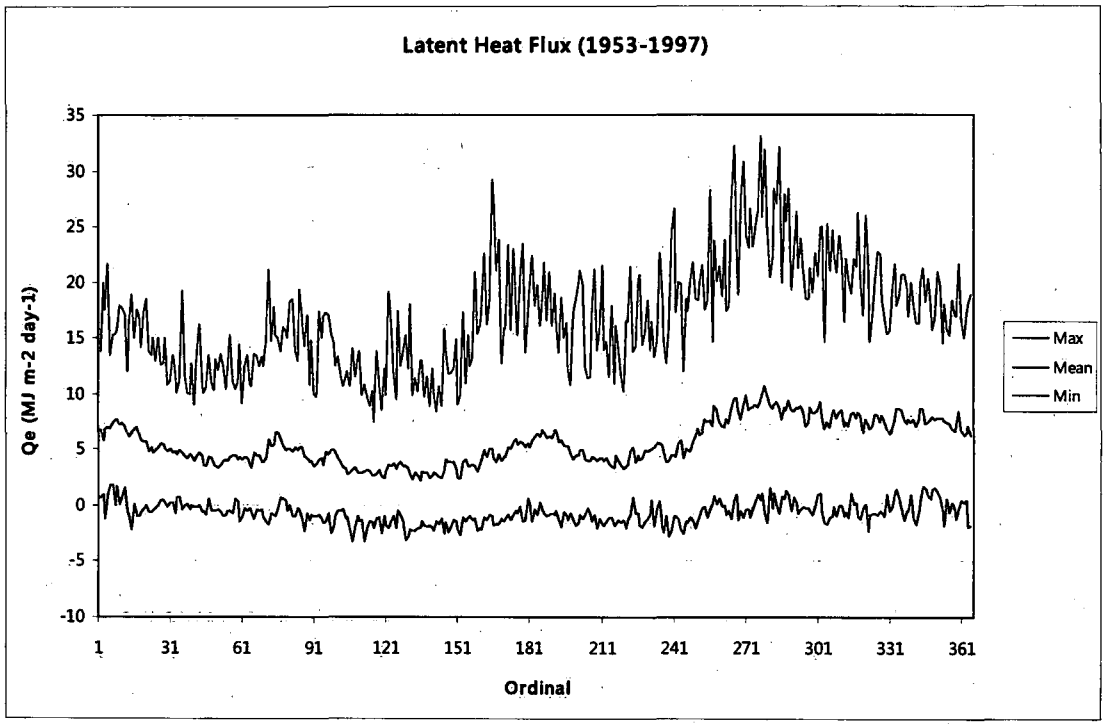
1981
1983
1985
1987
1989
1991
1993
1995
1997
Year


Latent Heat Flux (1953-1997)
Qe (MJ m-2 day-1)
35
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5
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-5
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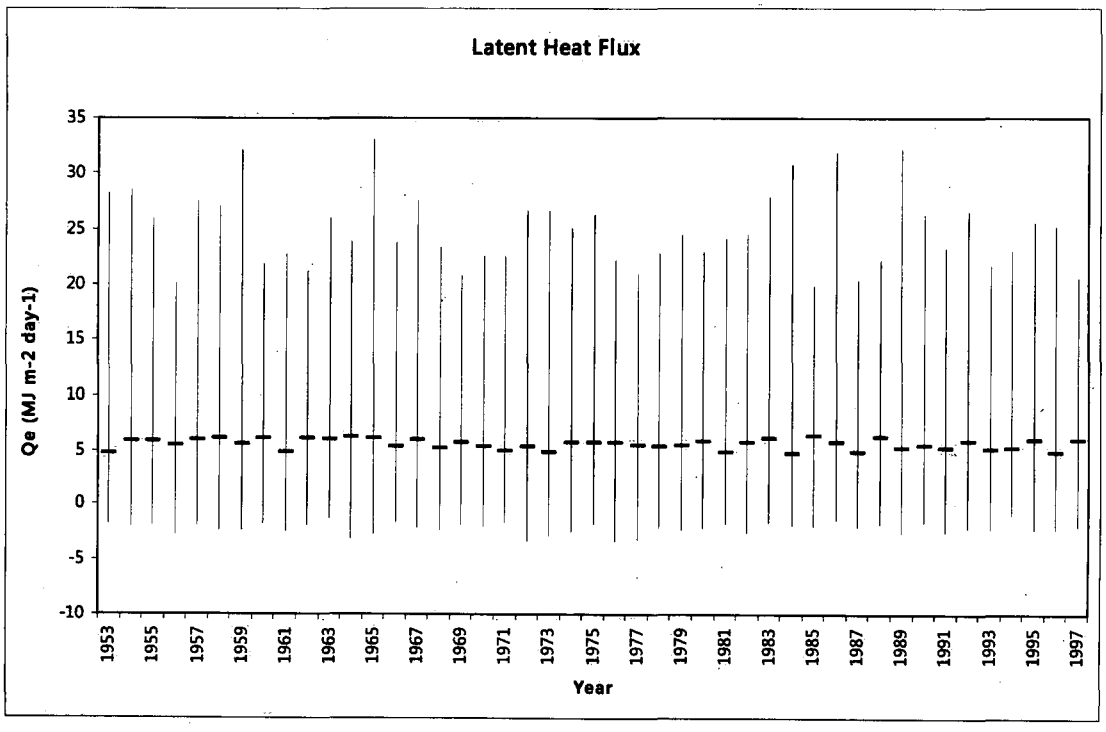
181
211
241
271
301
331
361
Ordinal
Max
Mean
Min


Latent Heat Flux
Qe (MJ m-2 day-1)
35
30
25
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15
10
5
0
-5
-10
1953
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1957
1959
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1981
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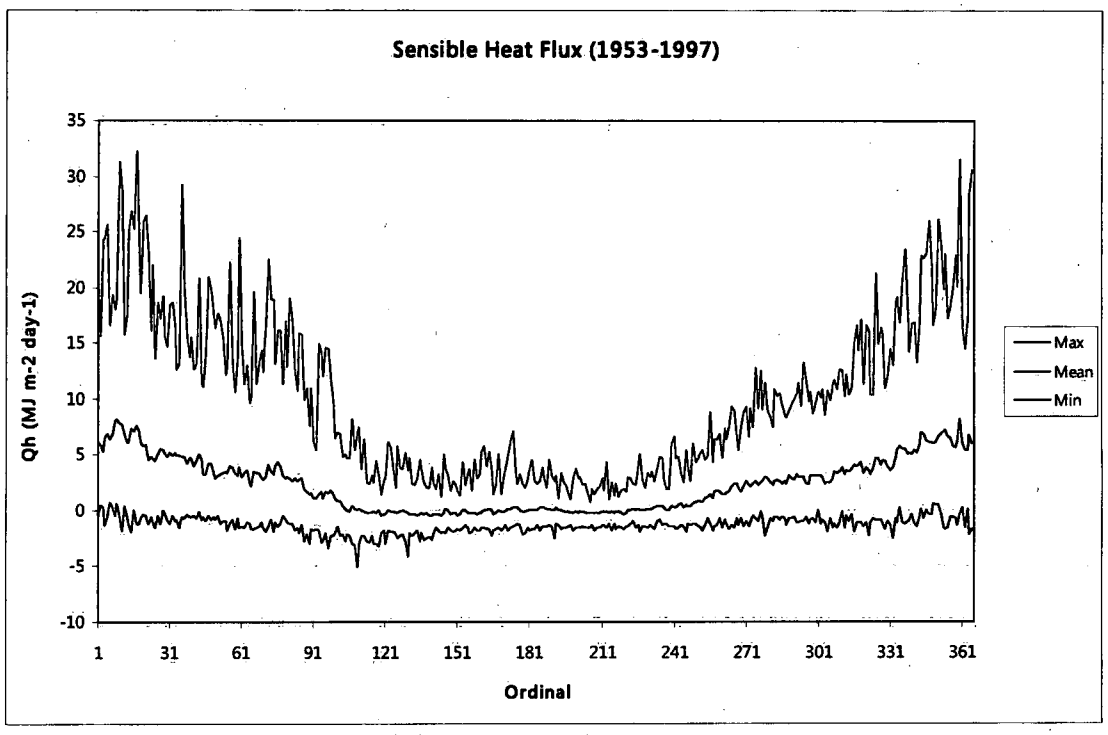
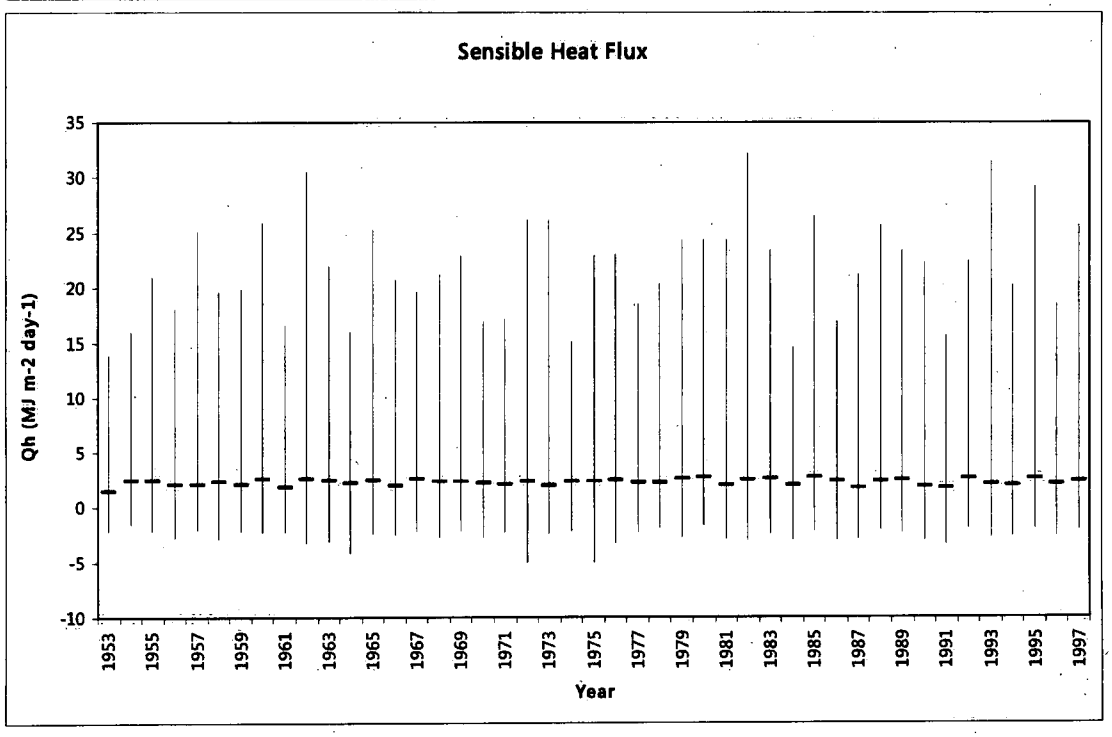
1991
1993
1995
1997
Year


Sensible Heat Flux (1953-1997)
Qh (MJ m-2 day-1)
35
30
25
20
15
10
5
0
-5
-10
1
31
61
91
121
151
181
211
241
271
301
331
361
Ordinal
Max
Mean
Min


Sensible Heat Flux
Qh (MJ m-2 day-1)
35
30
25
20
15
10
5
0
-5
-10
1953
1955
1957
1959
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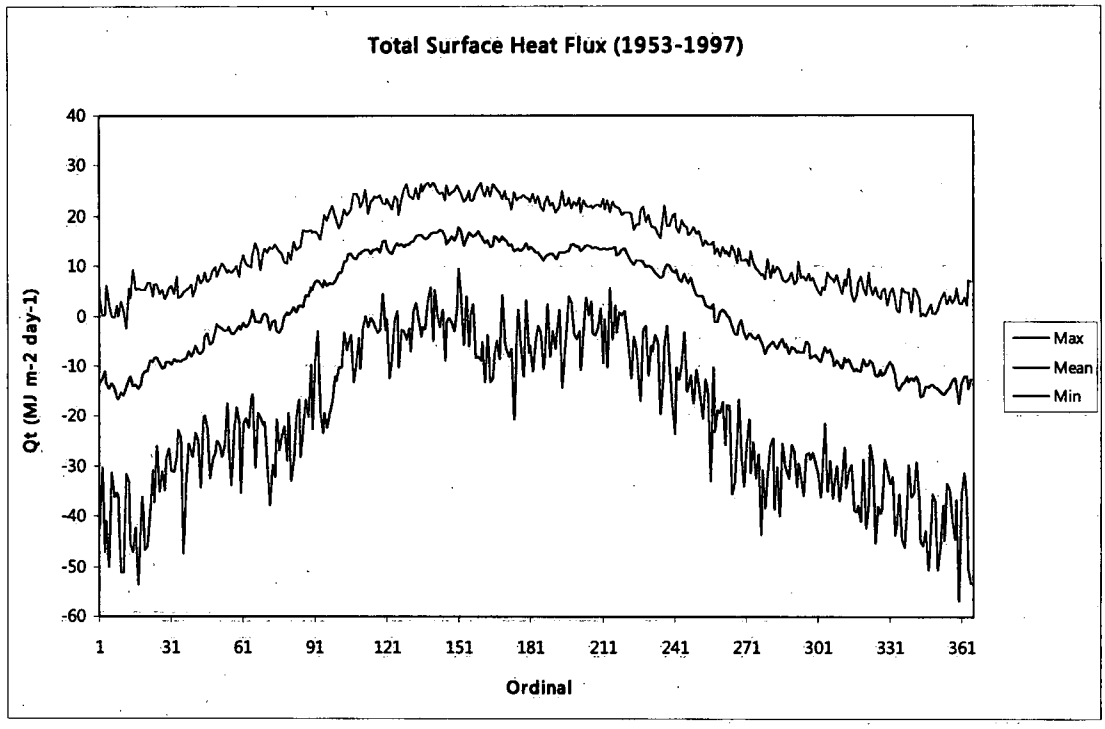
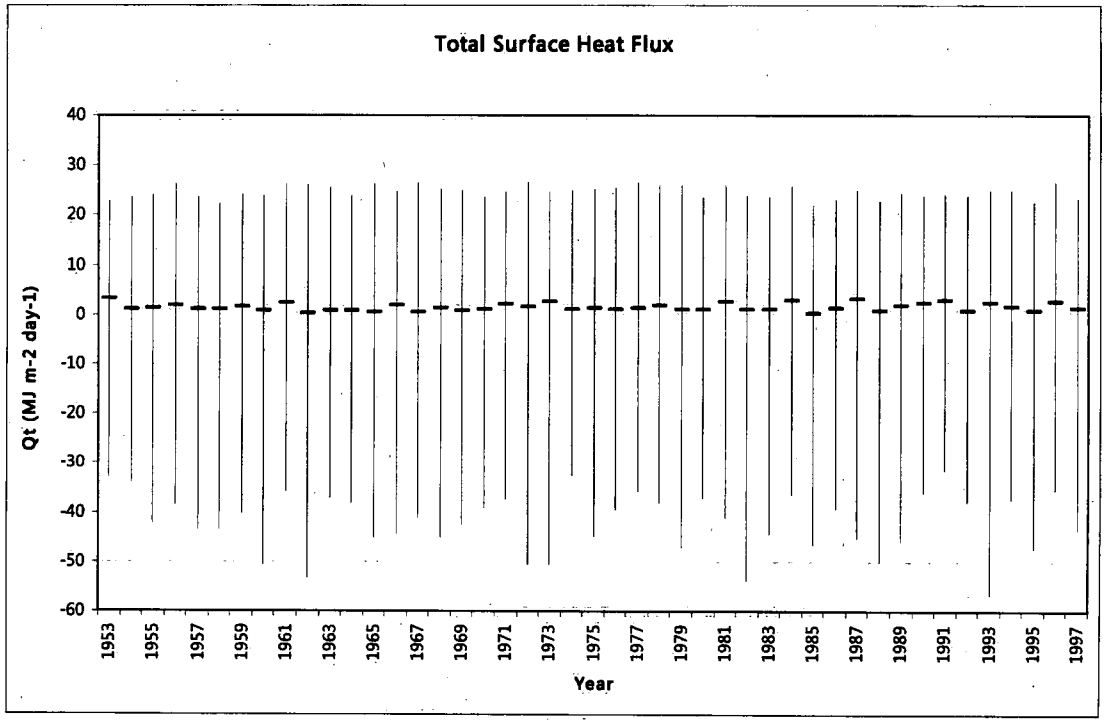
1987
1989
1991
1993
1995
1997
Year


Total Surface Heat Flux (1953-1997)
Qt (MJ m-2 day-1)
40
30
20
10
0
-10
-20
-30
-40
-50
-60
1
31
61
91
121
151
181
211
241
271
301
331
361
Ordinal
Max
Mean
Min


Total Surface Heat Flux
Qt (MJ m-2 day-1)
40
30
20
10
0
-10
-20
-30
-40
-50
-60
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
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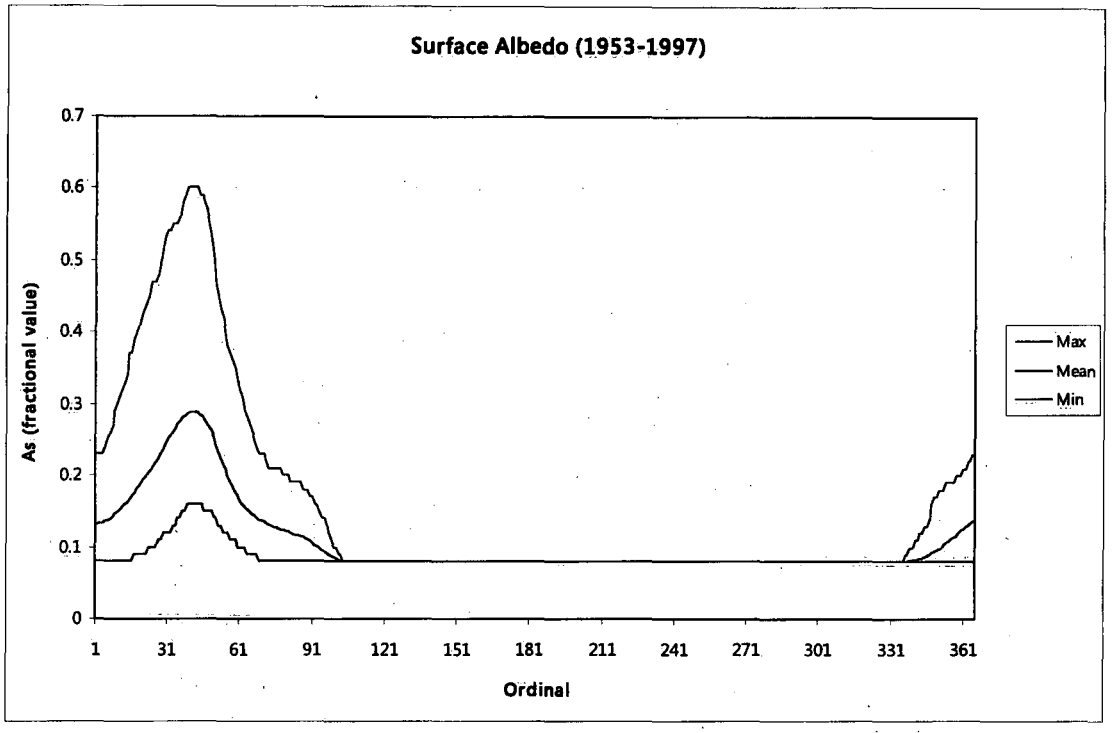
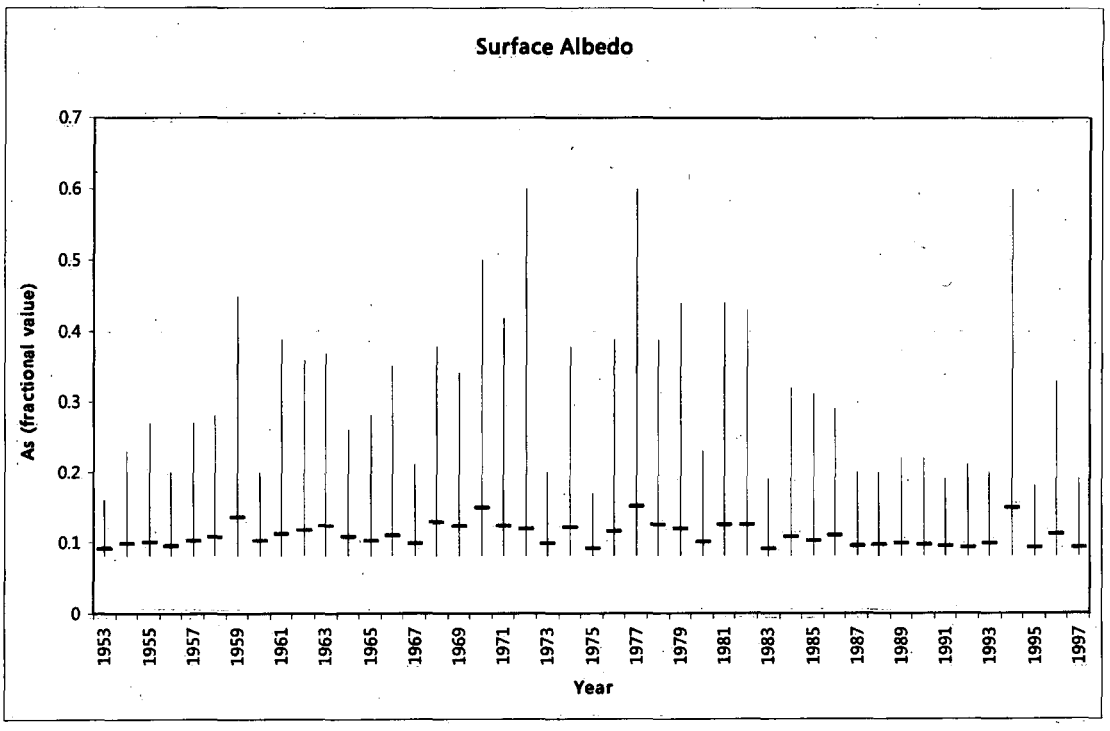
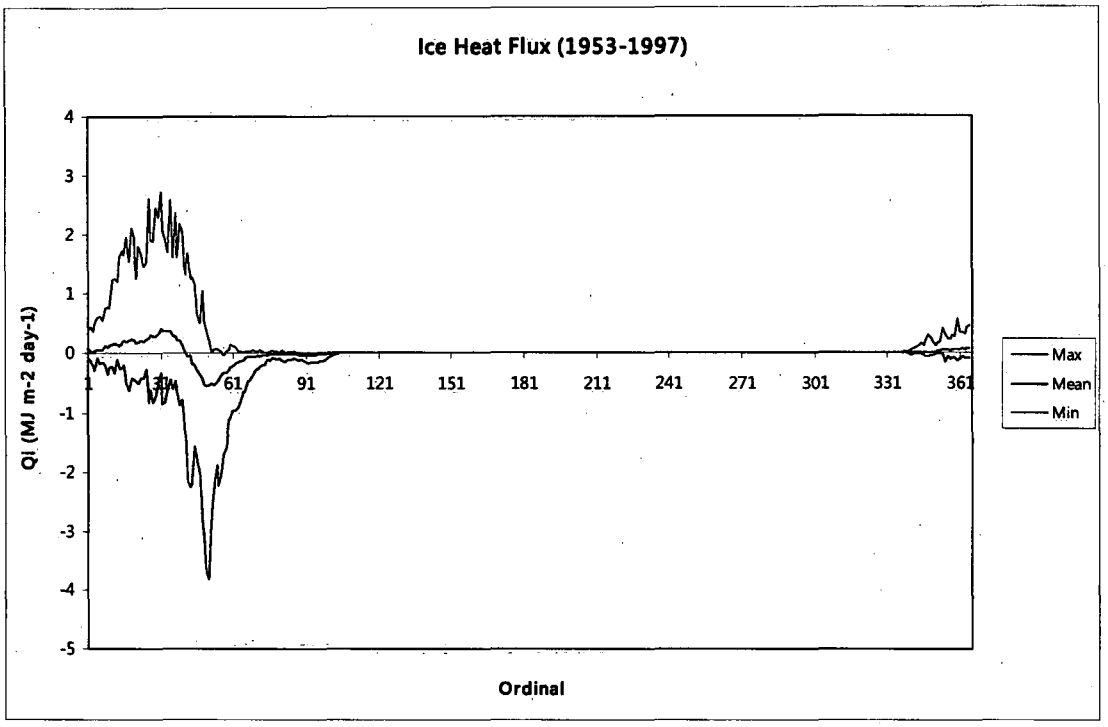
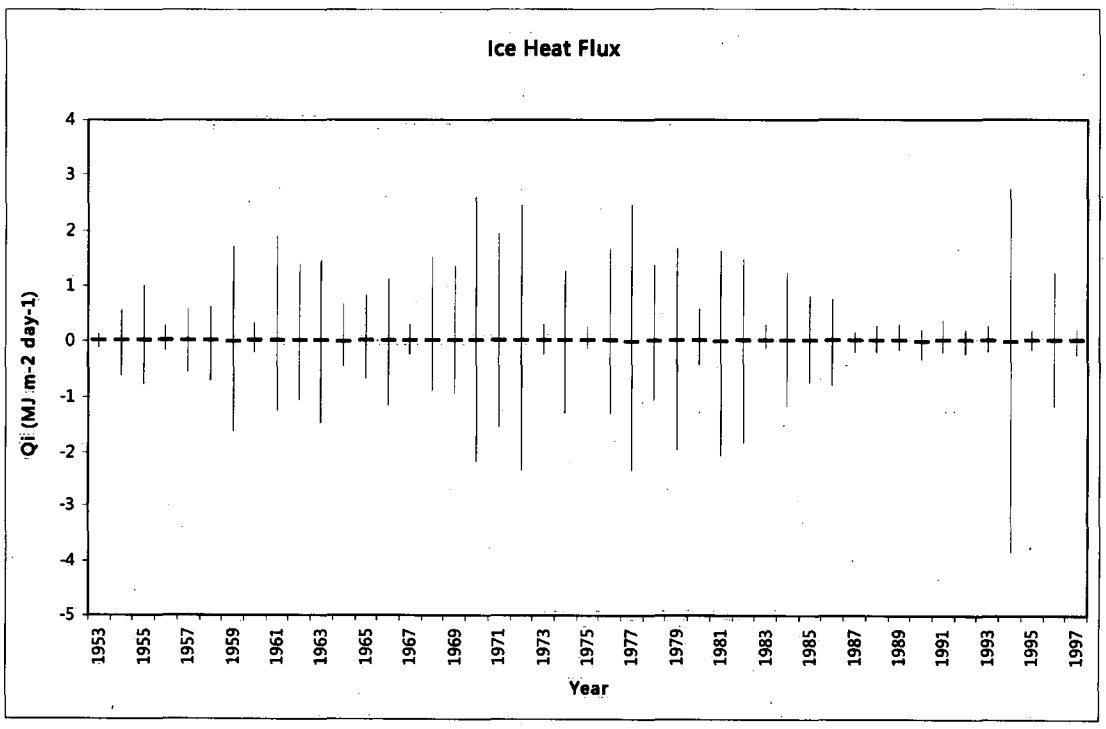
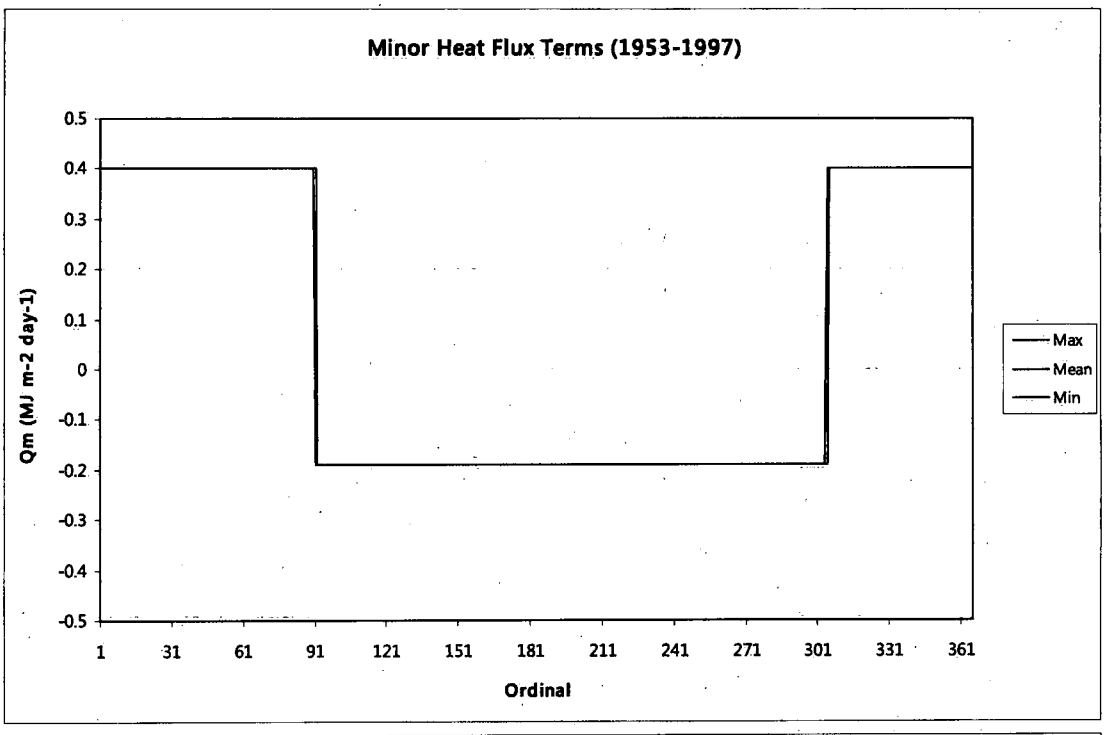
1993
1995
1997
Year

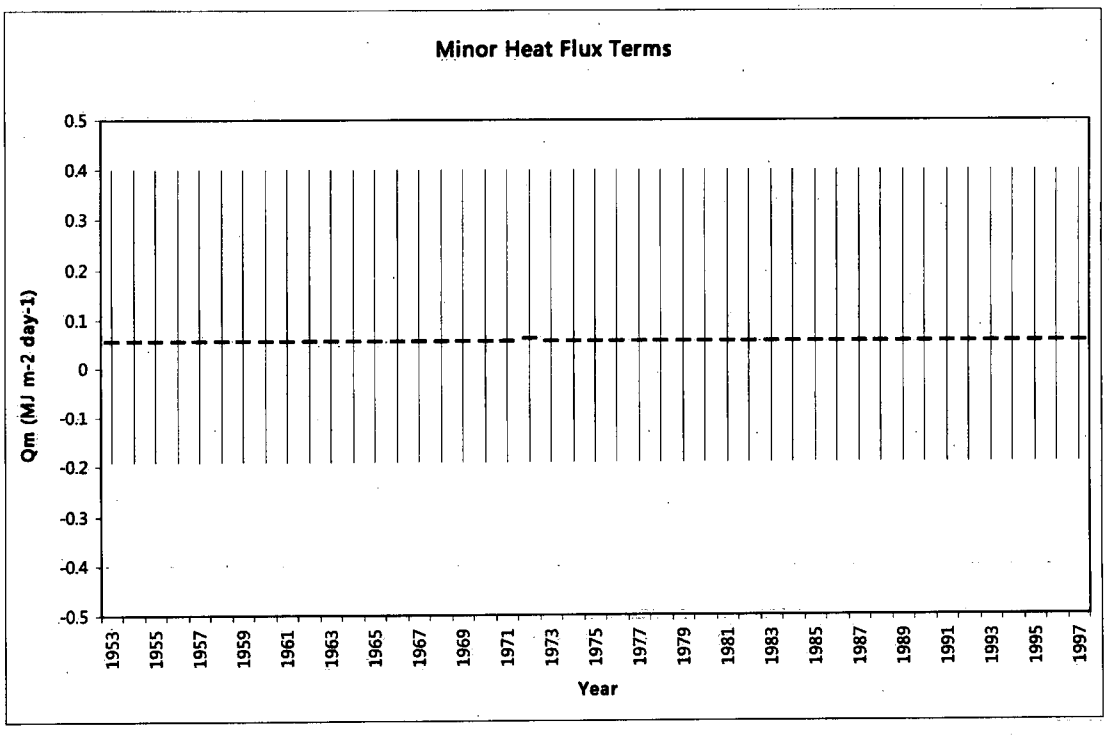

Surface Albedo (1953-1997)
As (fractional value)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
31
61
91
121
151
181
211
241
271
301
331
361
Ordinal
Max
Mean
Min

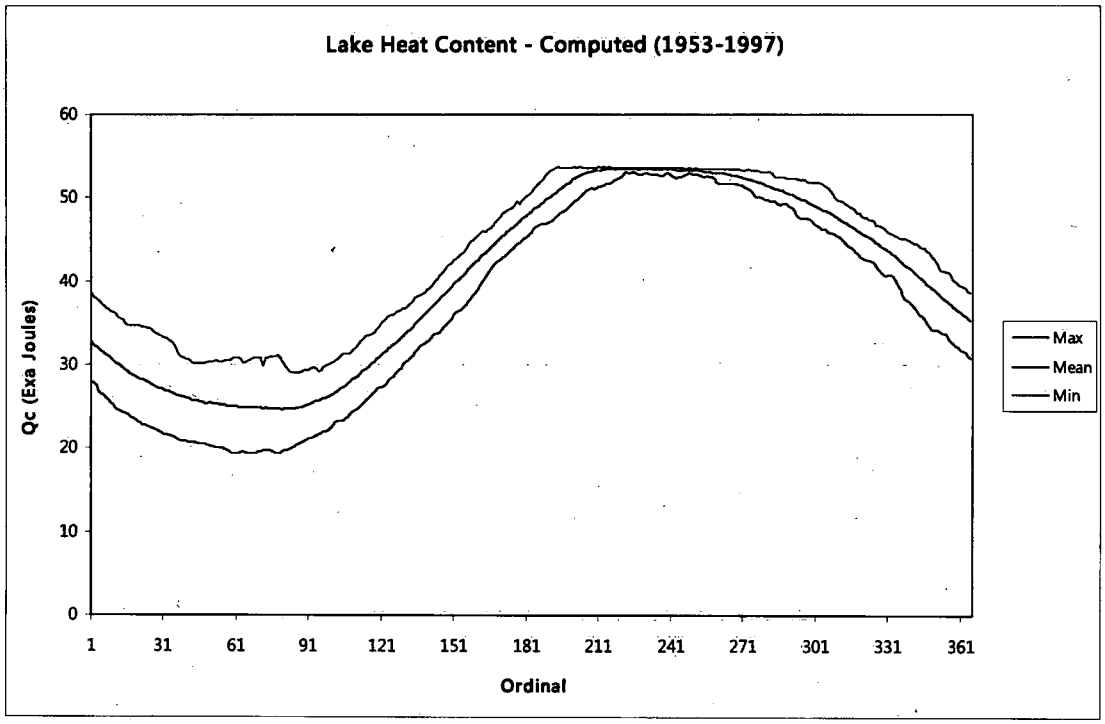

Surface Albedo
As (fractional value)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
Year

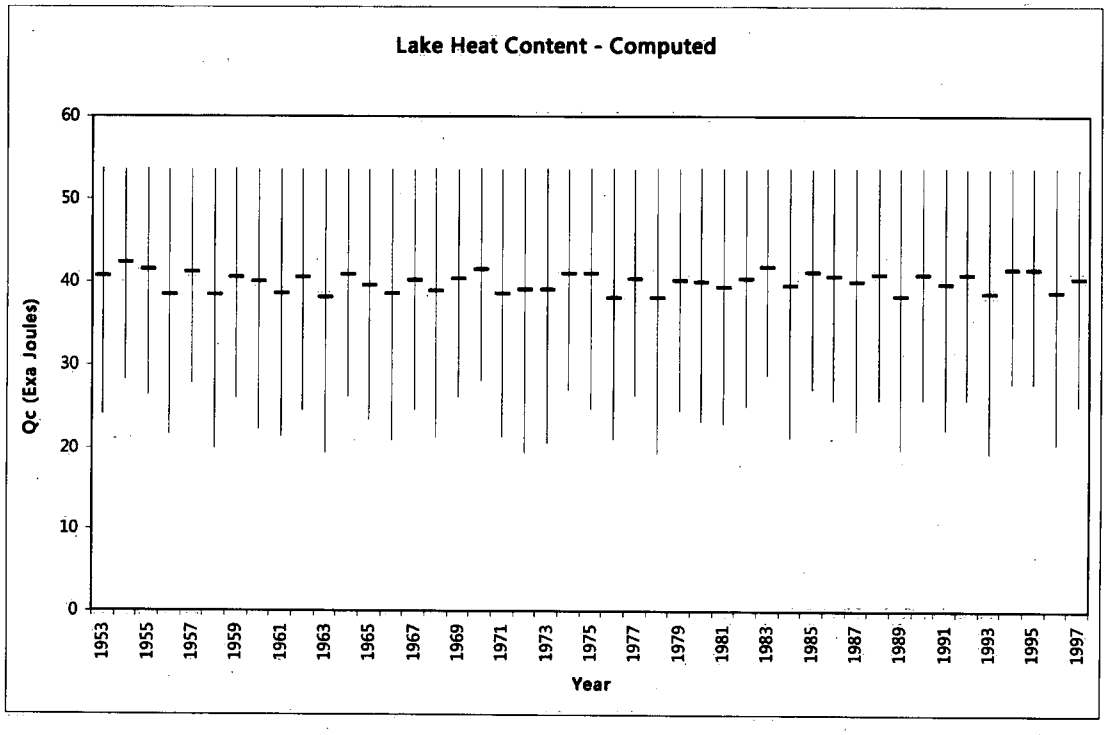

Ice Heat Flux (1953-1997)
Qi (MJ m-2 day-1)
4
3
2
1
0
-1
-2
-3
-4
-5
1
31
61
91
121
151
181
211
241
271
301
331
361
Ordinal
Max
Mean
Min

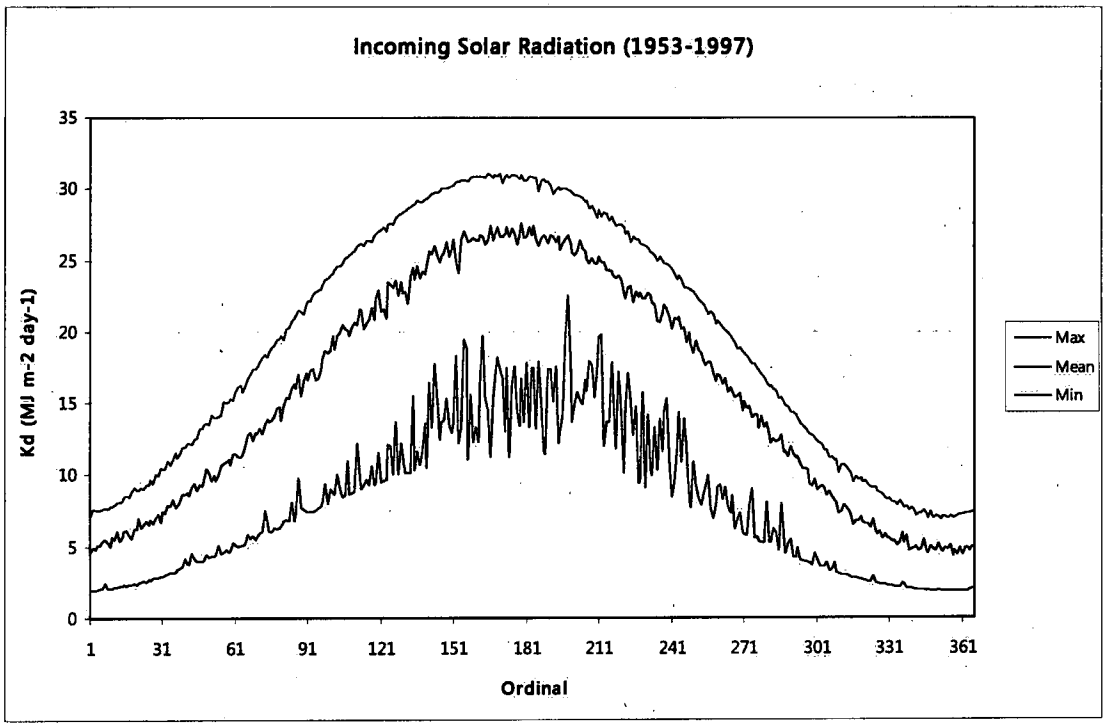

Ice Heat Flux
Qi (MJ m-2 day-1)
4
3
2
1
0
-1
-2
-3
-4
-5
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
Year

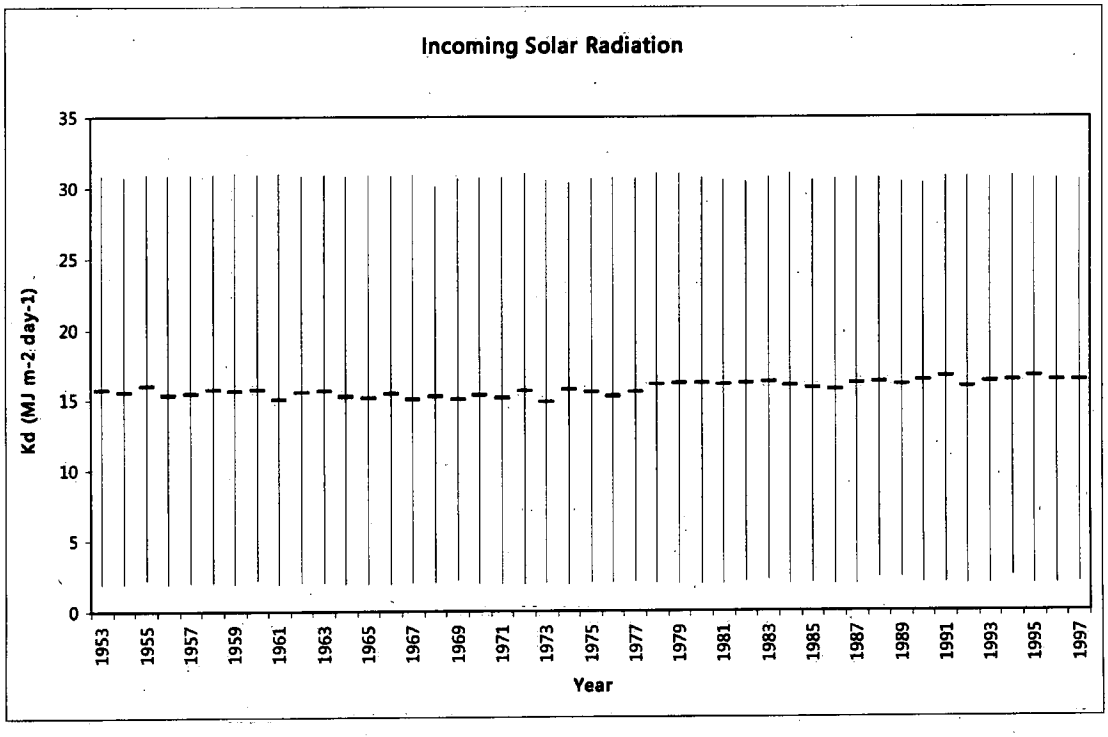

Minor Heat Flux Terms (1953-1997)
Qm (MJ m-2 day-1)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
1
31
61
91
121
151
181
211
241
271
301
331
361
Ordinal
Max
Mean
Min

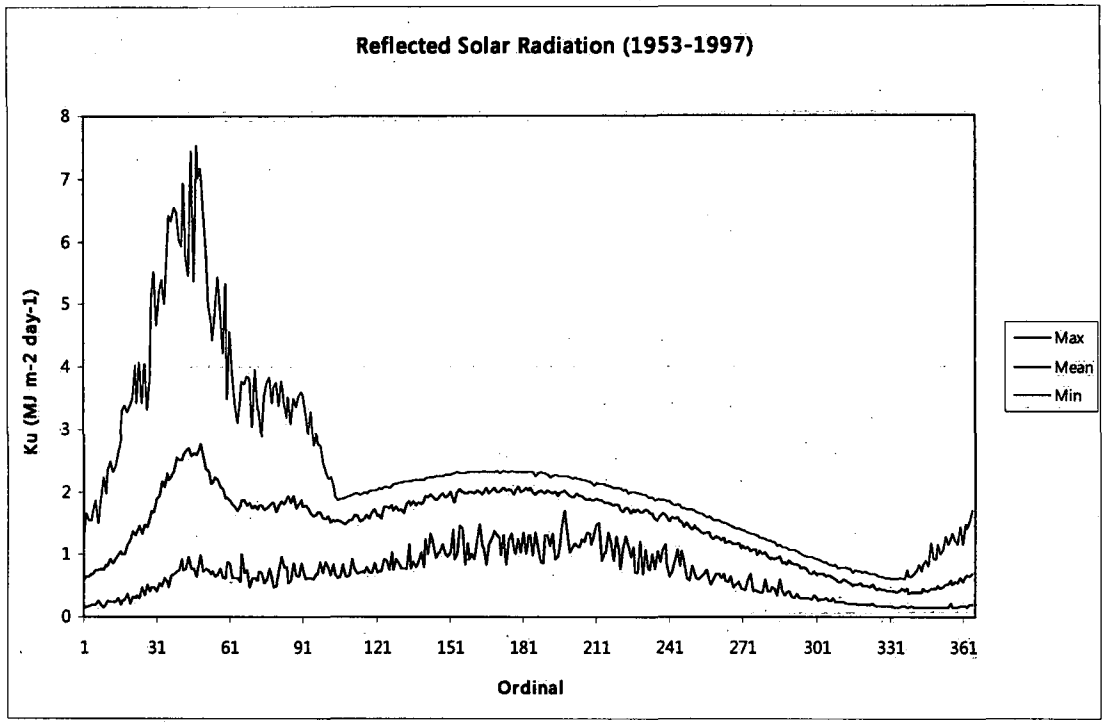

Minor Heat Flux Terms
Qm (MJ m-2 day-1)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
Year

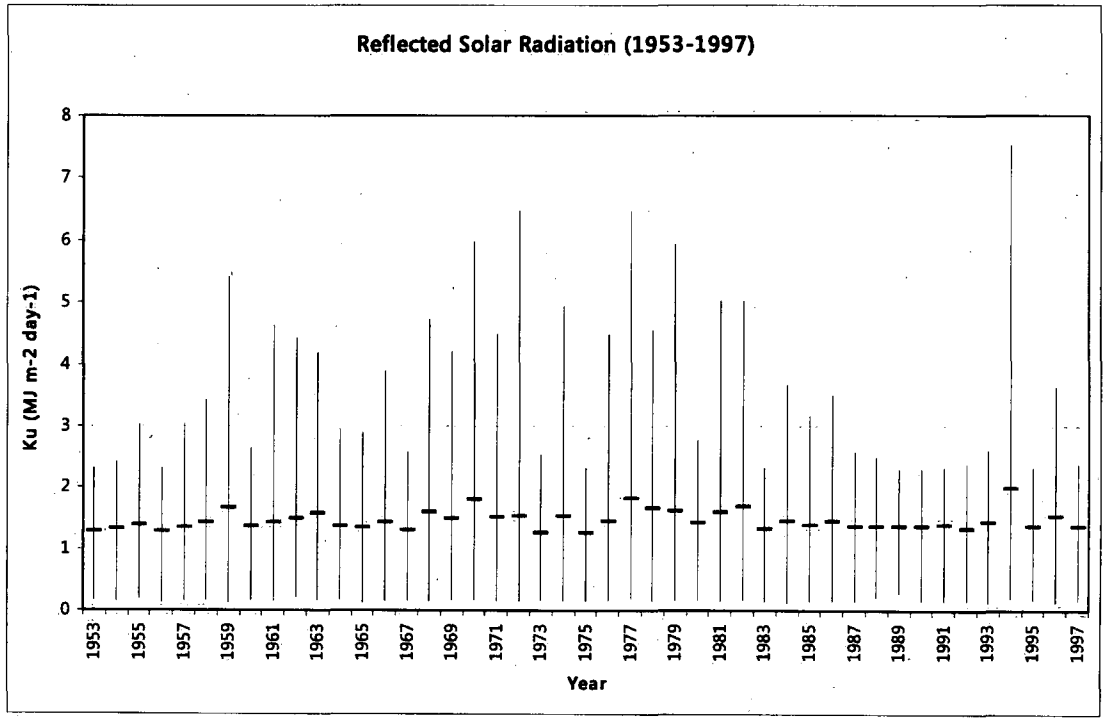

Lake Heat Content - Computed (1953-1997)
Qc (Exa Joules)
60
50
40
30
20
10
0
1
31
61
91
121
151
181
211
241
271
301
331
361
Ordinal
Max
Mean
Min

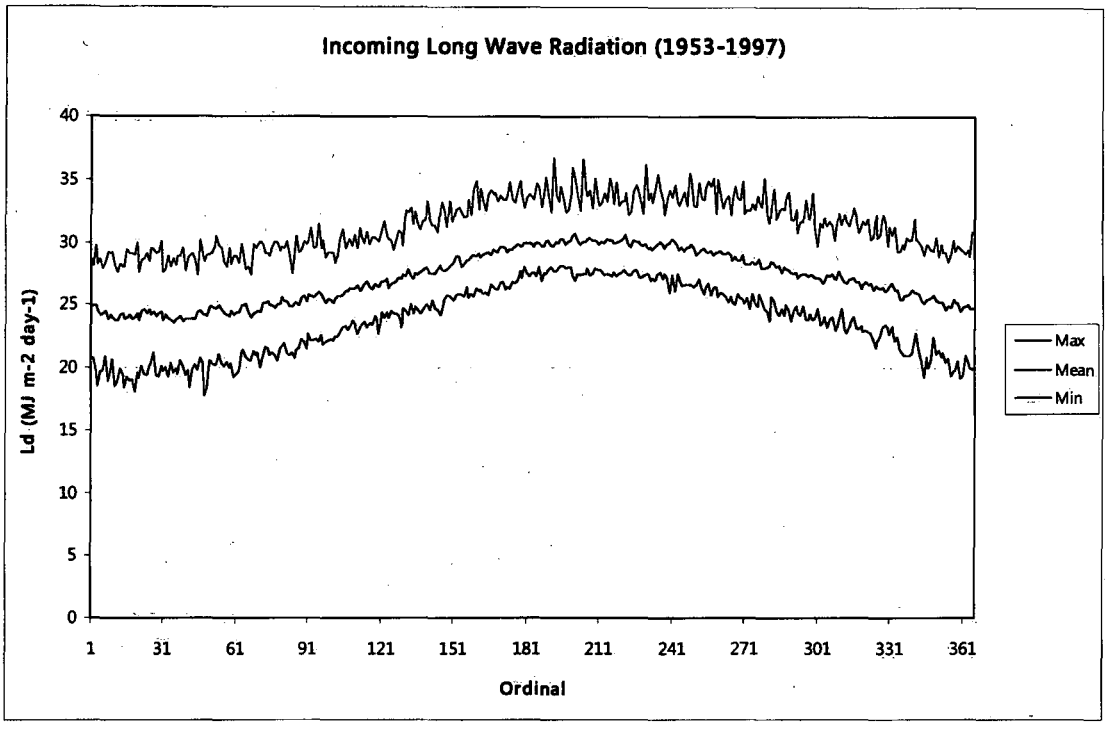

Lake Heat Content - Computed
Qc (Exa Joules)
60
50
40
30
20
10
0
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
Year

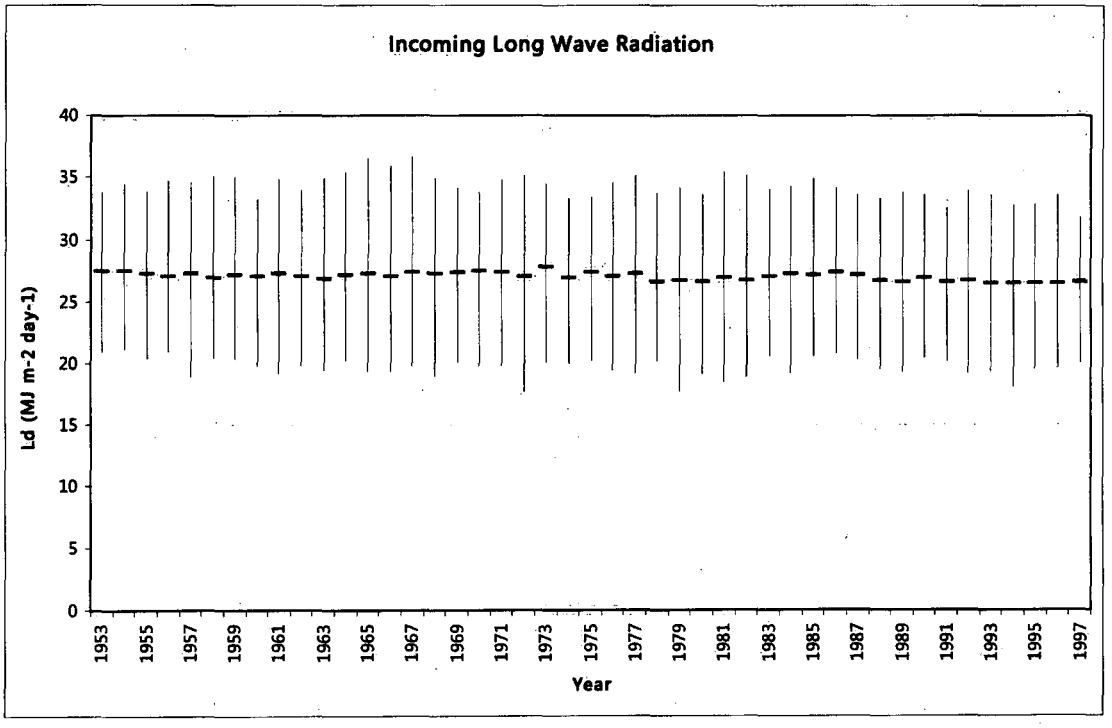

Incoming Solar Radiation (1953-1997)
Kd (MJ m-2 day-1)
0
5
10
15
20
25
30
35
1
31
61
91
121
151
181
211
241
271
301
331
361
Ordinal
Max
Mean
Min

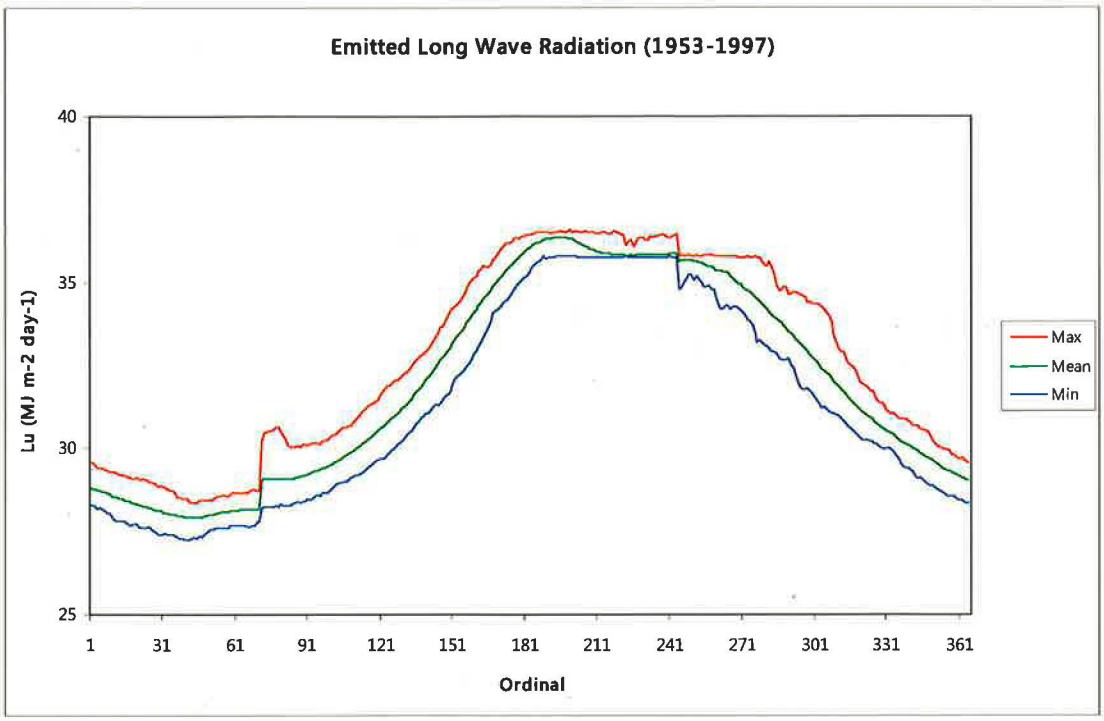

Incoming Solar Radiation
Kd (MJ m-2 day-1)
0
5
10
15
20
25
30
35
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
Year

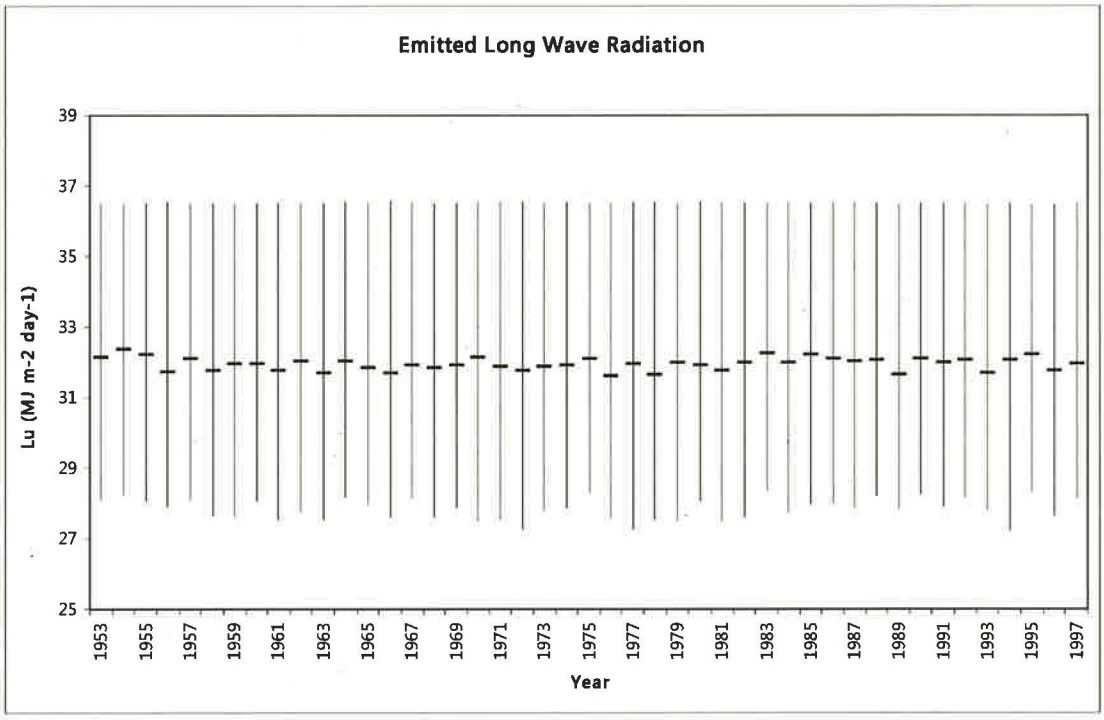

Reflected Solar Radiation (1953-1997)
Ku (MJ m-2 day-1)
0
1
2
3
4
5
6
7
8
1
31
61
91
121
151
181
211
241
271
301
331
361
Ordinal
Max
Mean
Min

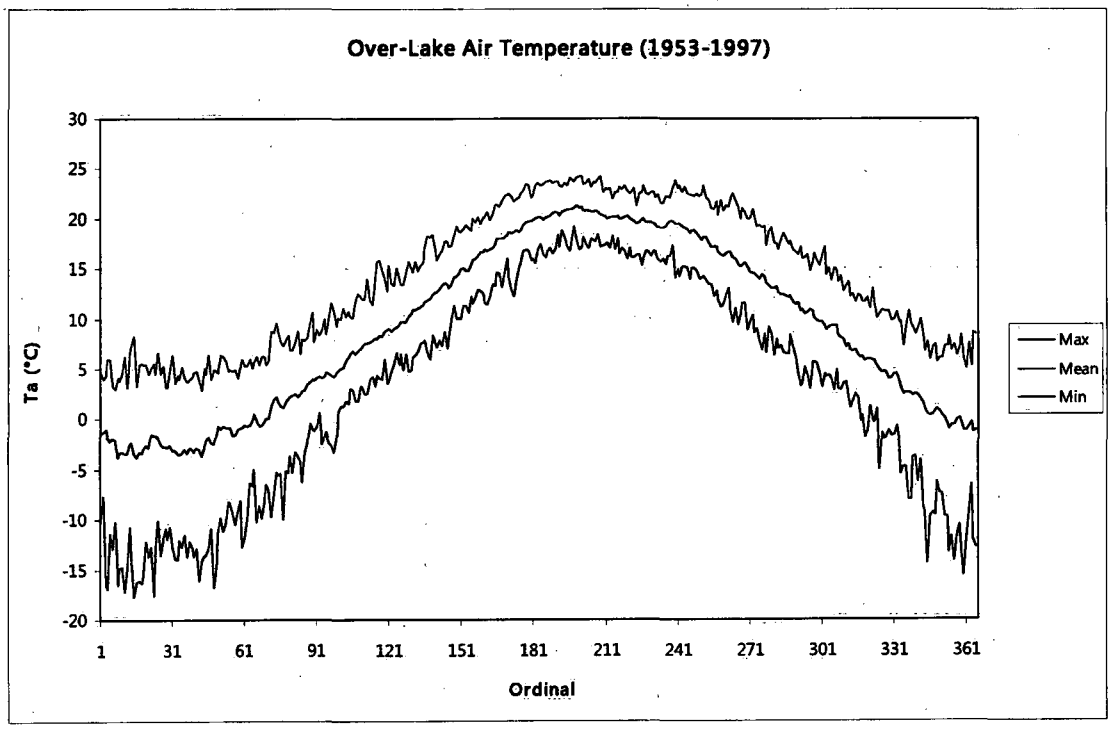

Reflected Solar Radiation (1953-1997)
Ku (MJ m-2 day-1)
0
1
2
3
4
5
6
7
8
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
Year

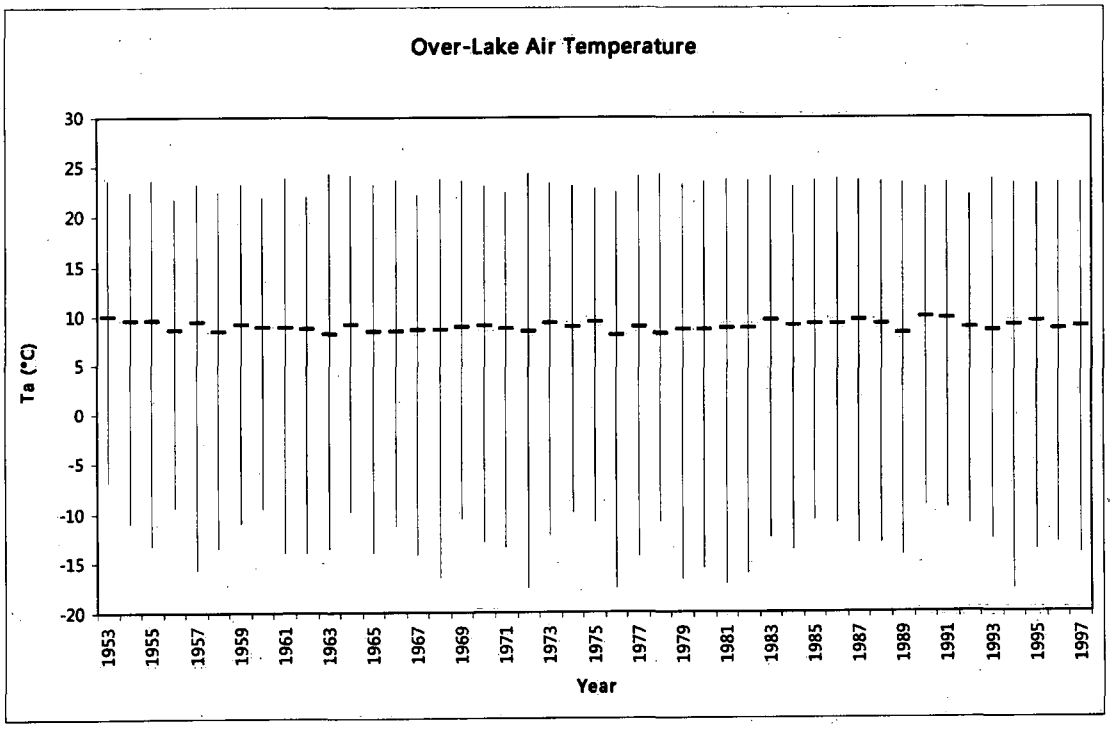

Incoming Long Wave Radiation (1953-1997)
Ld (MJ m-2 day-1)
0
5
10
15
20
25
30
35
40
1
31
61
91
121
151
181
211
241
271
301
331
361
Ordinal
Max
Mean
Min

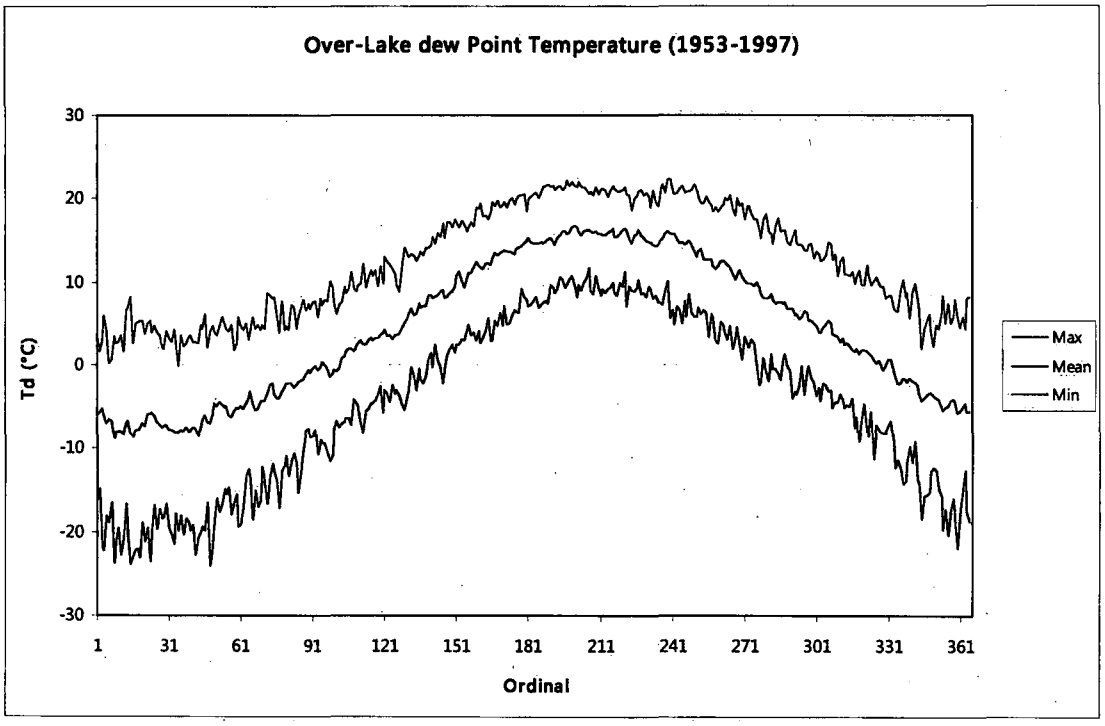

Incoming Long Wave Radiation
Ld (MJ m-2 day-1)
0
5
10
15
20
25
30
35
40
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
Year

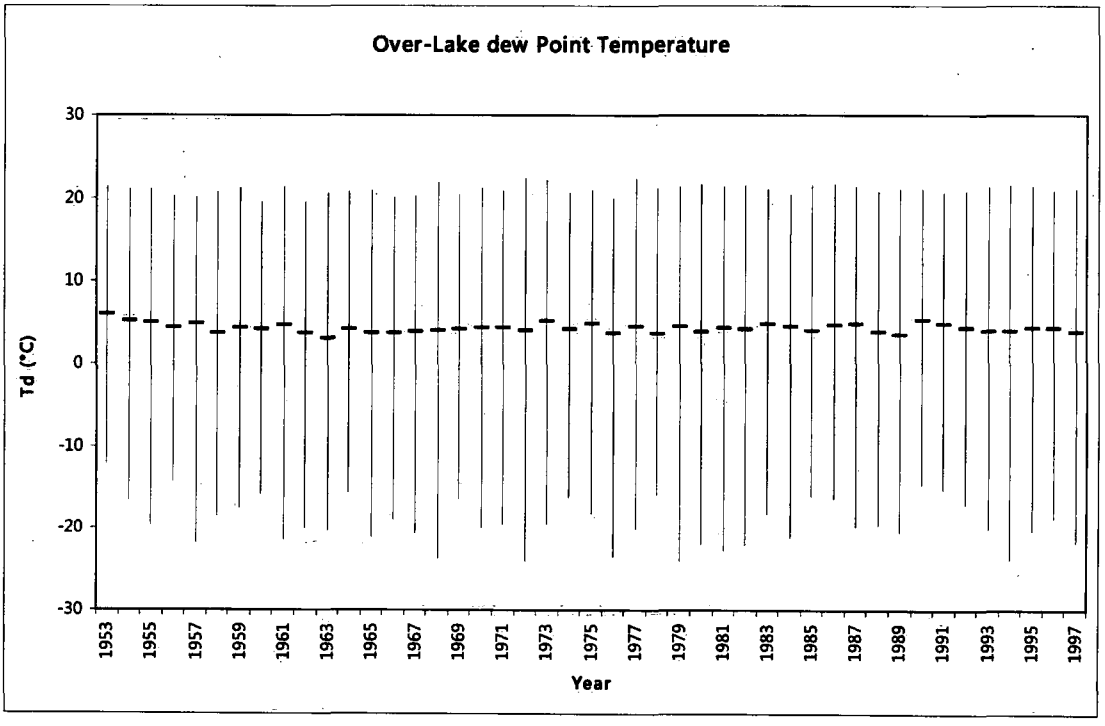

Emitted Long Wave Radiation (1953-1997)
Lu (MJ m-2 day-1)
40
35
30
25
1
31
61
91
121
151
181
211
241
271
301
331
361
Ordinal
Max
Mean
Min

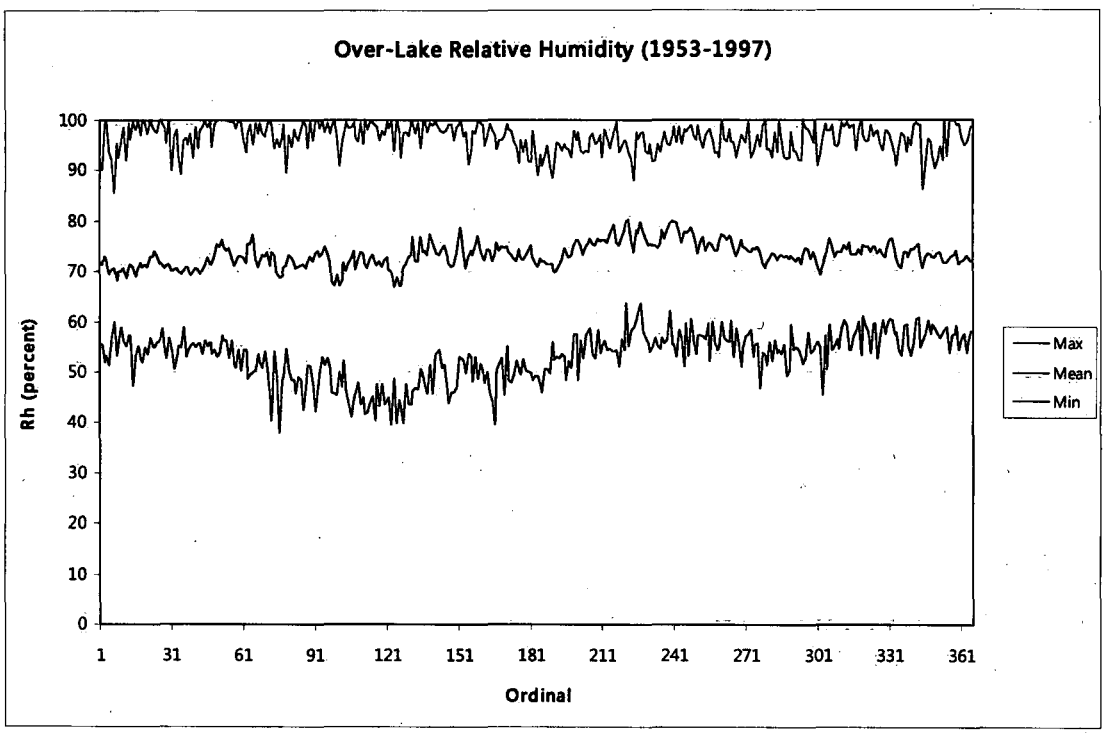

Emitted Long Wave Radiation
Lu (MJ m-2 day-1)
39
37
35
33
31
29
27
25
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
Year

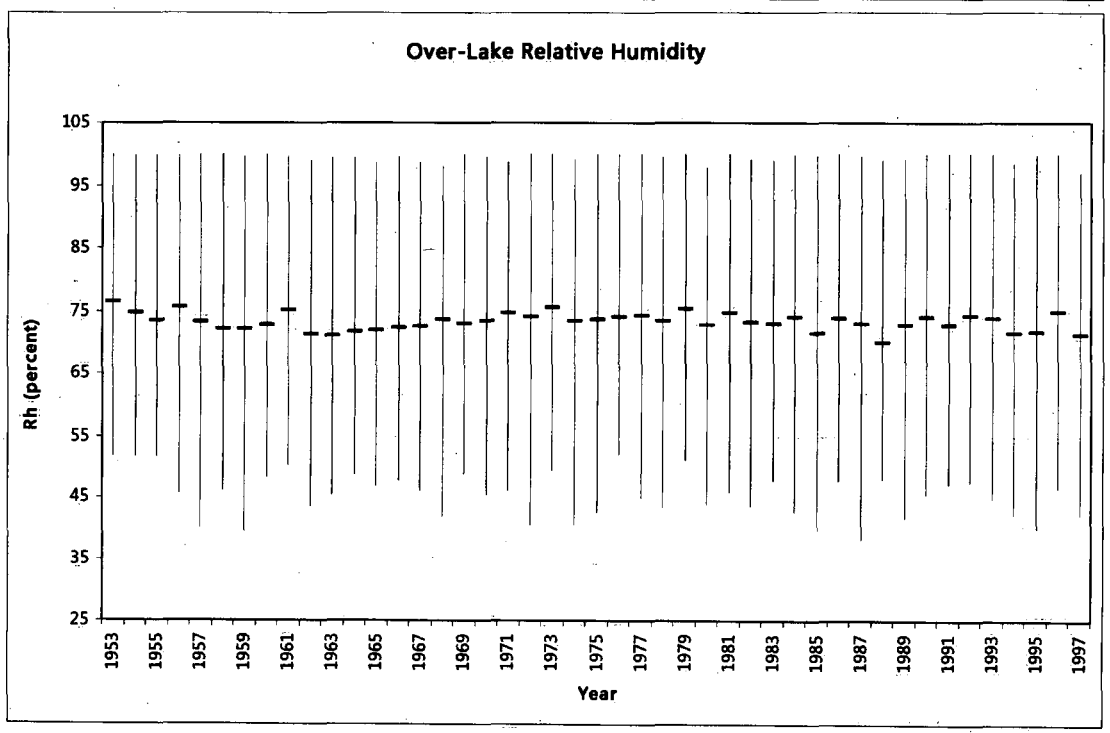

Over-Lake Air Temperature (1953-1997)
Ta (°C)
30
25
20
15
10
5
0
-5
-10
-15
-20
1
31
61
91
121
151
181
211
241
271
301
331
361
Ordinal
Max
Mean
Min

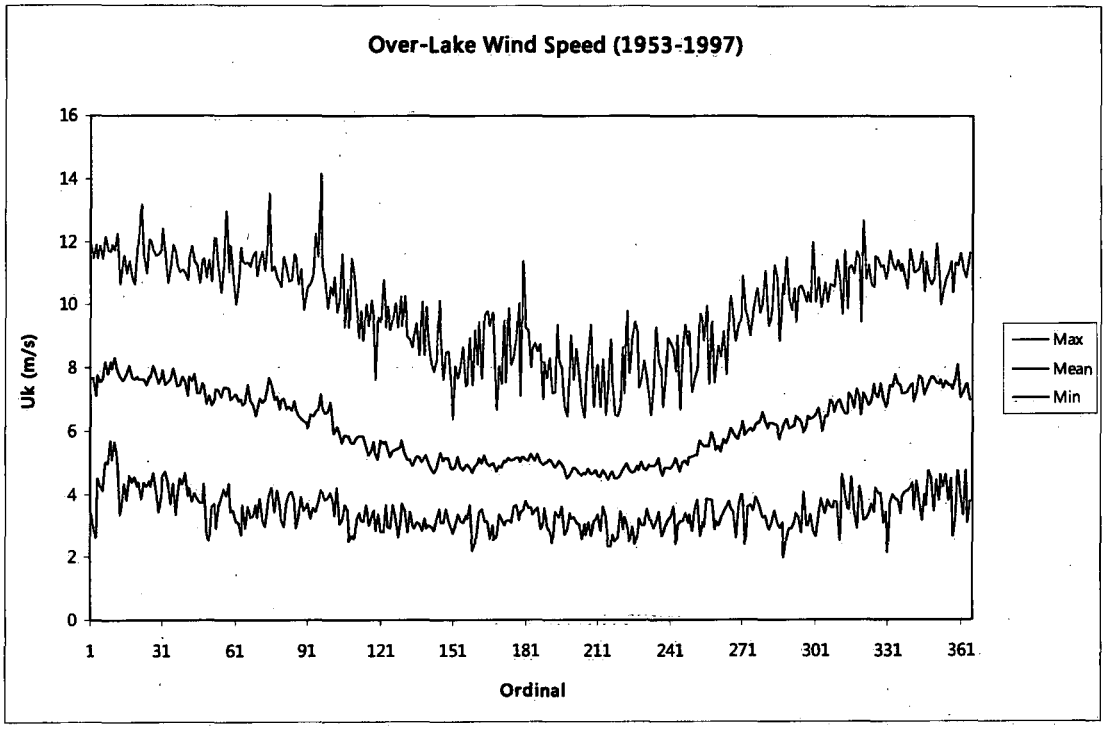

Over-Lake Air Temperature
Ta (°C)
30
25
20
15
10
5
0
-5
-10
-15
-20
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
Year

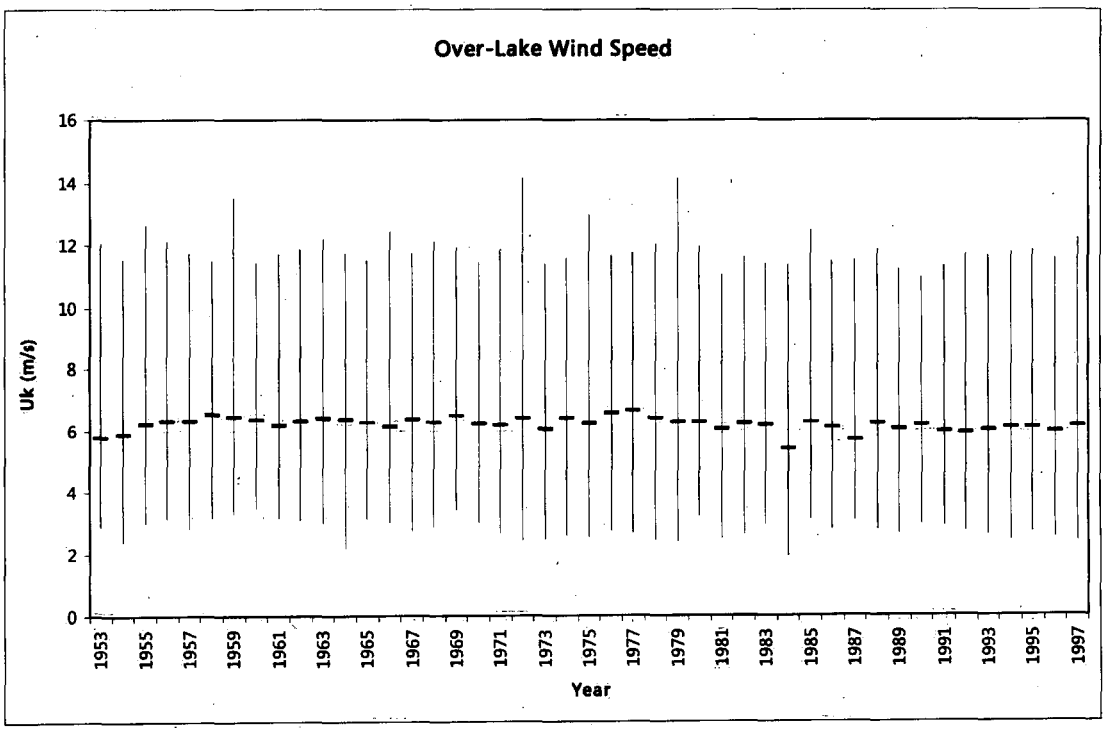

Over-Lake dew Point Temperature (1953-1997)
Td (°C)
30
20
10
0
-10
-20
-30
1
31
61
91
121
151
181
211
241
271
301
331
361
Ordinal
Max
Mean
Min

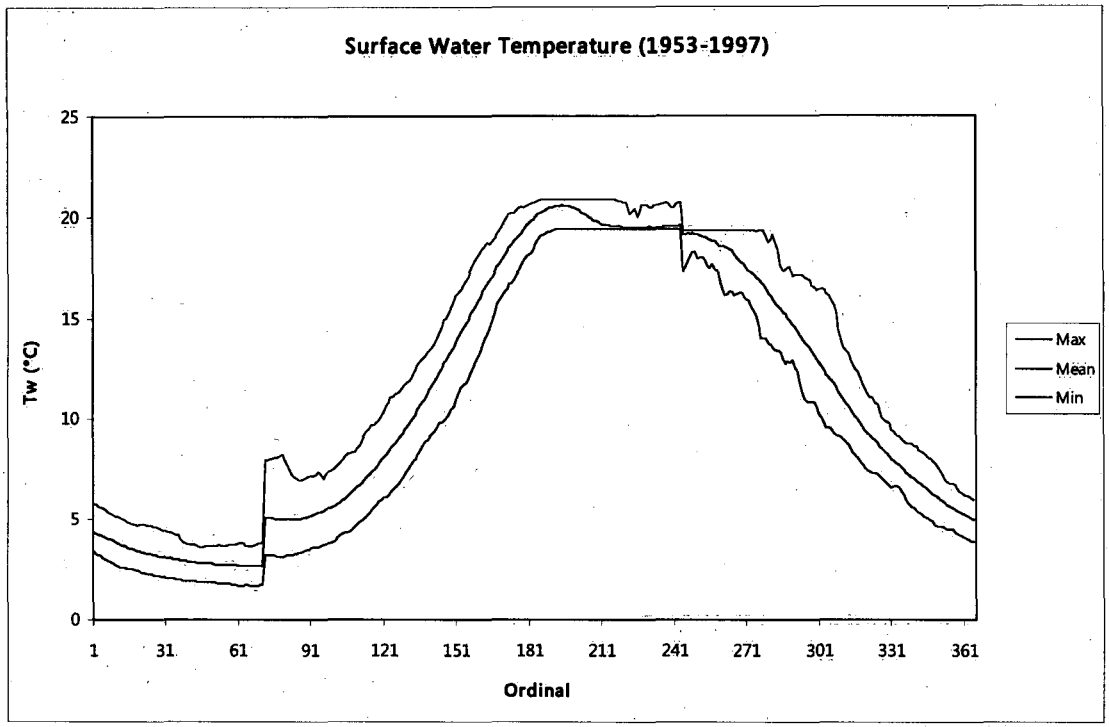

Over-Lake dew Point Temperature
Td (°C)
30
20
10
0
-10
-20
-30
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
Year

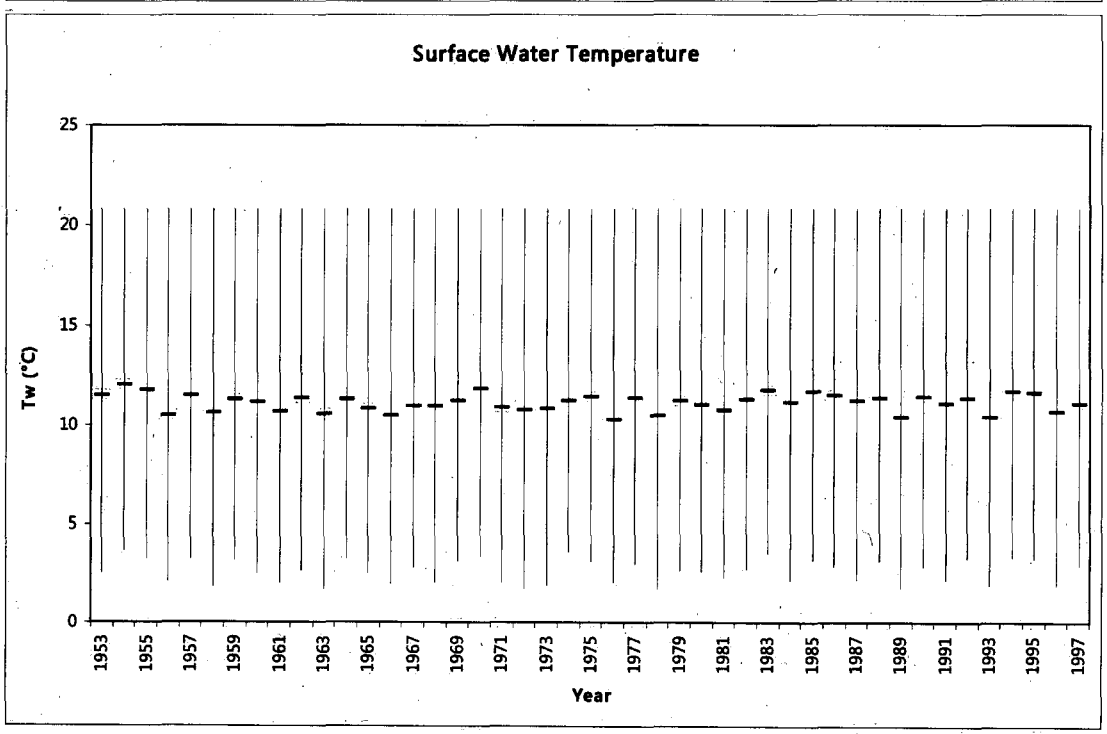

Over-Lake Relative Humidity (1953-1997)
Rh (percent)
100
90
80
70
60
50
40
30
20
10
0
1
31
61
91
121
151
181
211
241
271
301
331
361
Ordinal
Max
Mean
Min

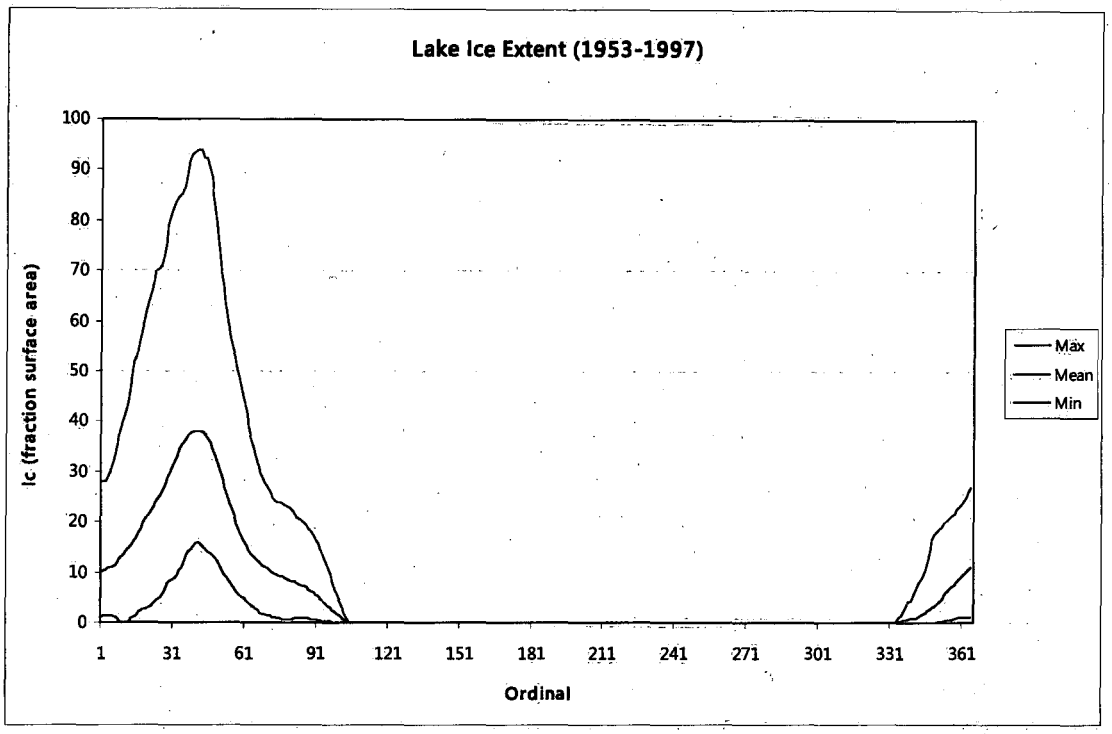

Over-Lake Relative Humidity
Rh (percent)
105
95
85
75
65
55
45
35
25
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
Year

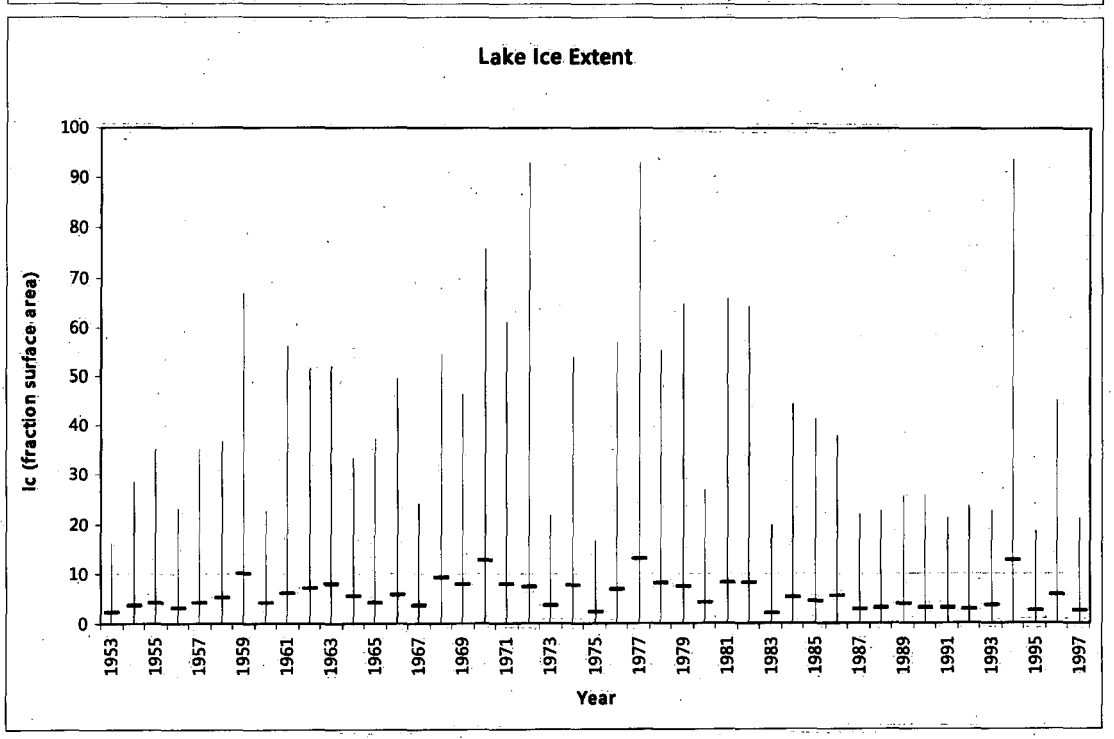

Over-Lake Wind Speed (1953-1997)
Uk (m/s)
Ordinal
Max
Mean
Min

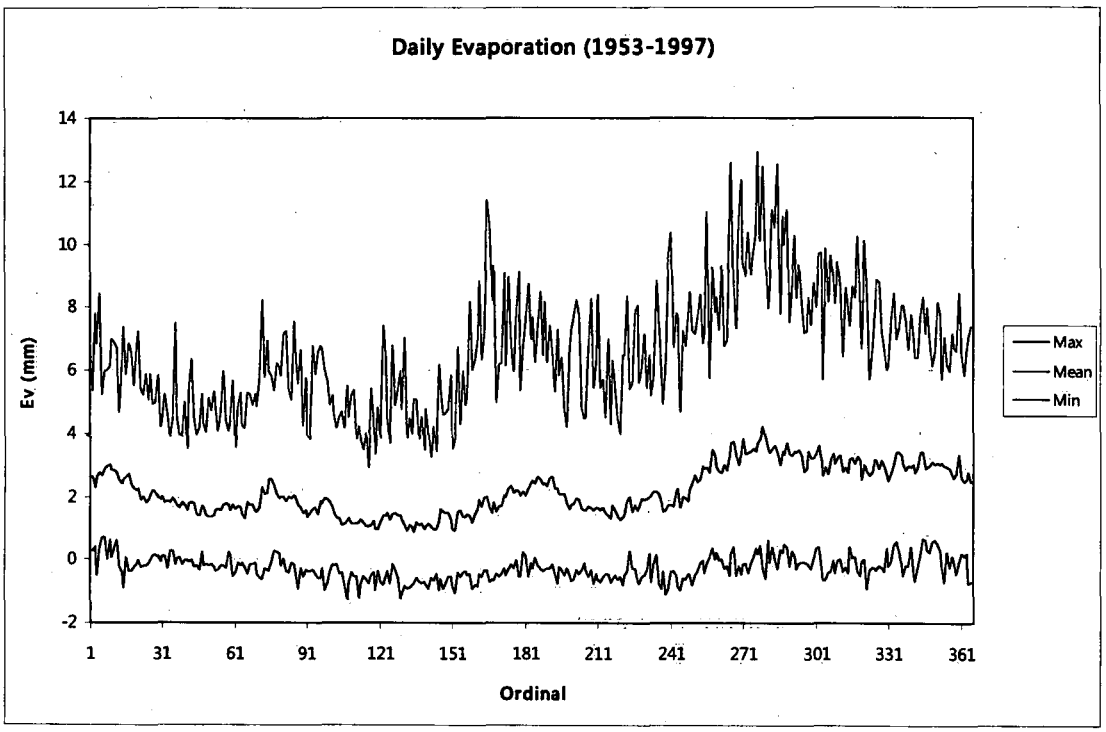

Over-Lake Wind Speed
Uk (m/s)
Year

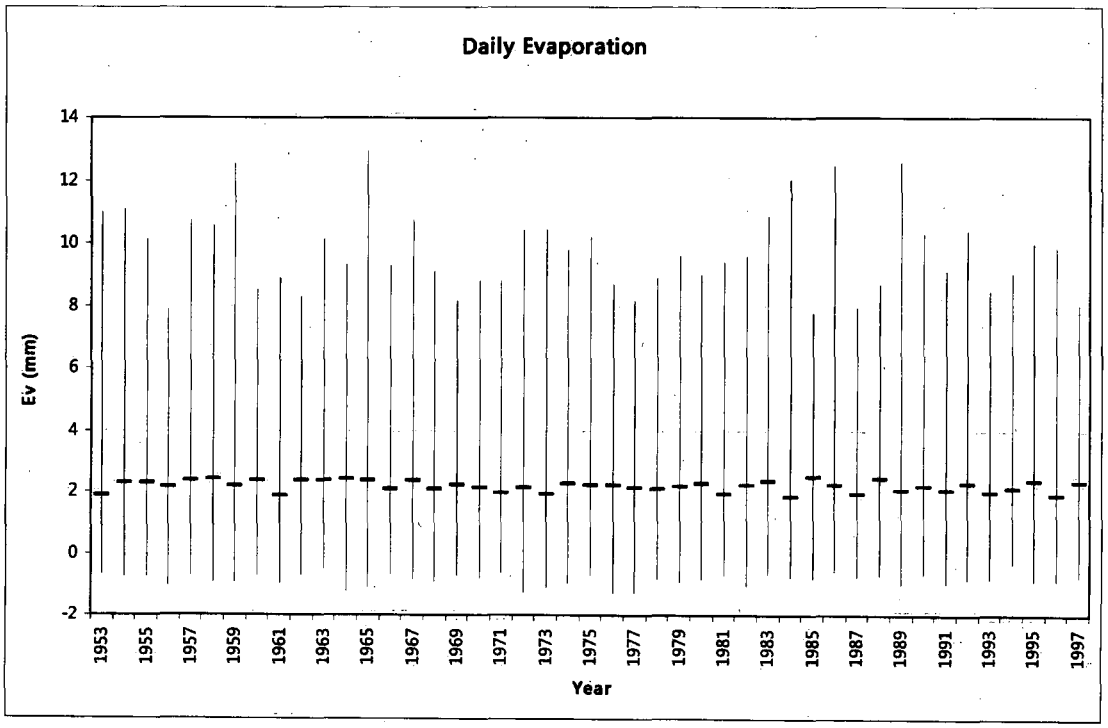

Surface Water Temperature (1953-1997)
Tw (°C)
25
20
15
10
5
0
1
31
61
91
121
151
181
211
241
271
301
331
361
Ordinal
Max
Mean
Min

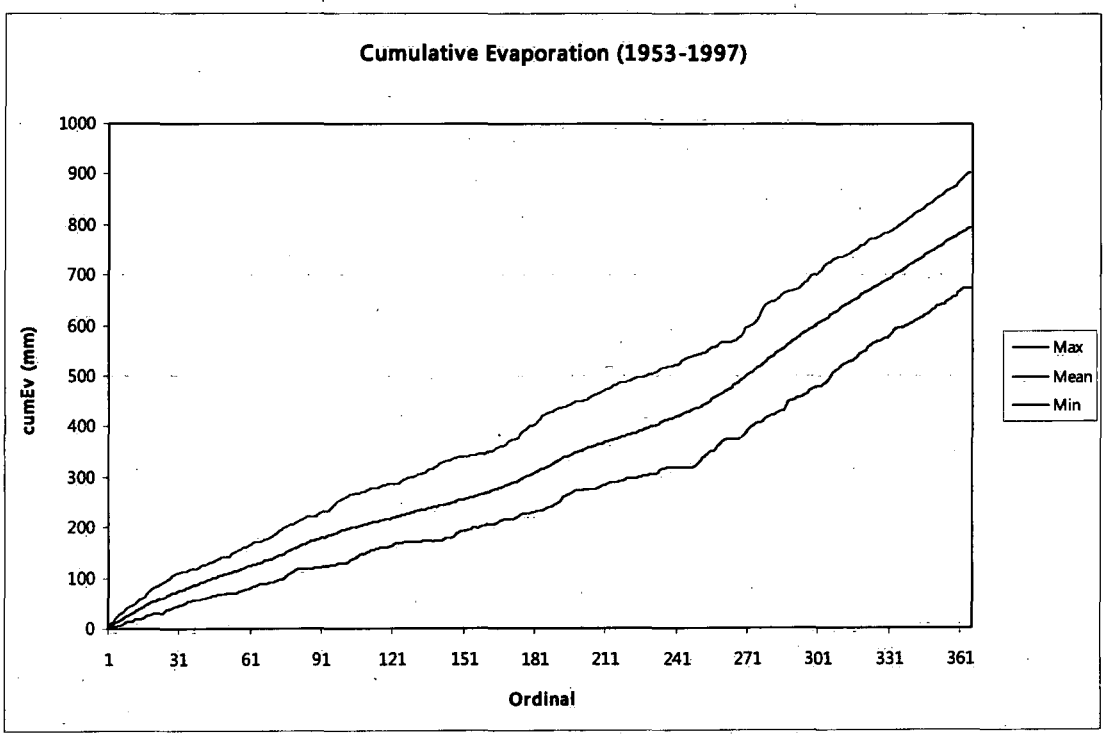

Surface Water Temperature
Tw (°C)
25
20
15
10
5
0
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
Year

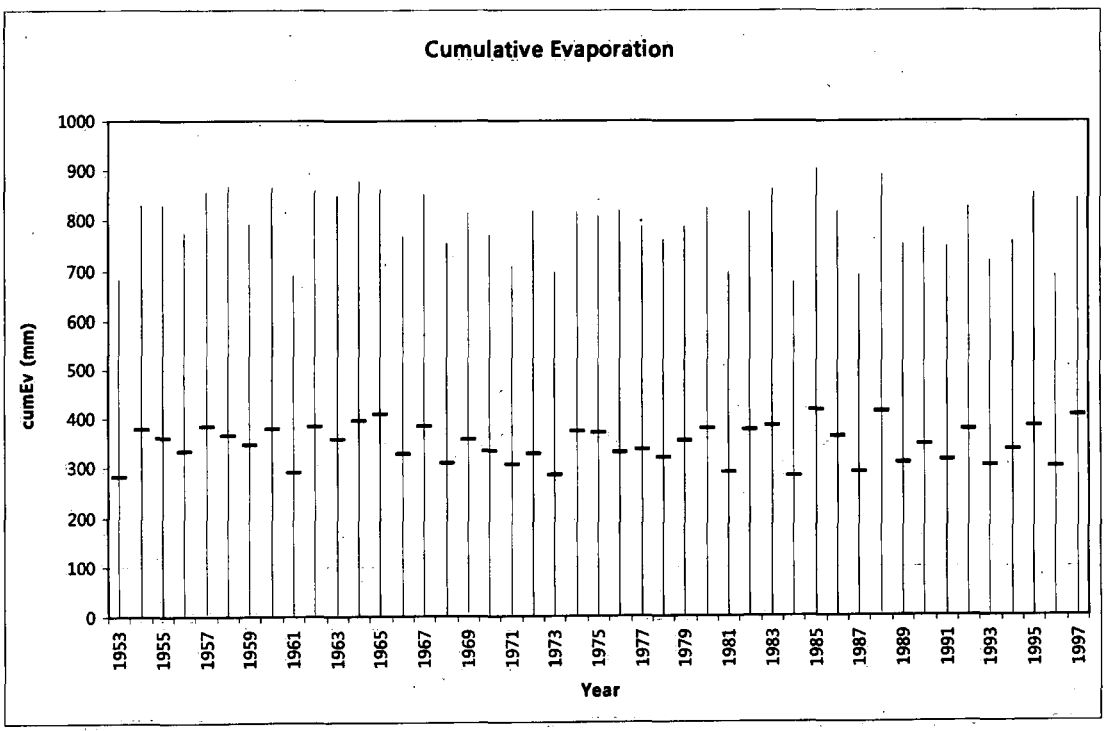

Lake Ice Extent (1953-1997)
Ic (fraction surface area)
Ordinal
Max
Mean
Min


Lake Ice Extent
Ic (fraction surface area)
Year

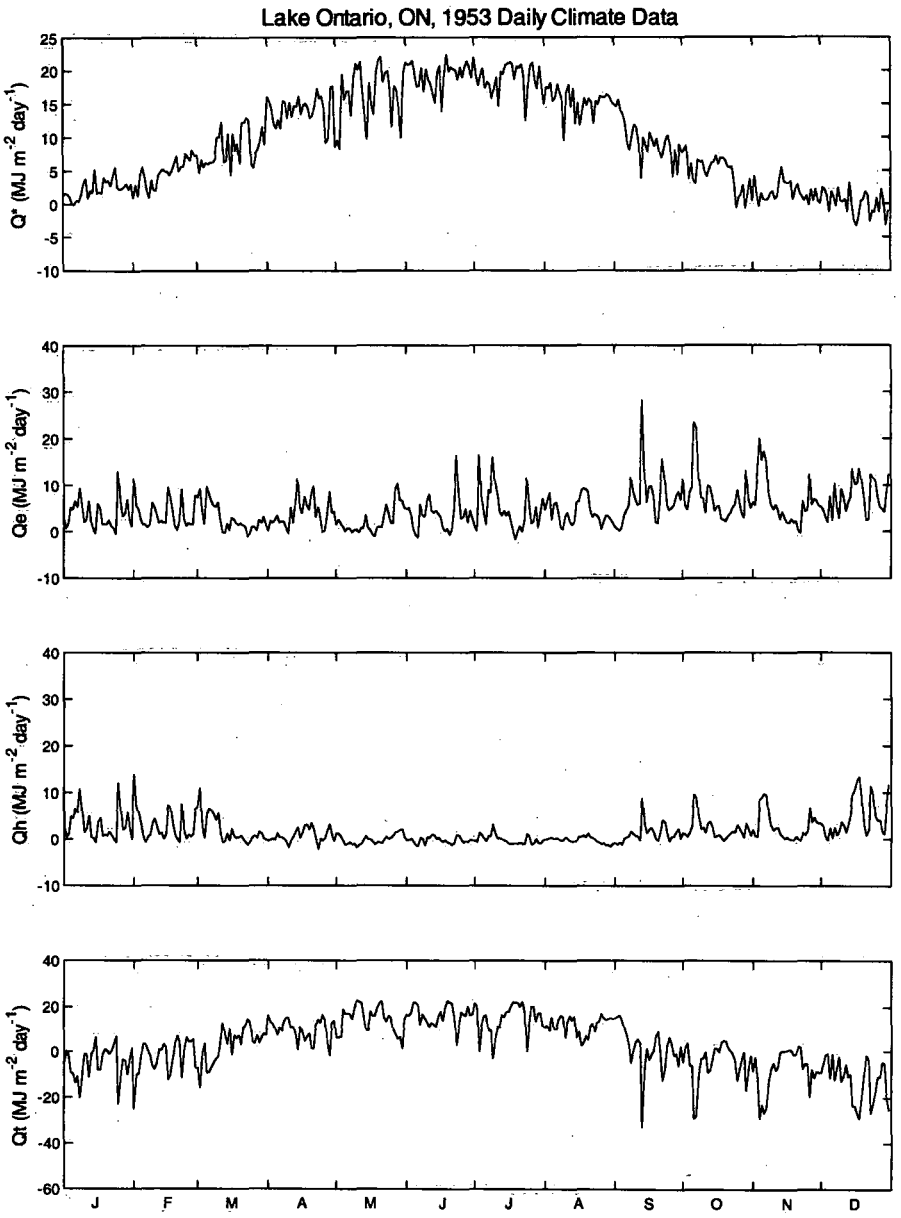

Daily Evaporation (1953-1997)
Ev (mm)
14
12
10
8
6
4
2
0
-2
1
31
61
91
121
151
181
211
241
271
301
331
361
Ordinal
Max
Mean
Min

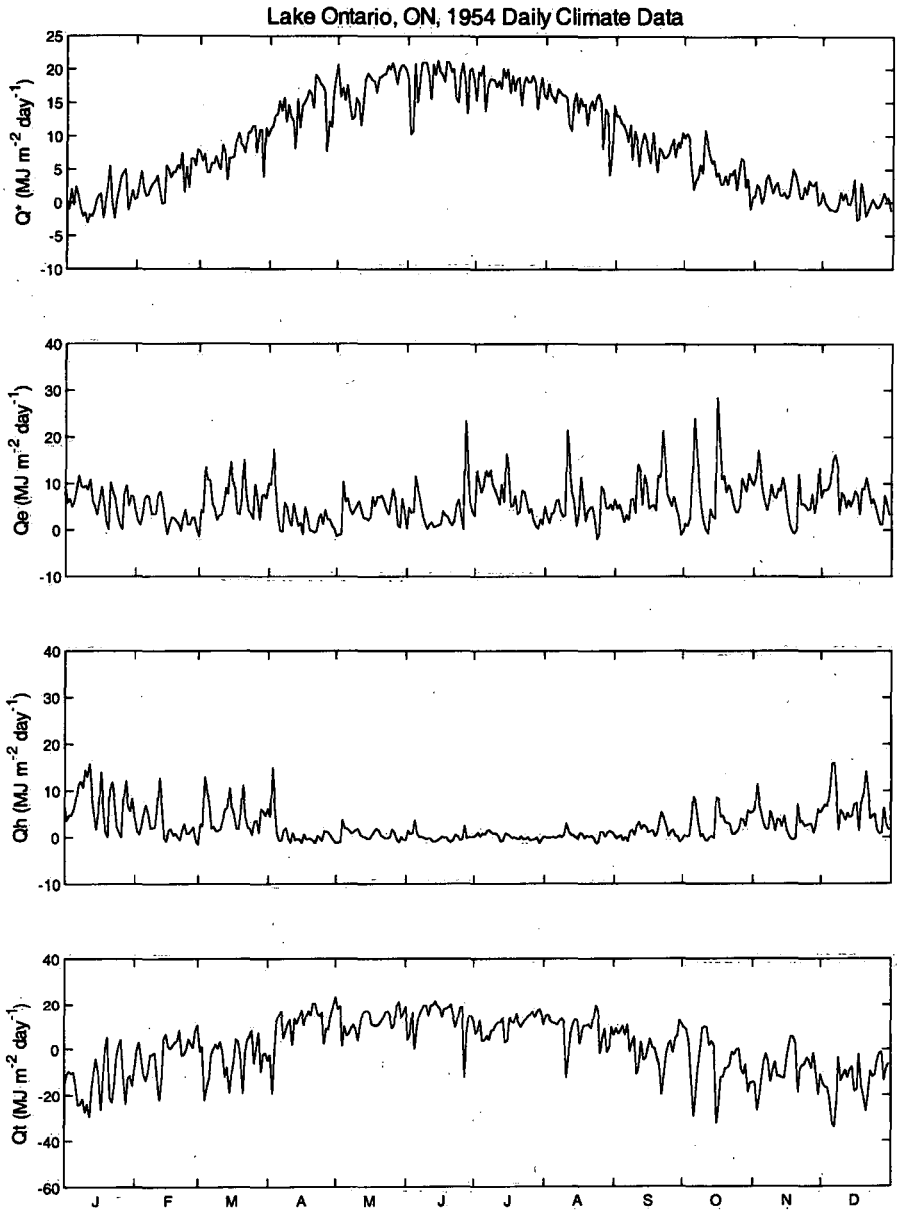

Daily Evaporation
Ev (mm)
14
12
10
8
6
4
2
0
-2
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
Year

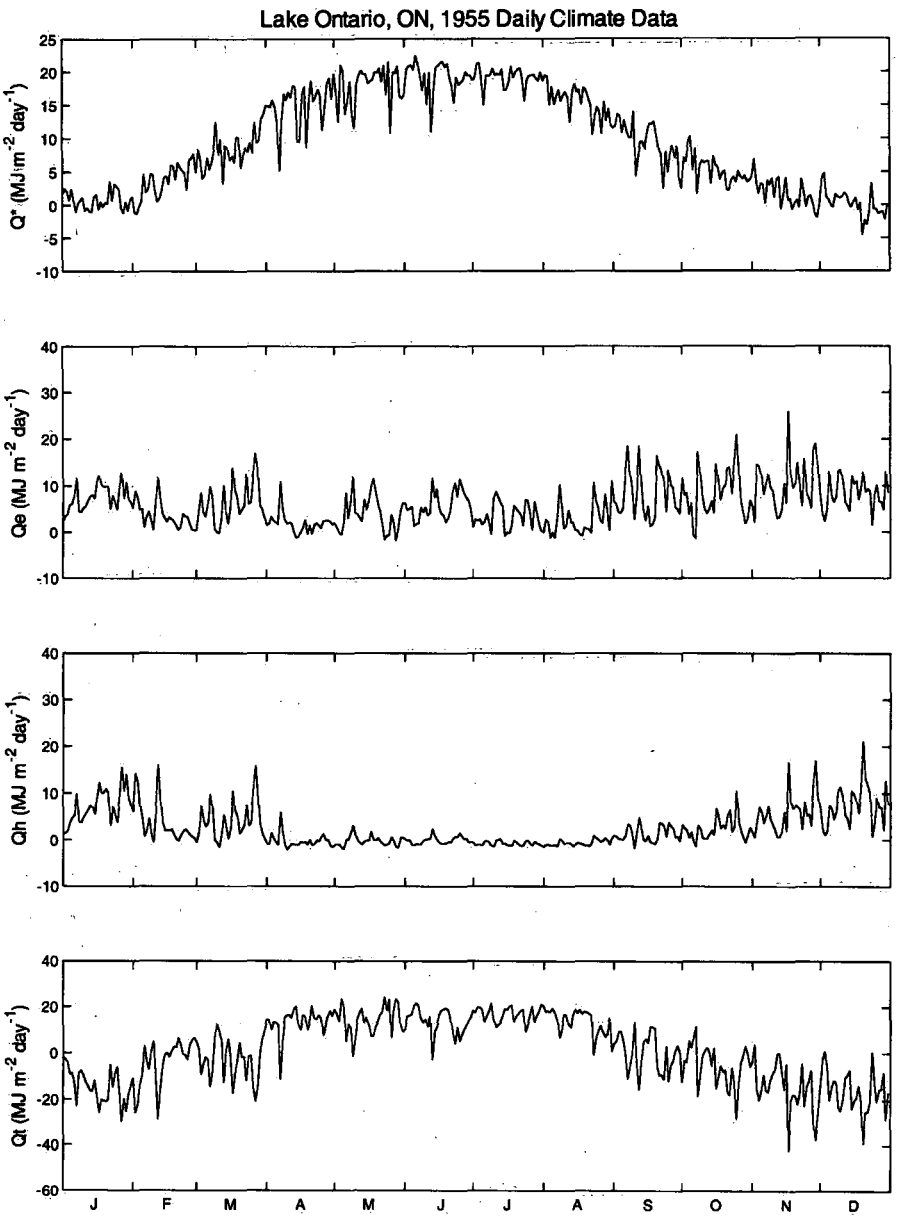

Cumulative Evaporation (1953-1997)
cumEv (mm)
1000
900
800
700
600
500
400
300
200
100
0
1
31
61
91
121
151
181
211
241
271
301
331
361
Ordinal
Max
Mean
Min

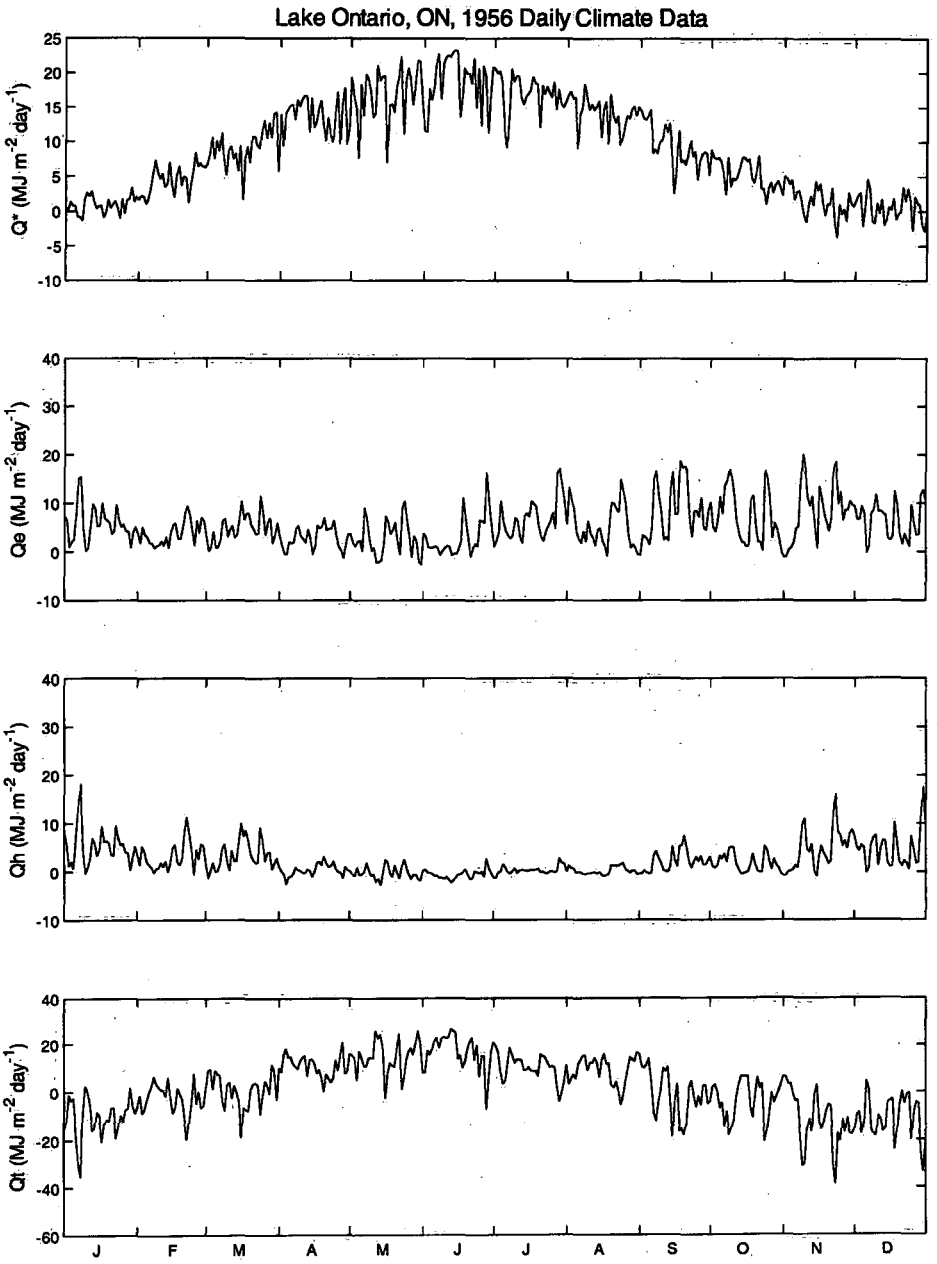

Cumulative Evaporation
cumEv (mm)
1000
900
800
700
600
500
400
300
200
100
0
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
Year

Appendix 2
Heat Fluxes




Lake Ontario, ON, 1954 Daily Climate Data
Q* (MJ m-2 day-1)
Qe (MJ m-2 day-1)
Qh (MJ m-2 day-1)
Qt (MJ m-2 day-1)
J
F
M
A
M
J
J
A
S
O
N
D


Lake Ontario, ON, 1955 Daily Climate Data
Q* (MJ m-2 day-1)
Qe (MJ m-2 day-1)
Qh (MJ m-2 day-1)
Qt (MJ m-2 day-1)
J
F
M
A
M
J
J
A
S
O
N
D


Lake Ontario, ON, 1956 Daily Climate Data
Q* (MJ m-2 day-1)
Qe (MJ m-2 day-1)
Qh (MJ m-2 day-1)
Qt (MJ m-2 day-1)
J
F
M
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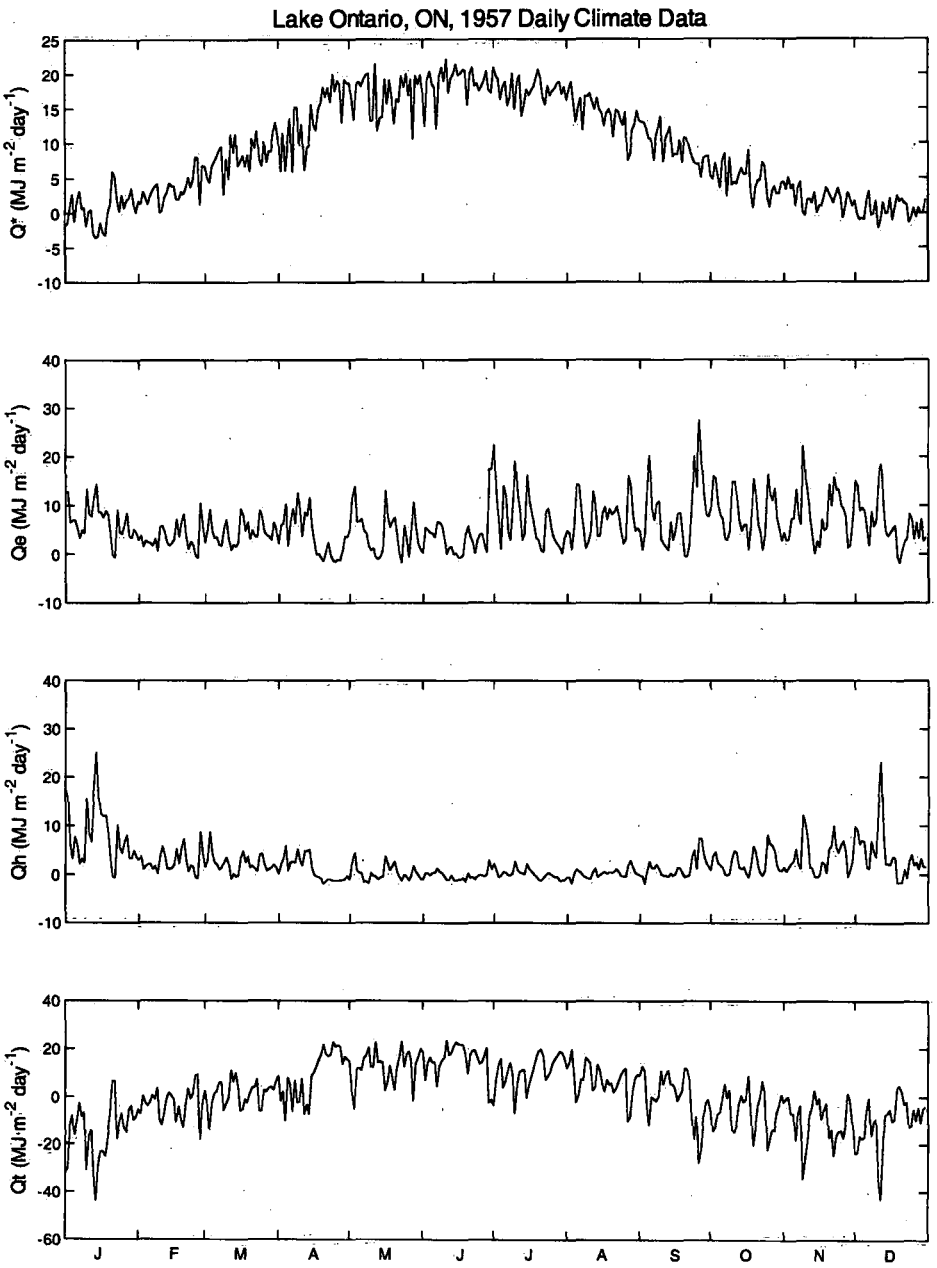
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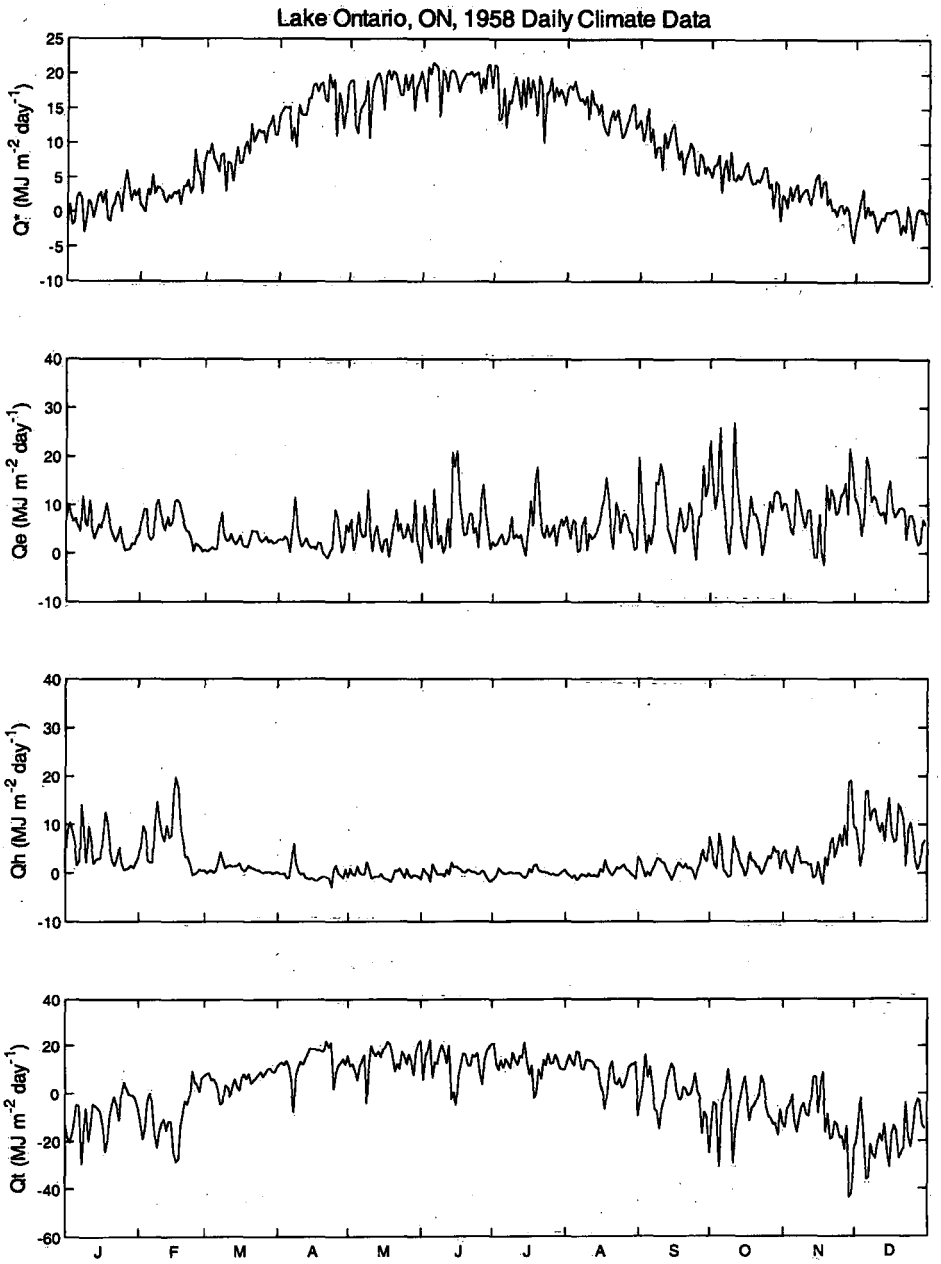
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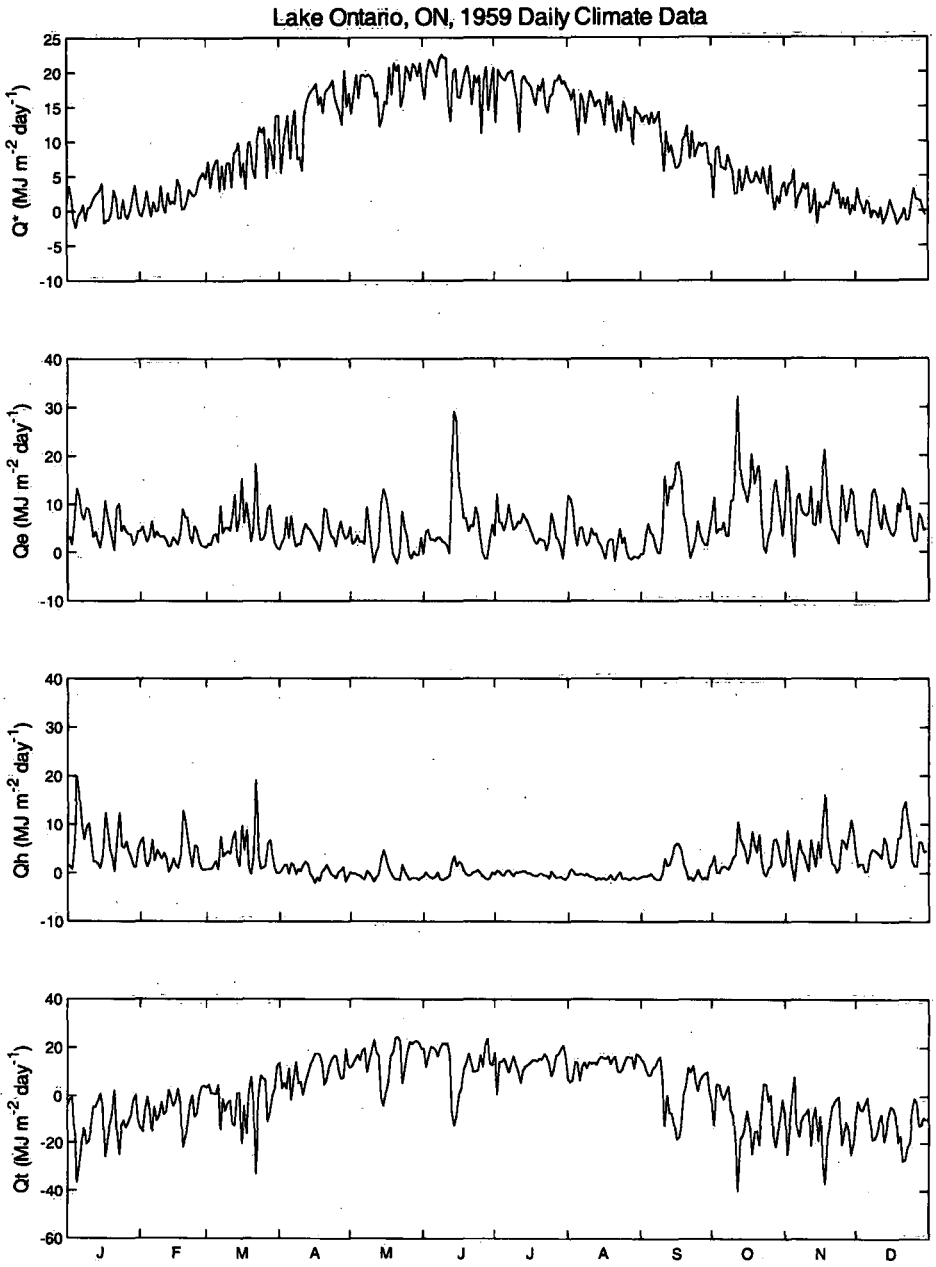
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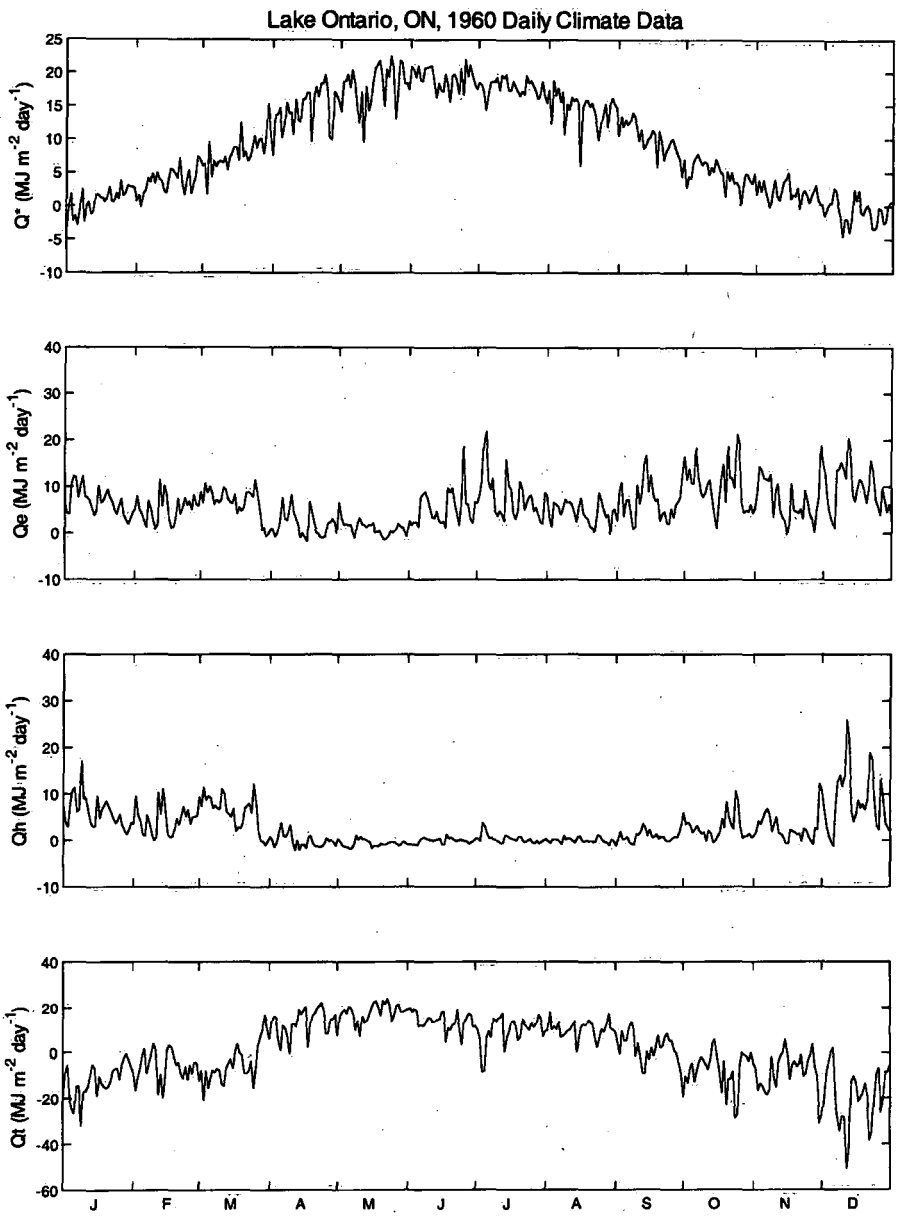
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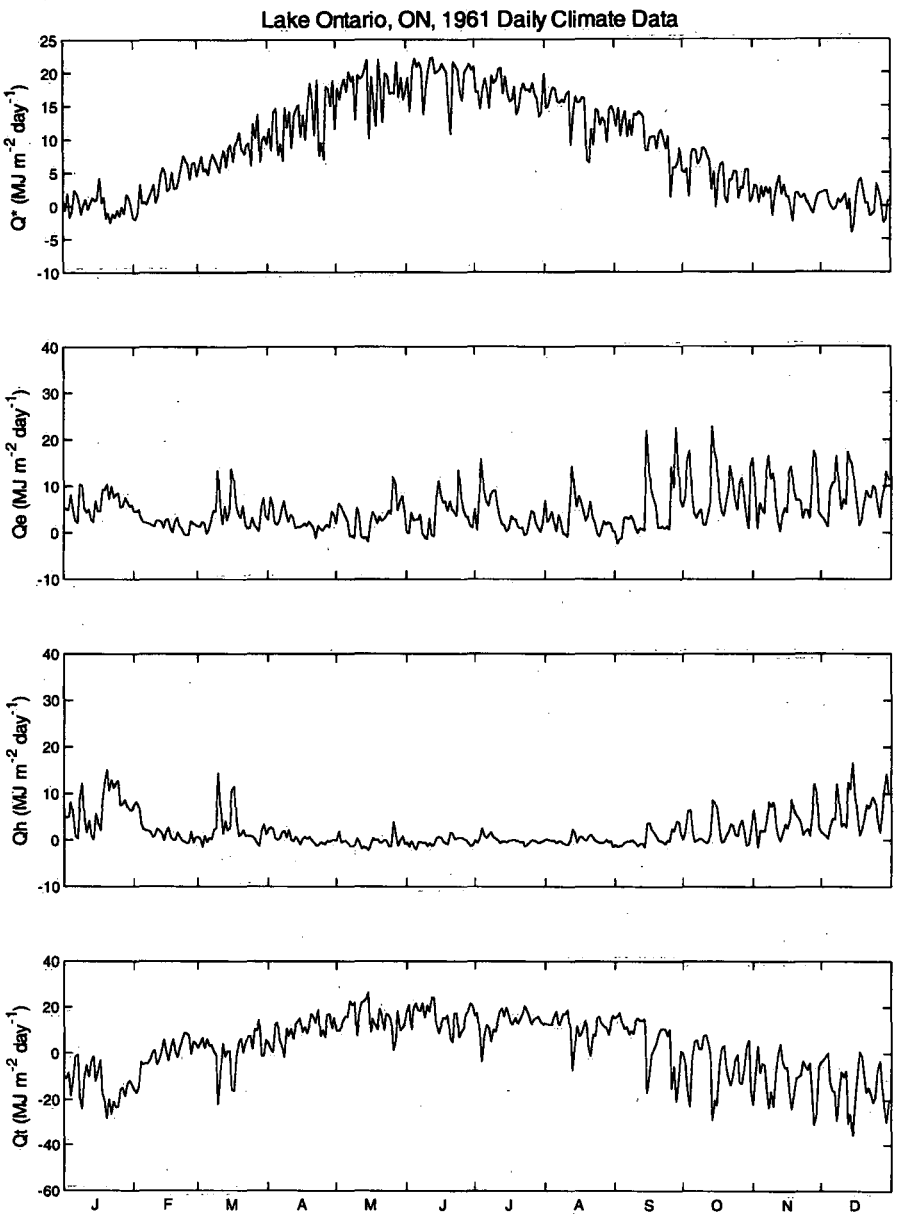
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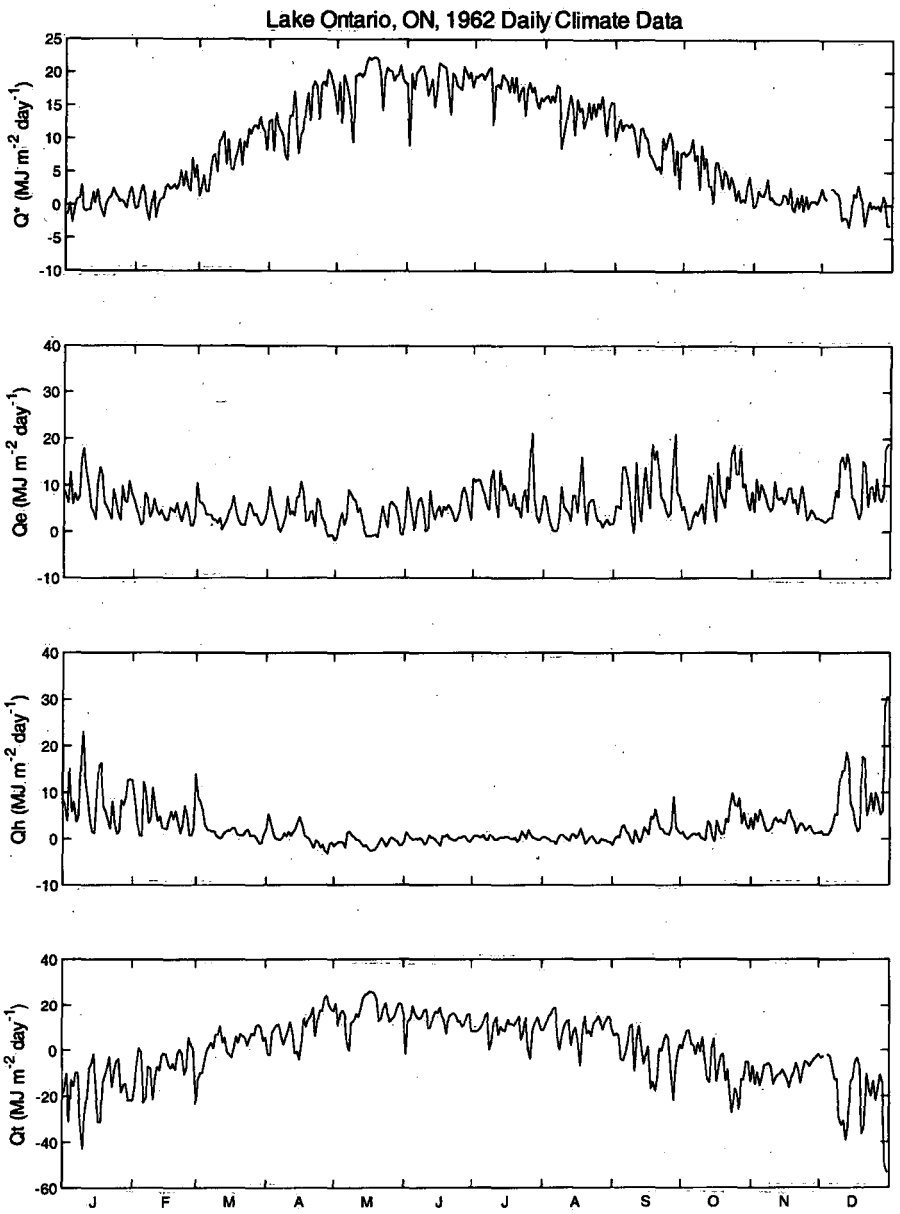
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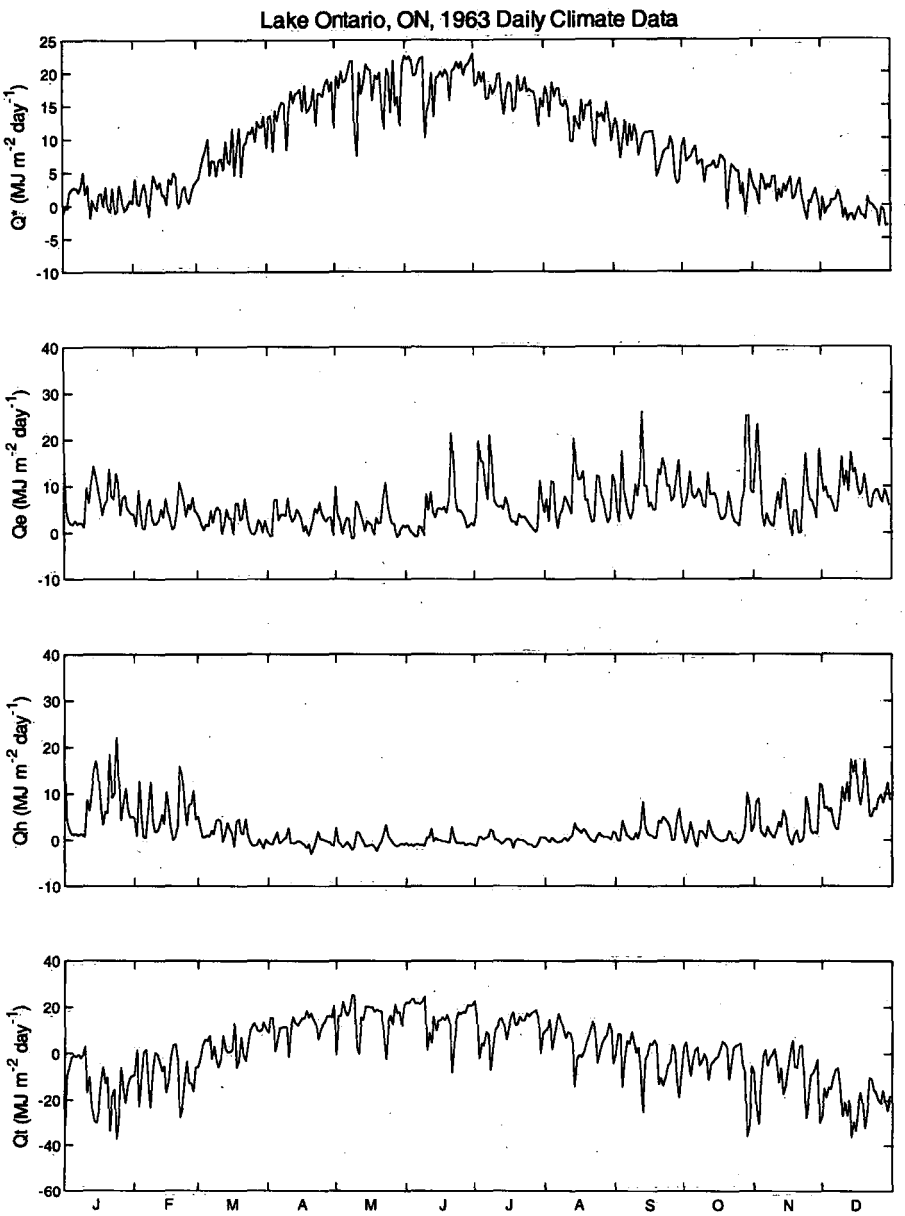
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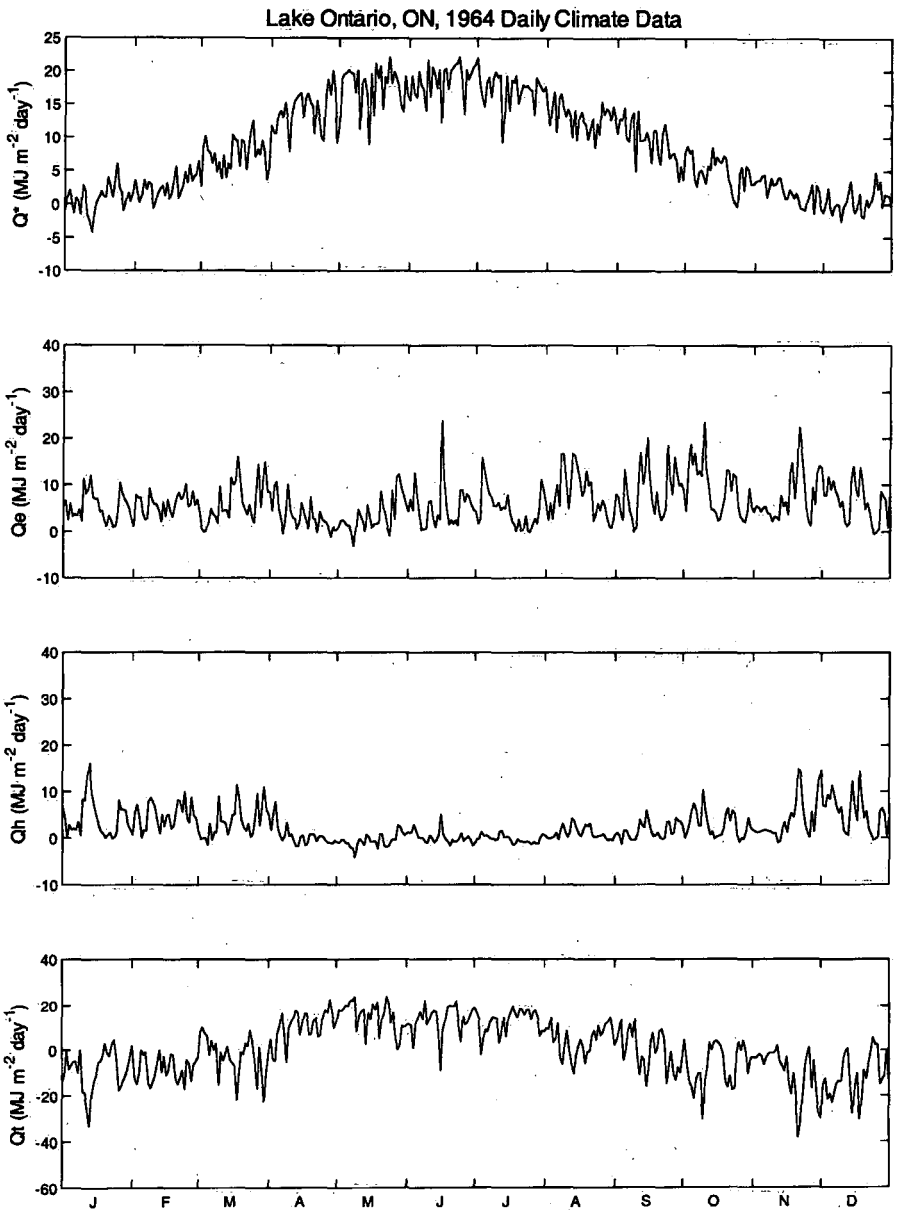
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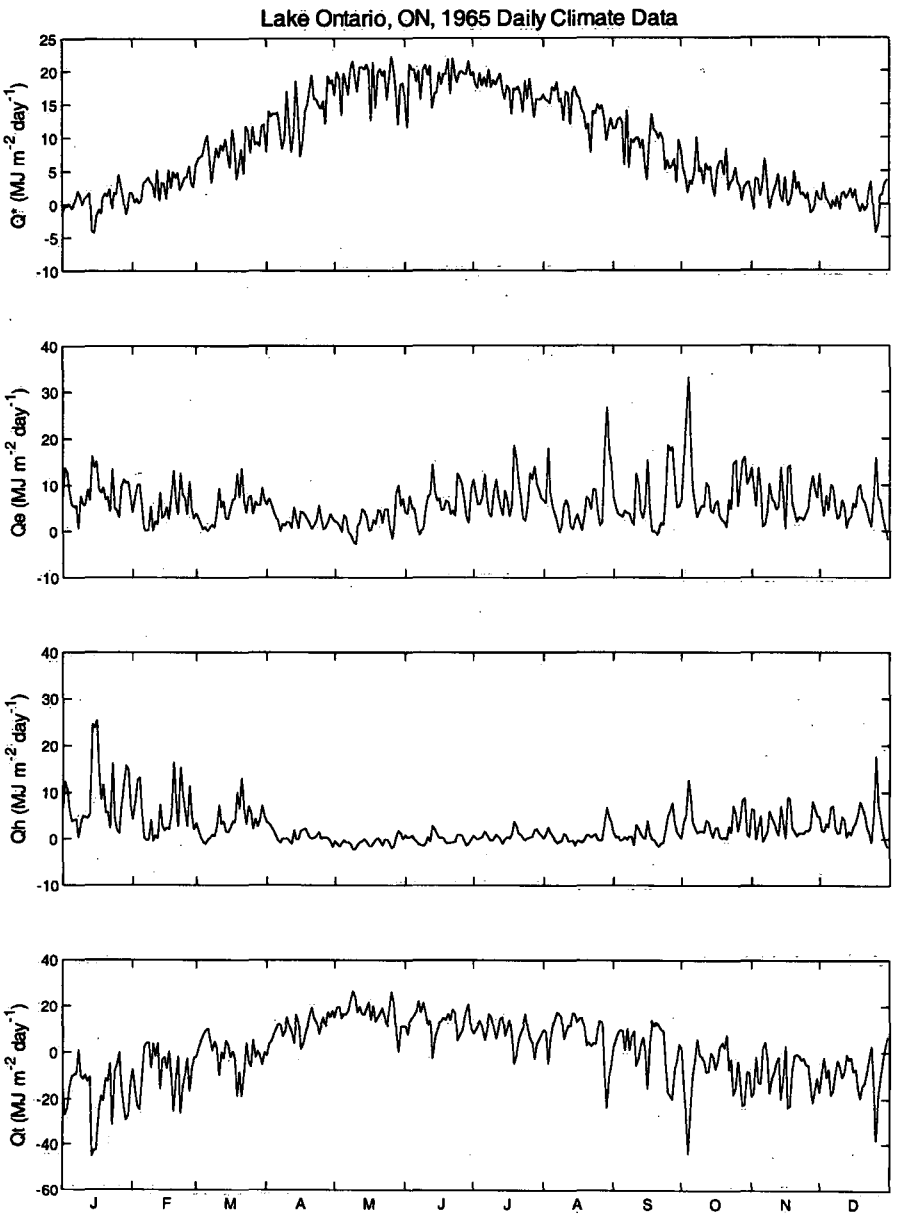
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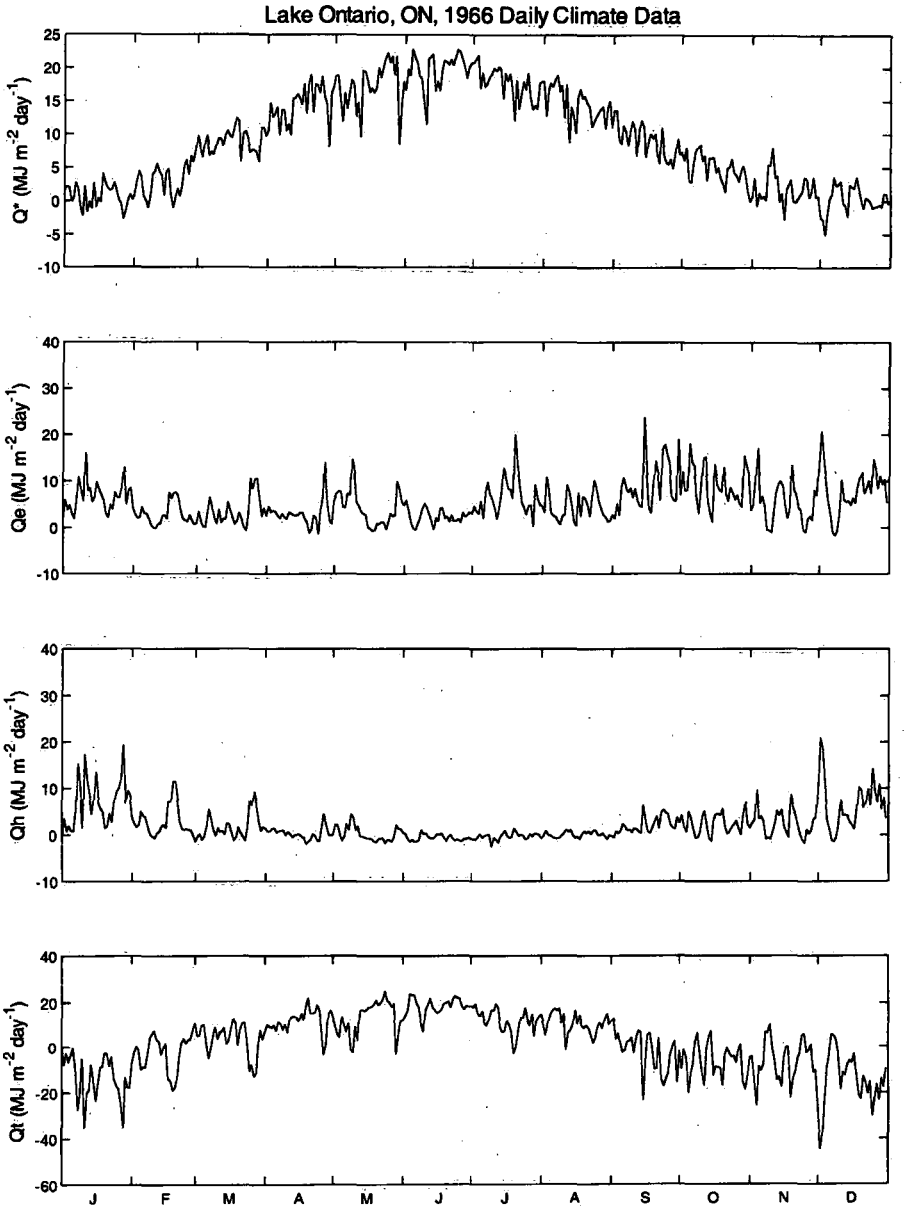
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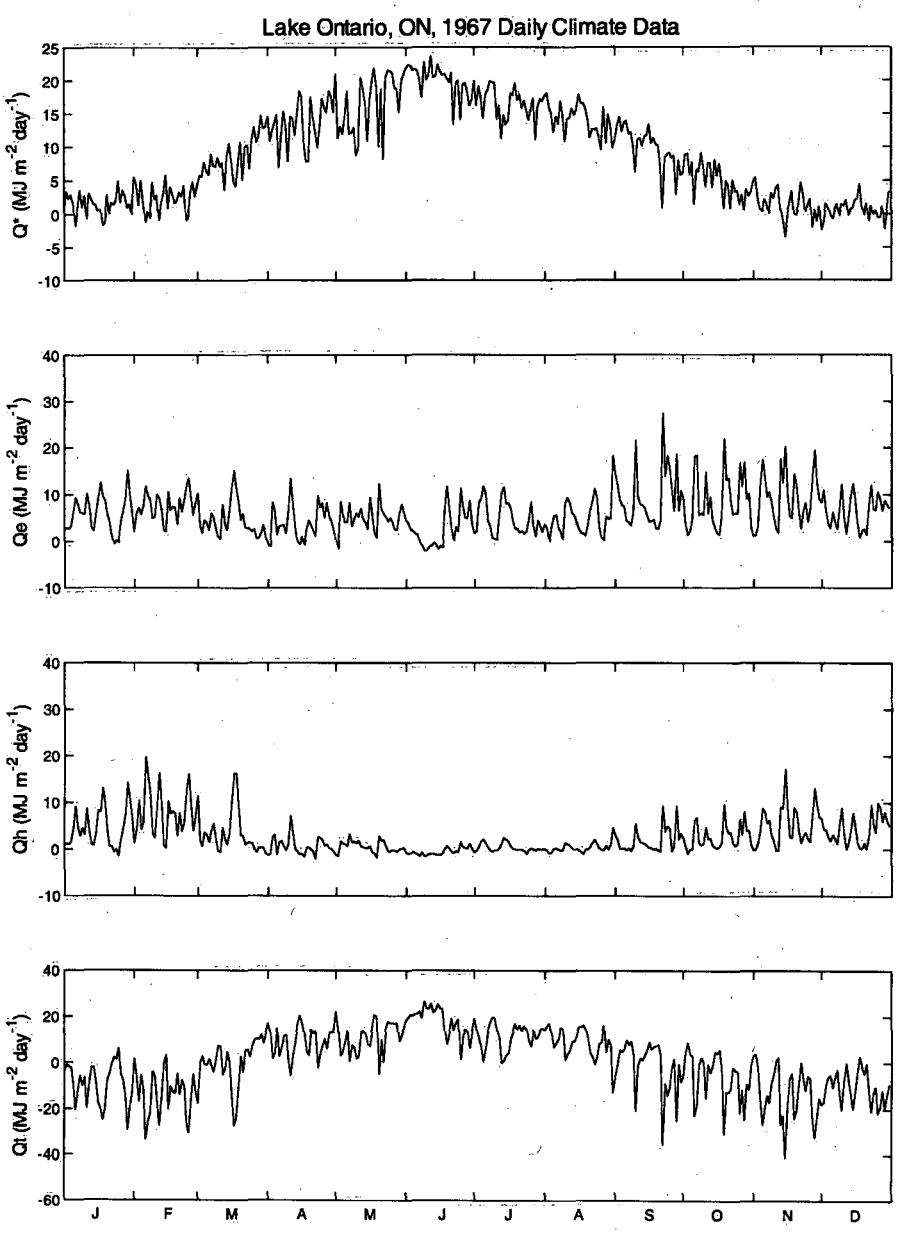
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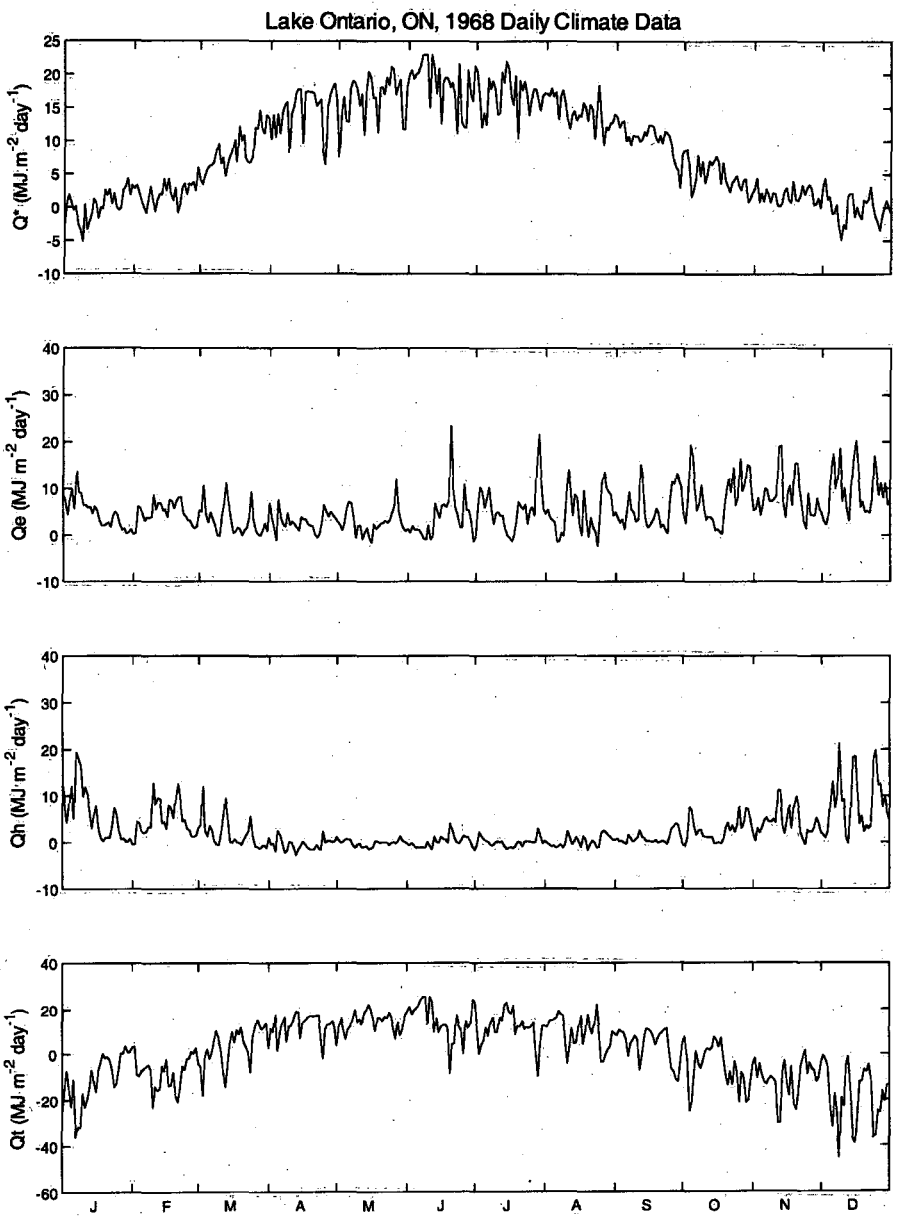
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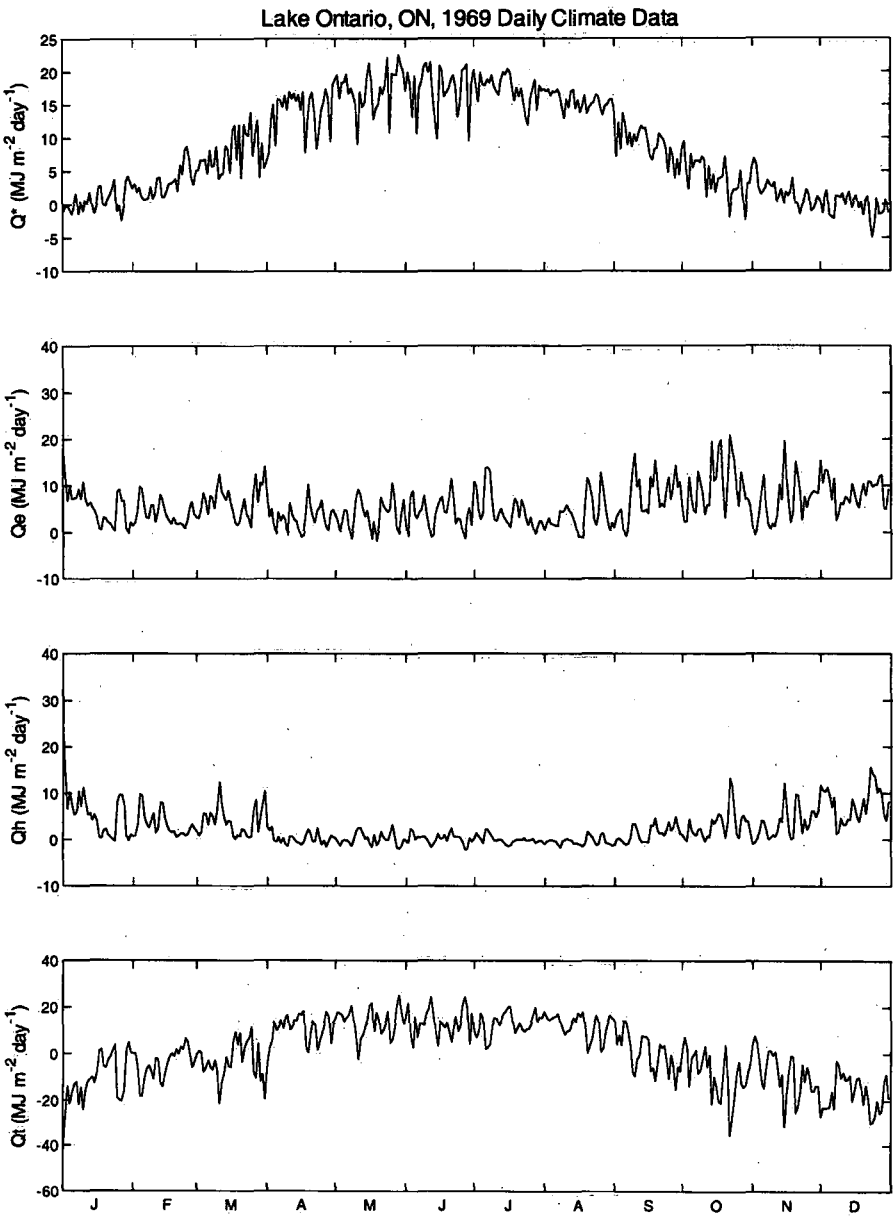
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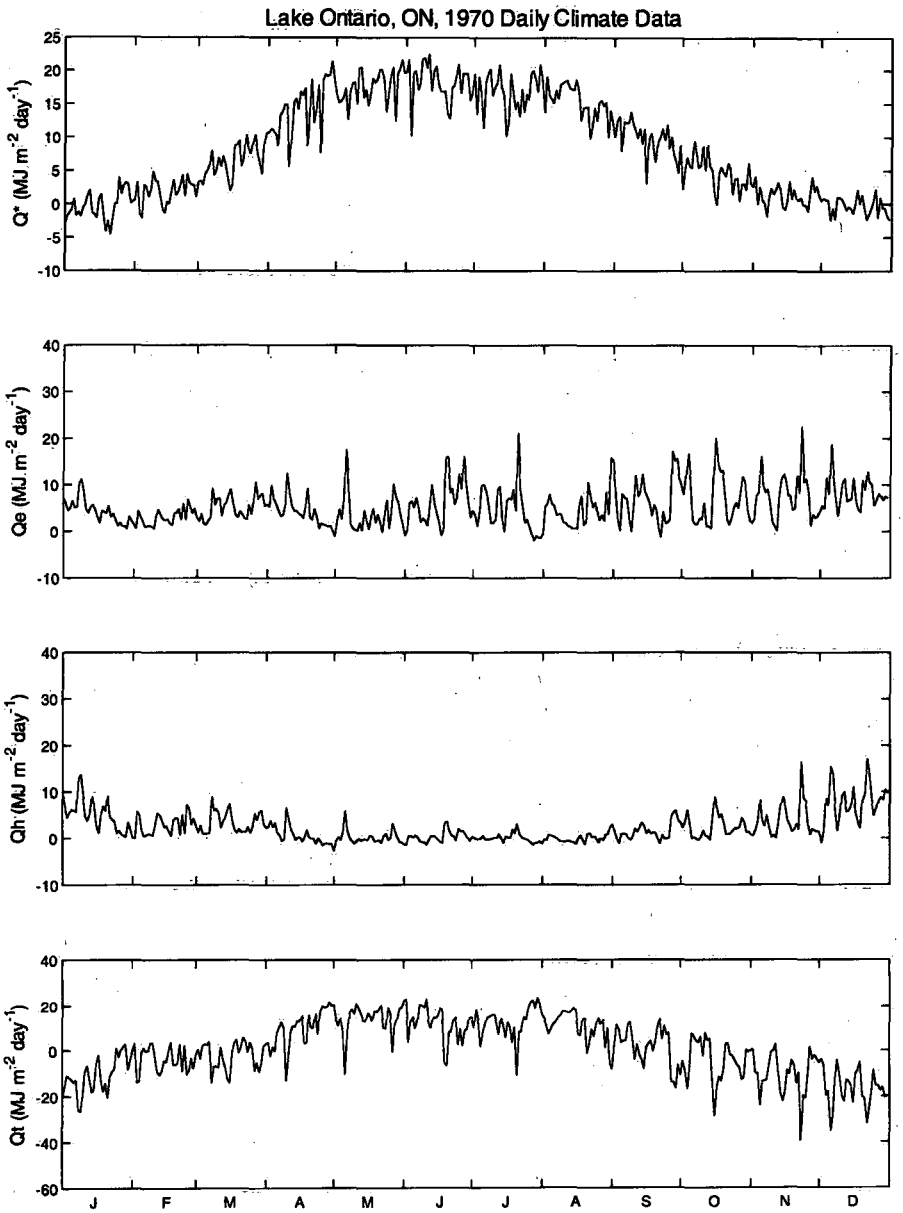
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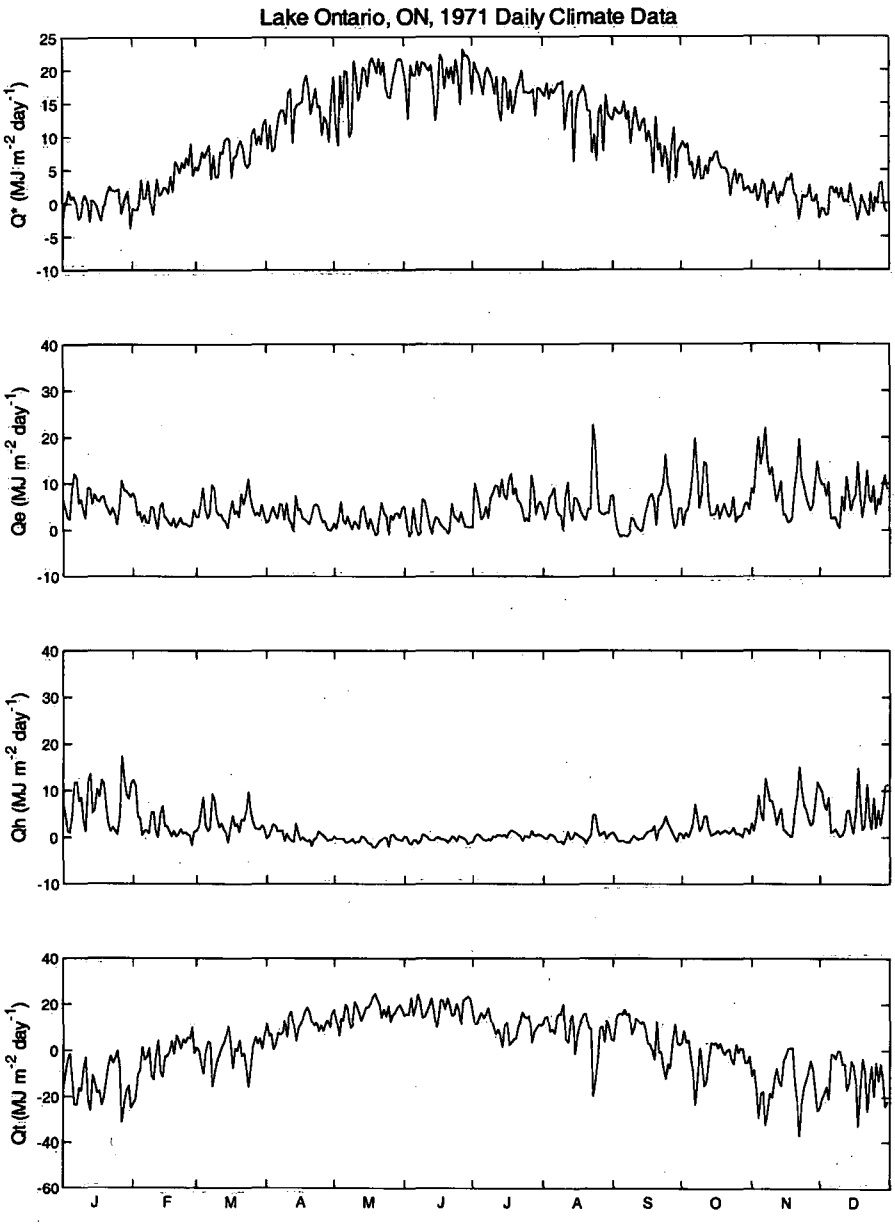
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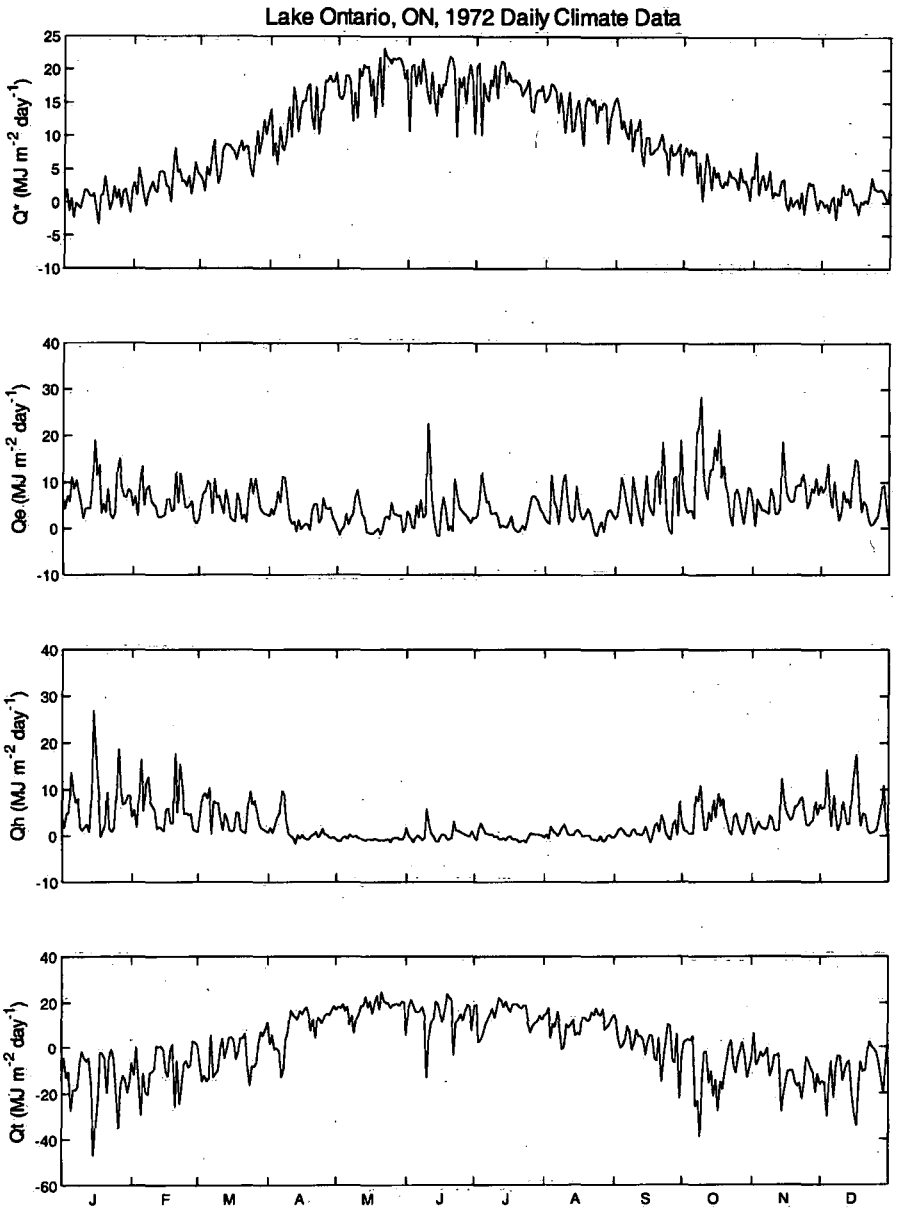
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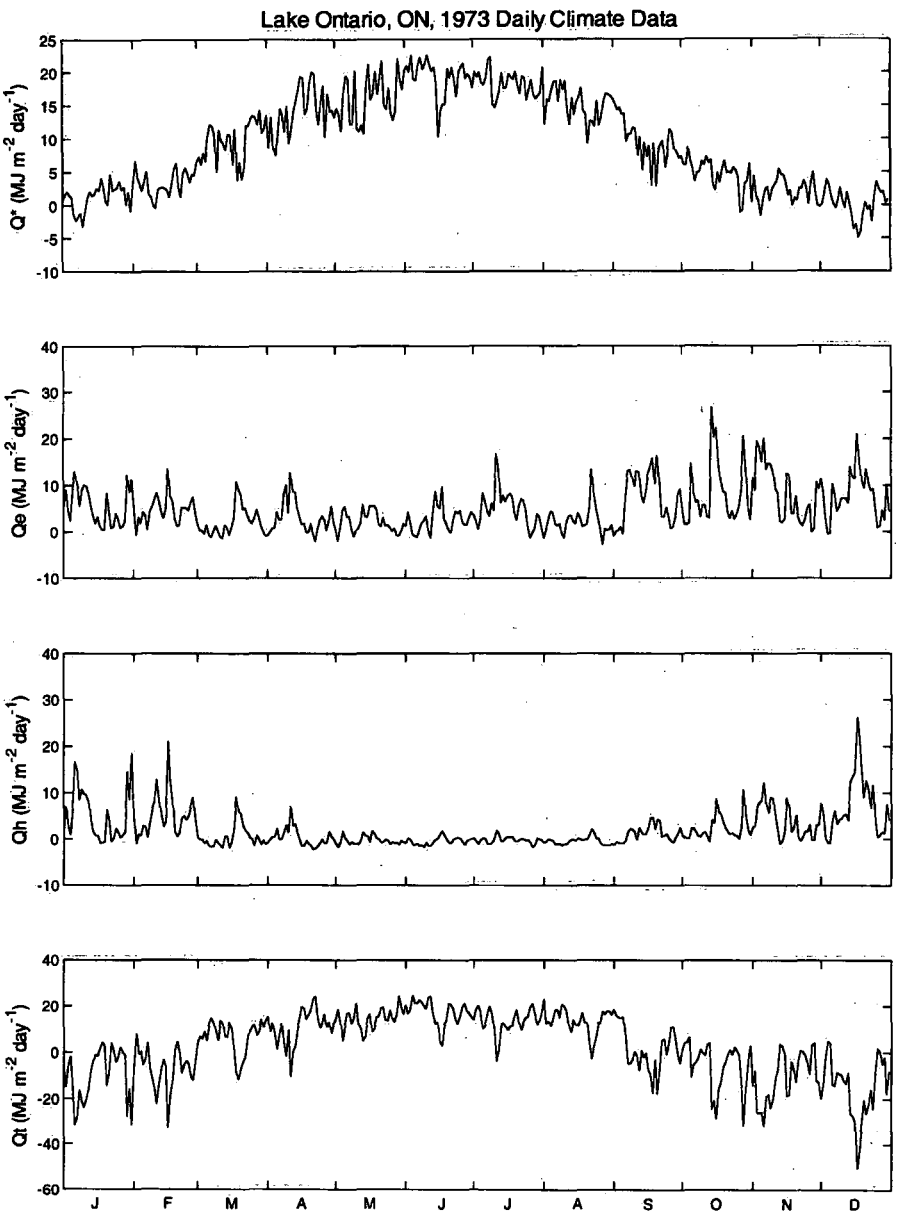
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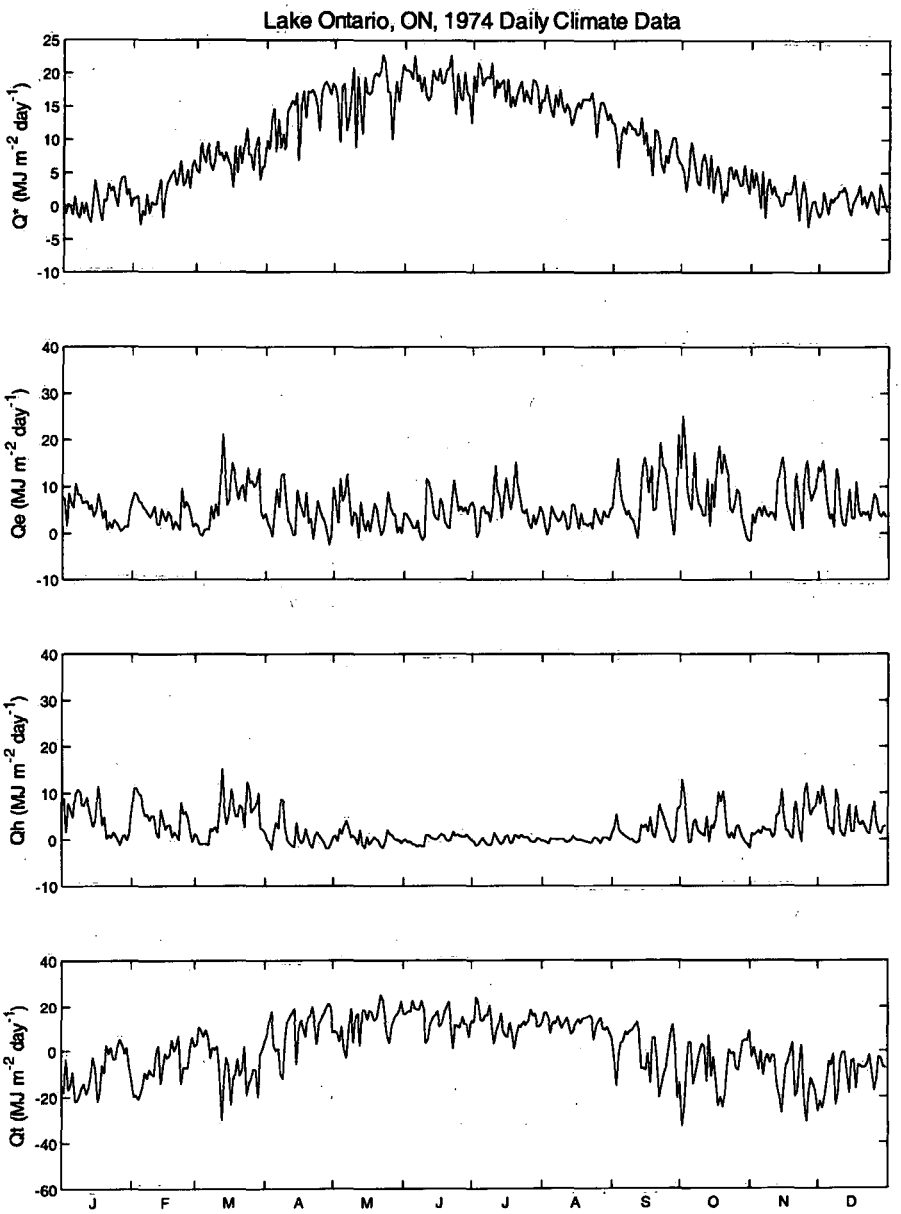
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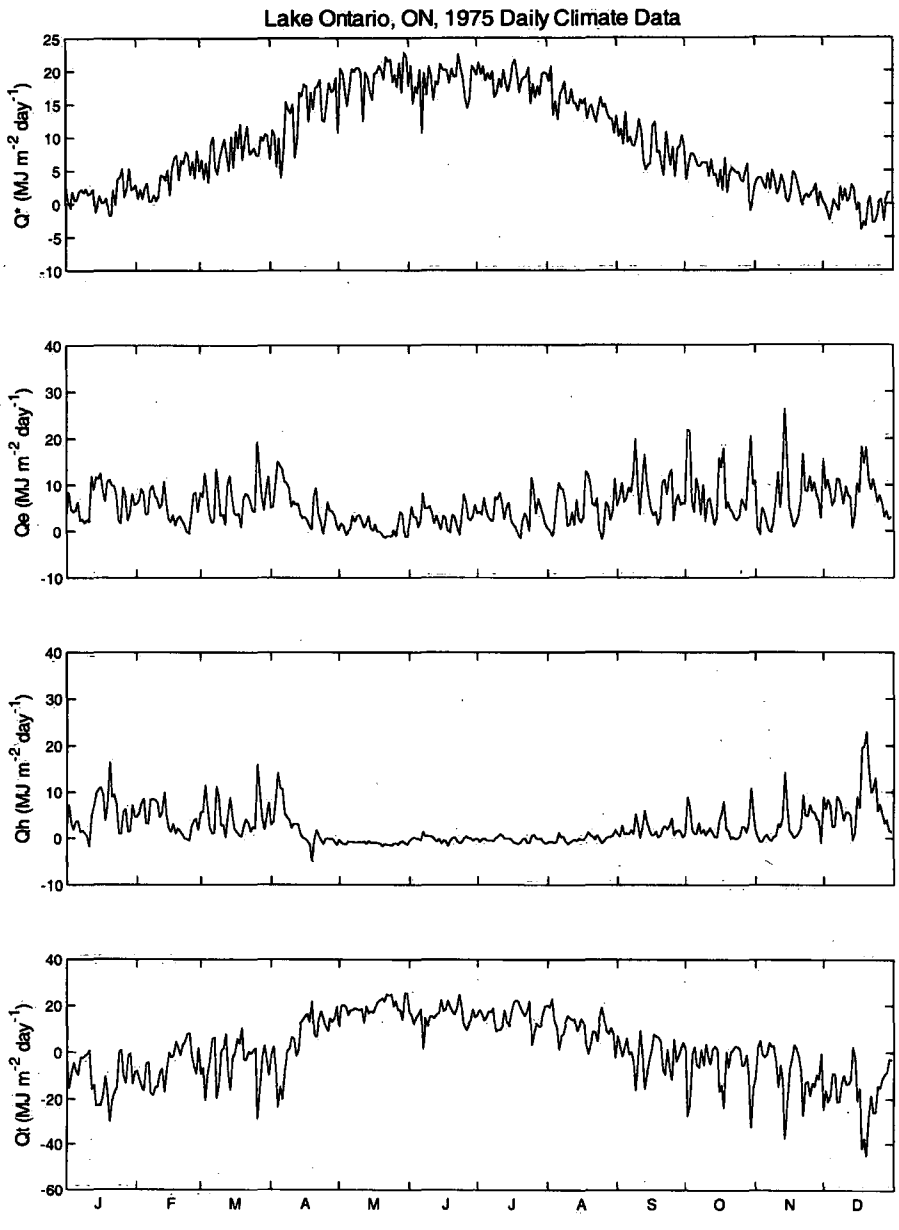
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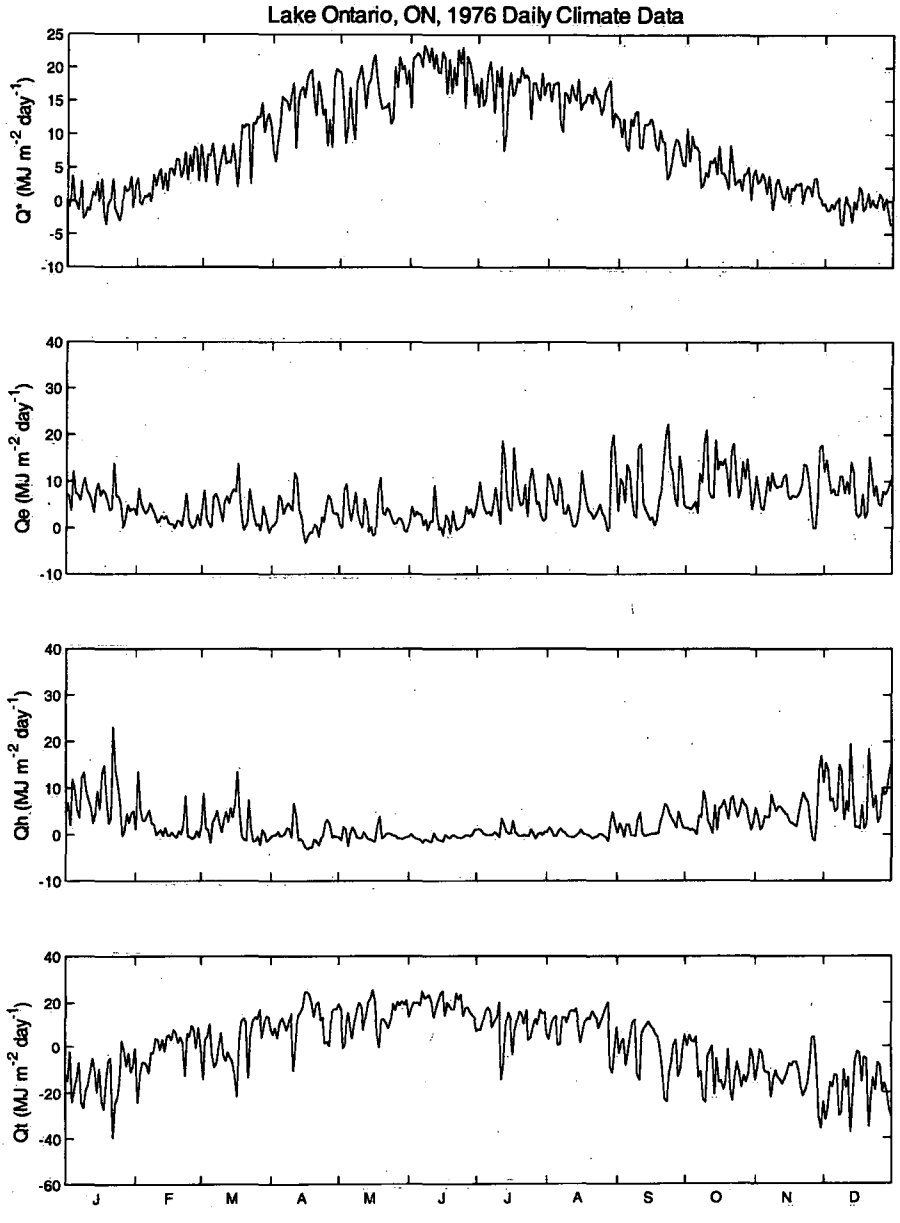
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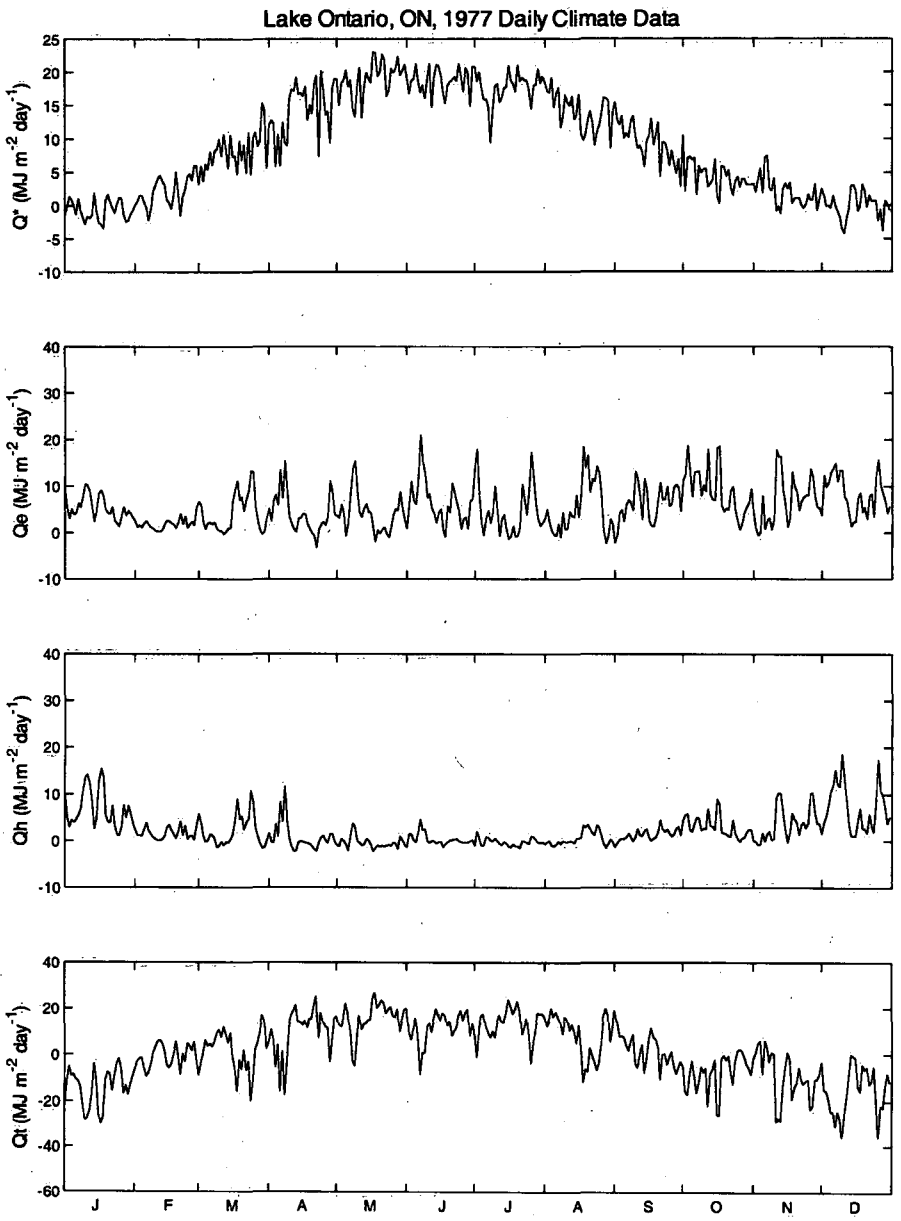
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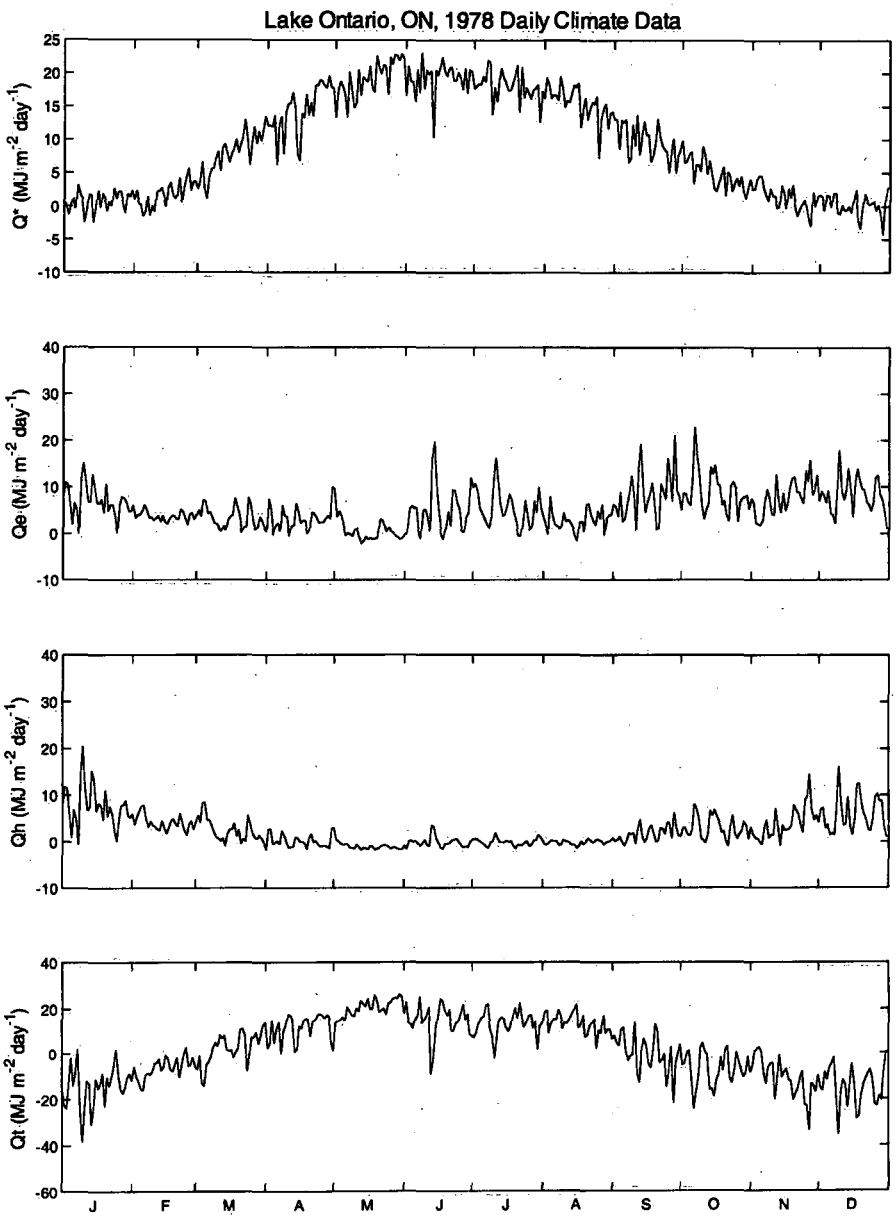
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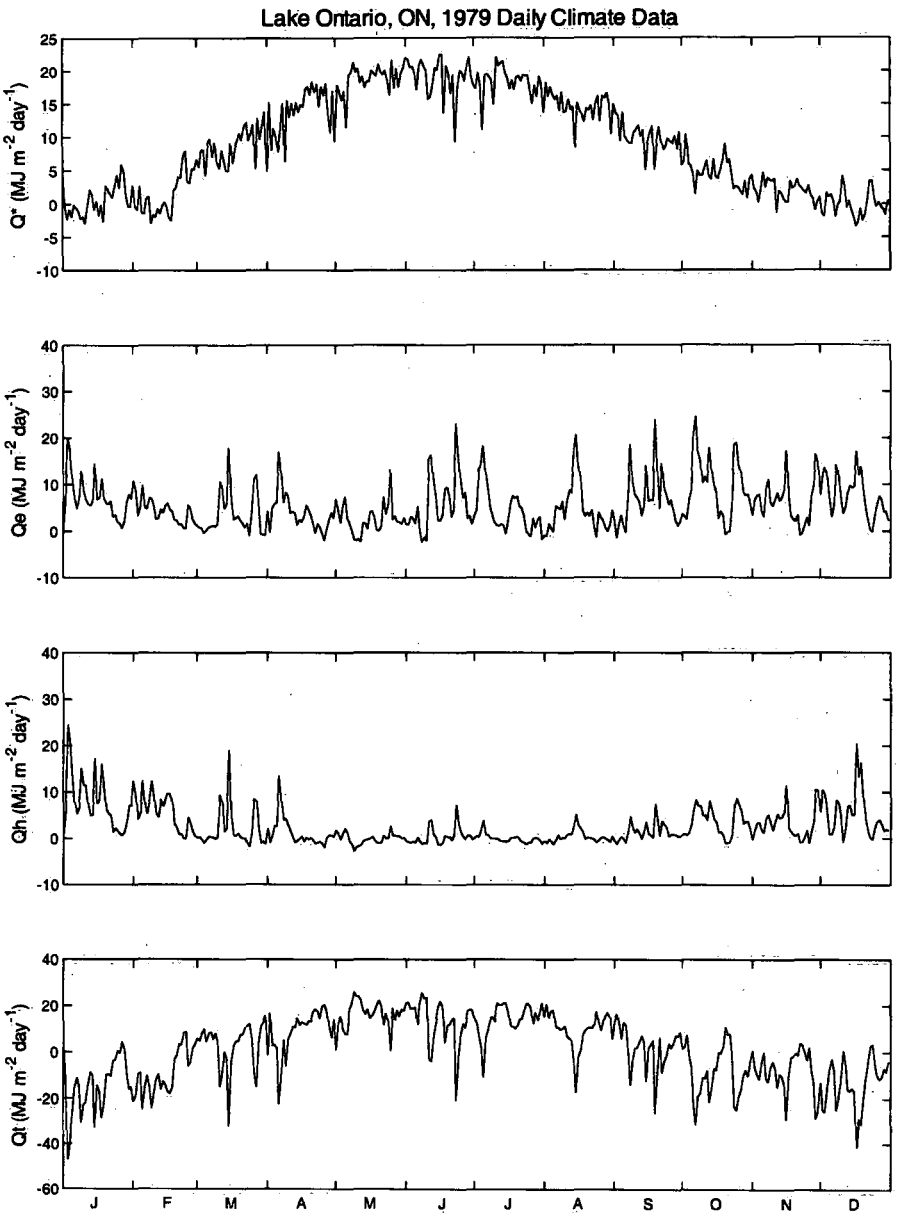
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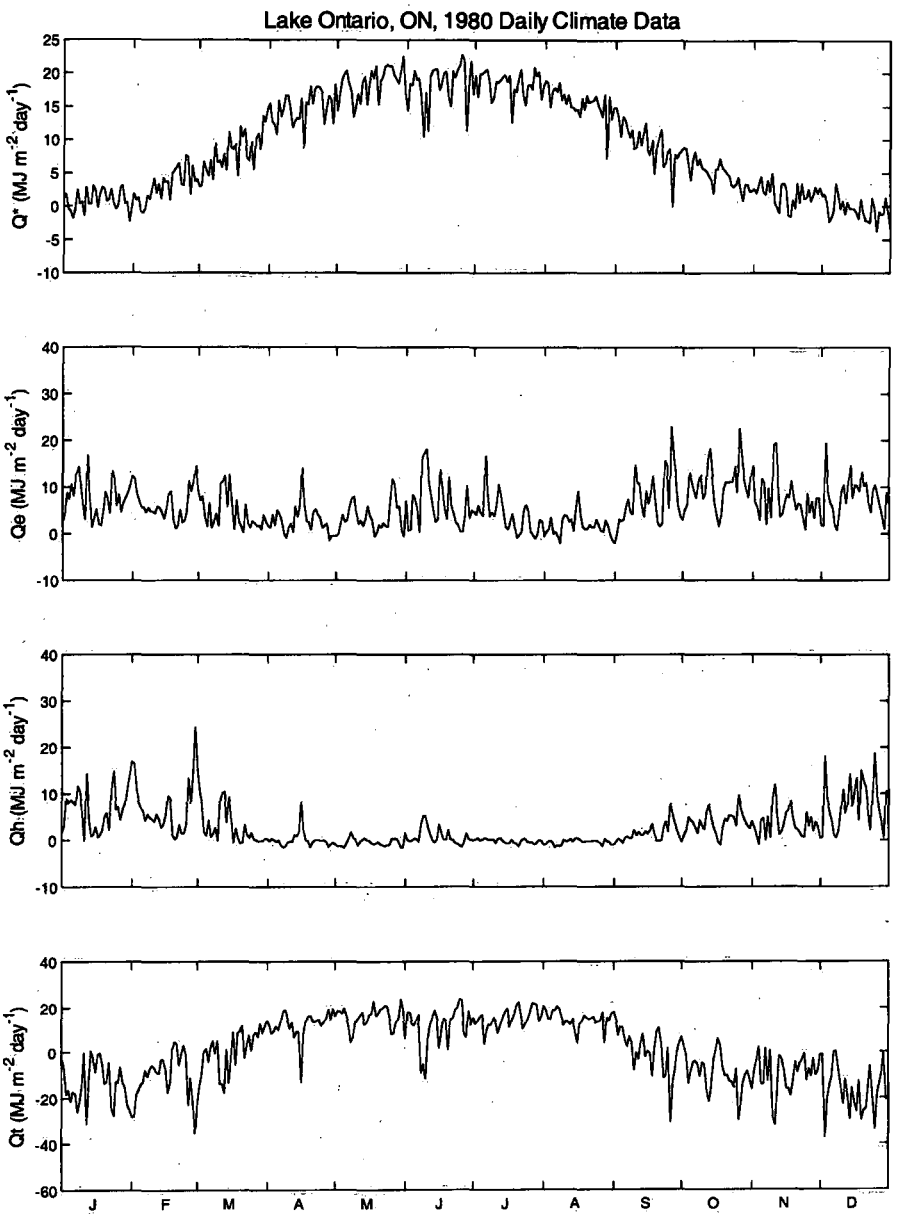
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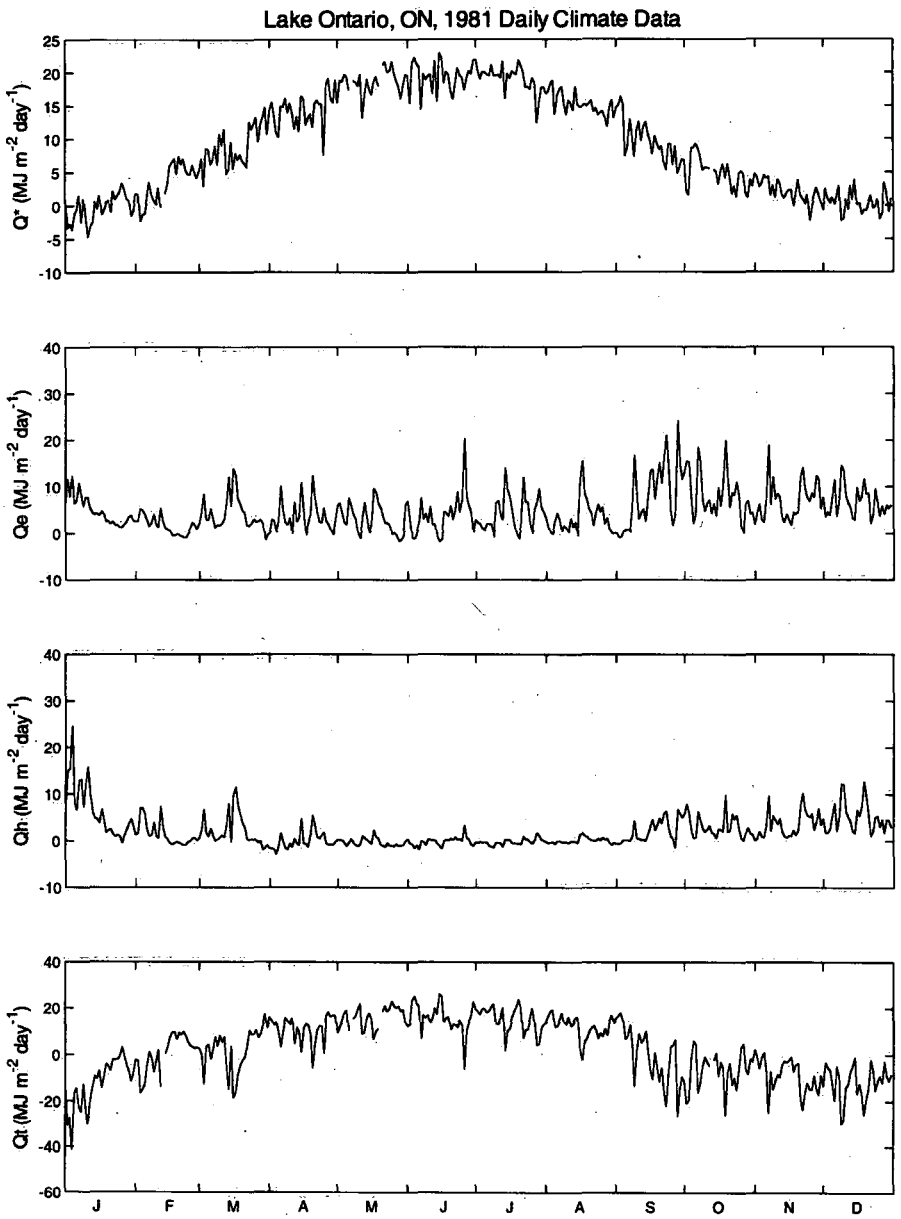
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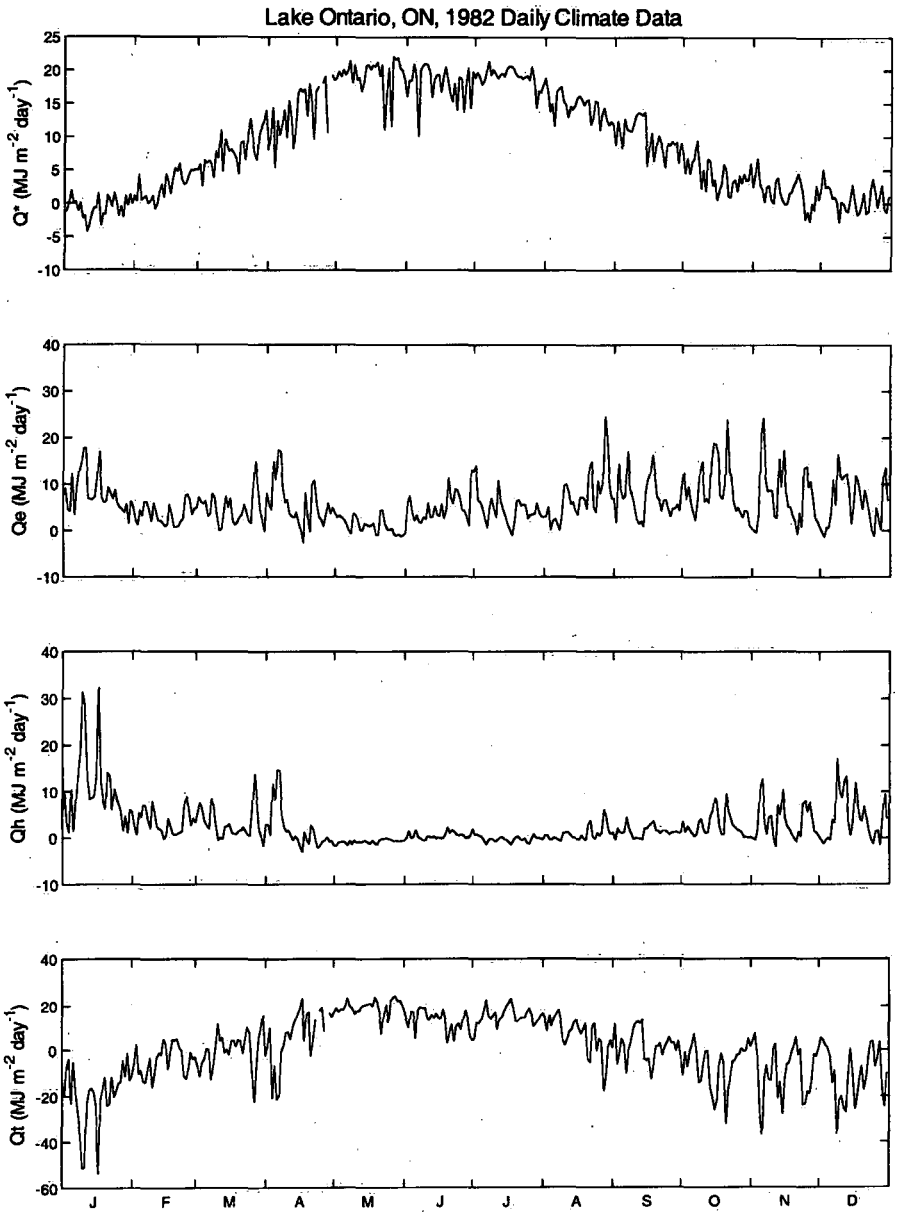
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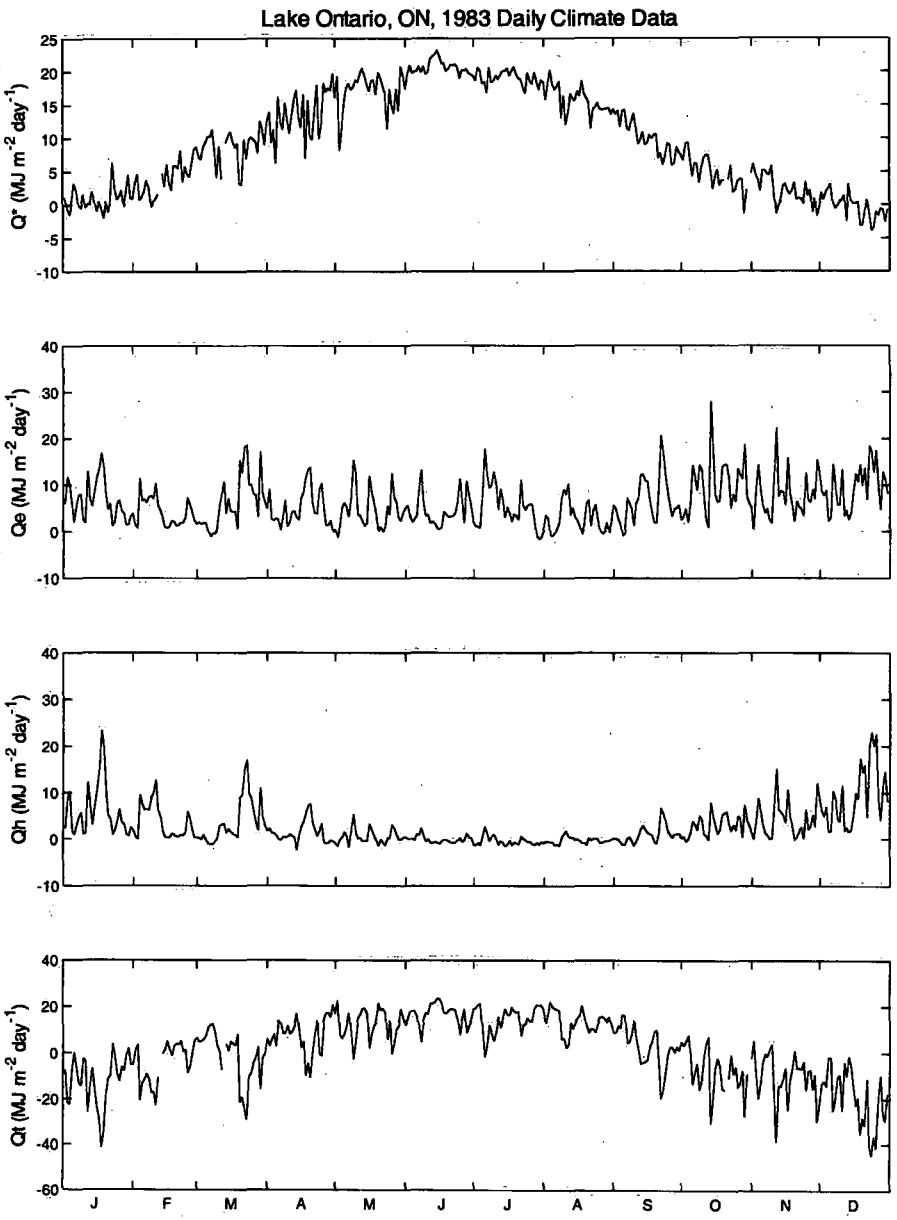
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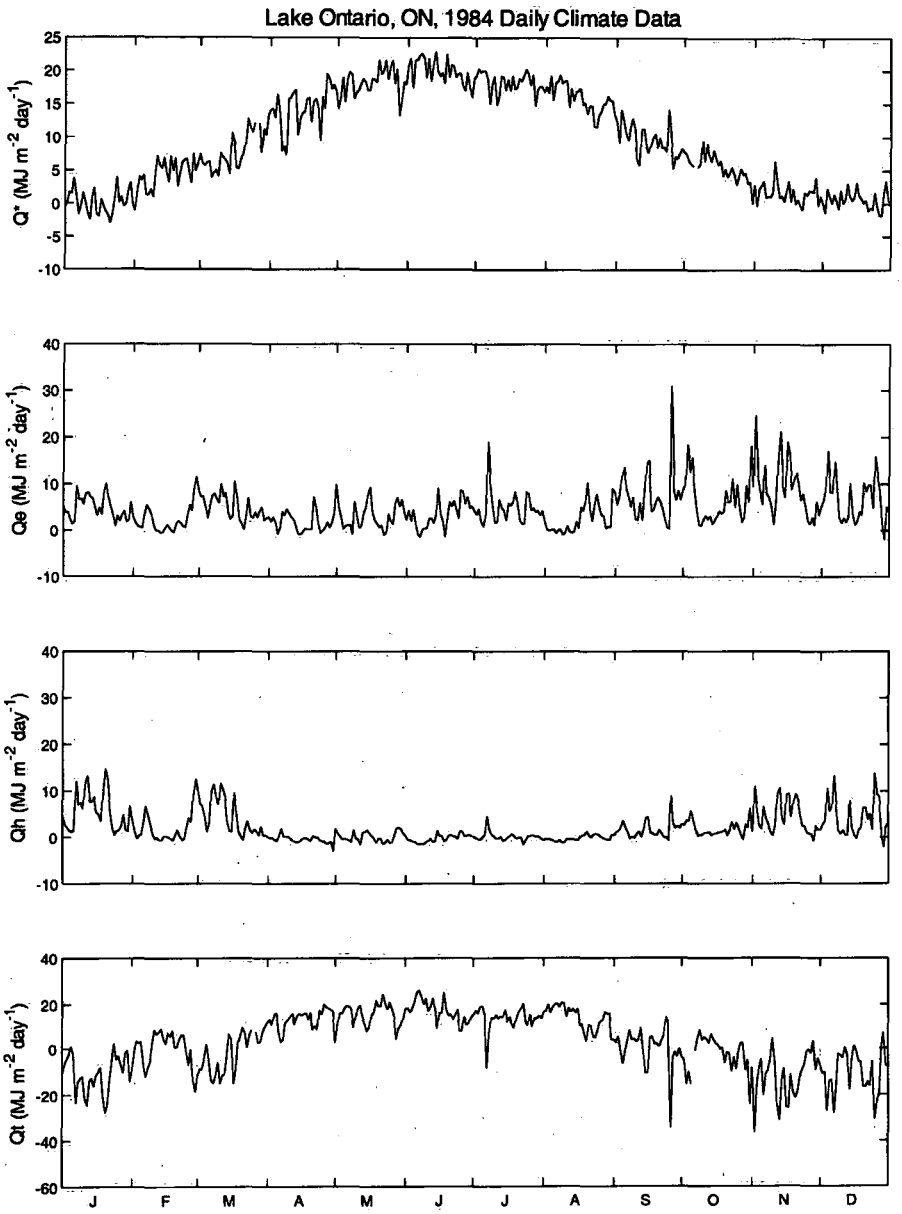
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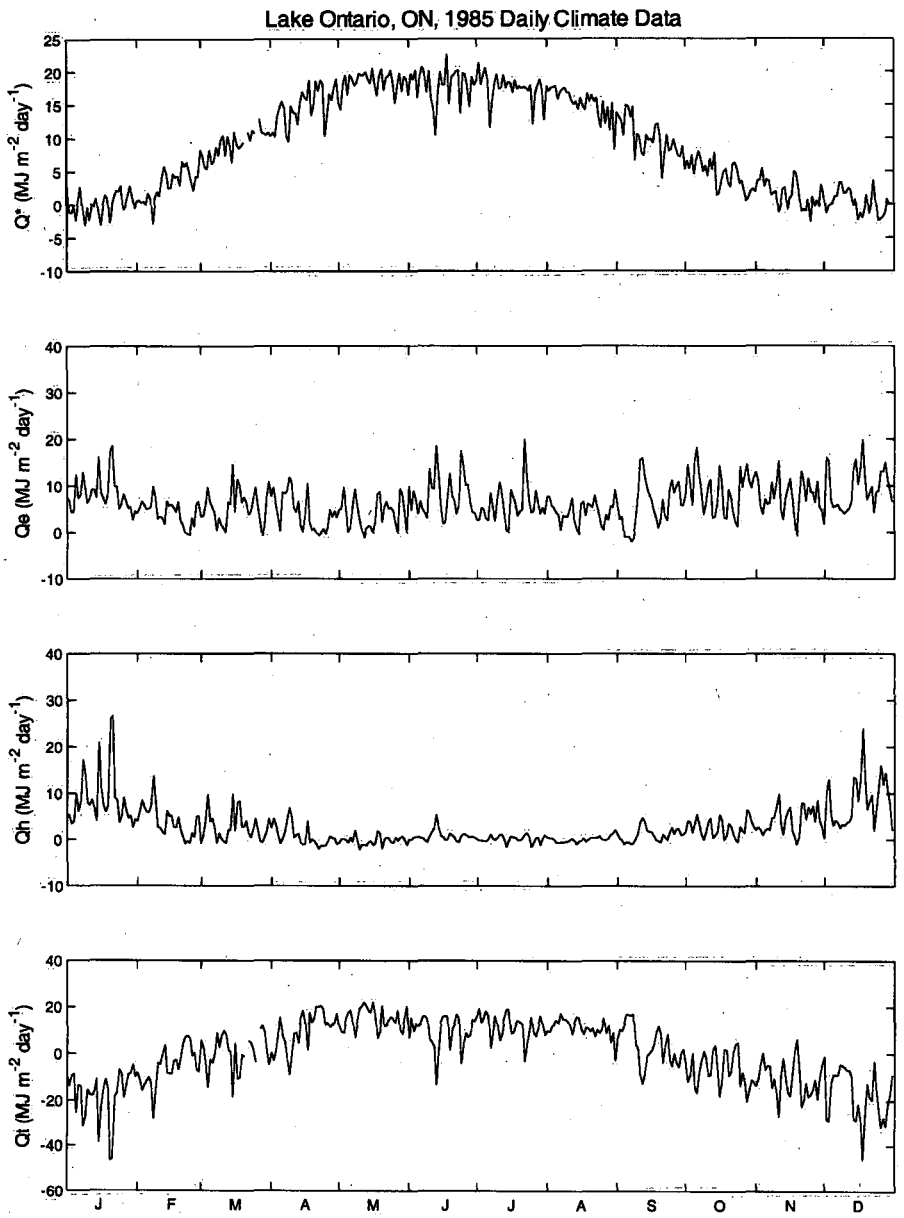
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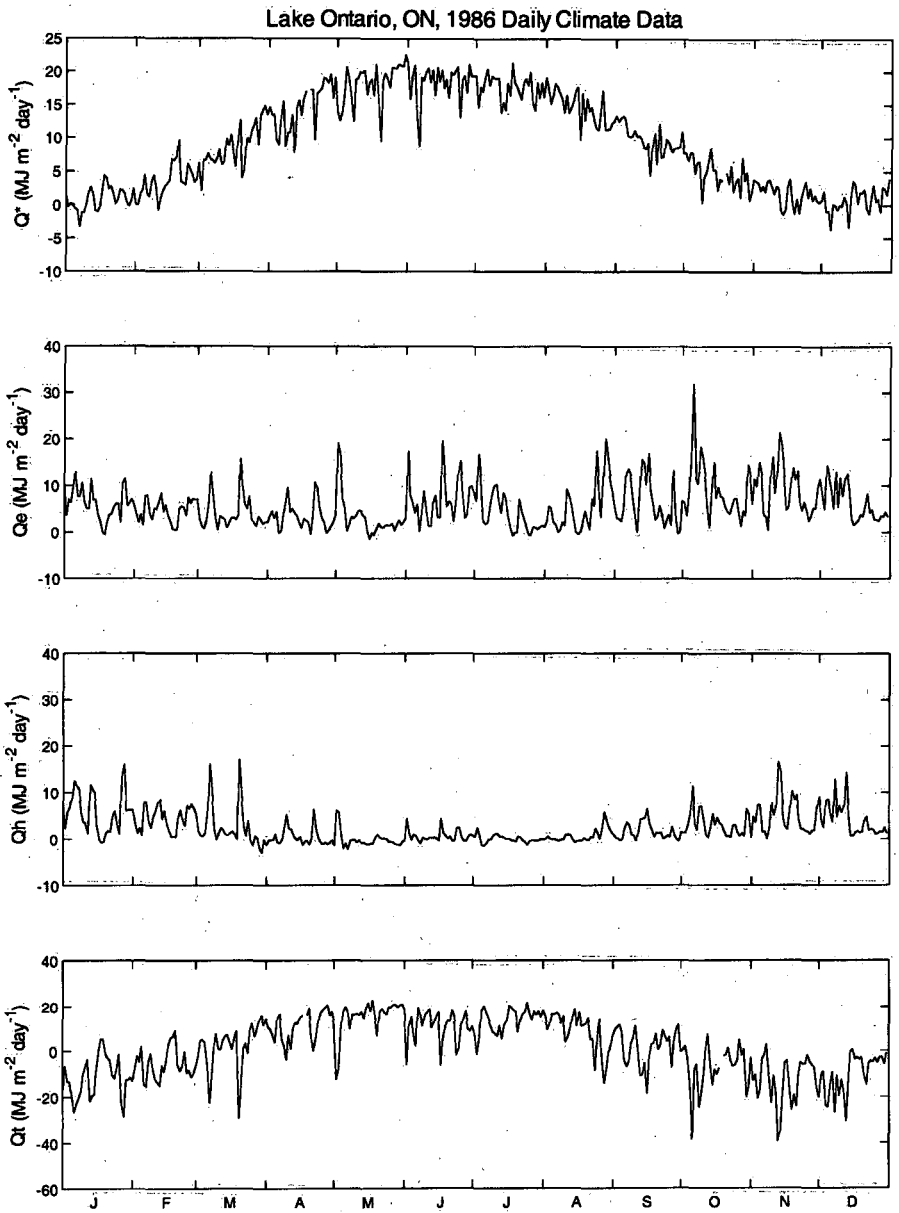
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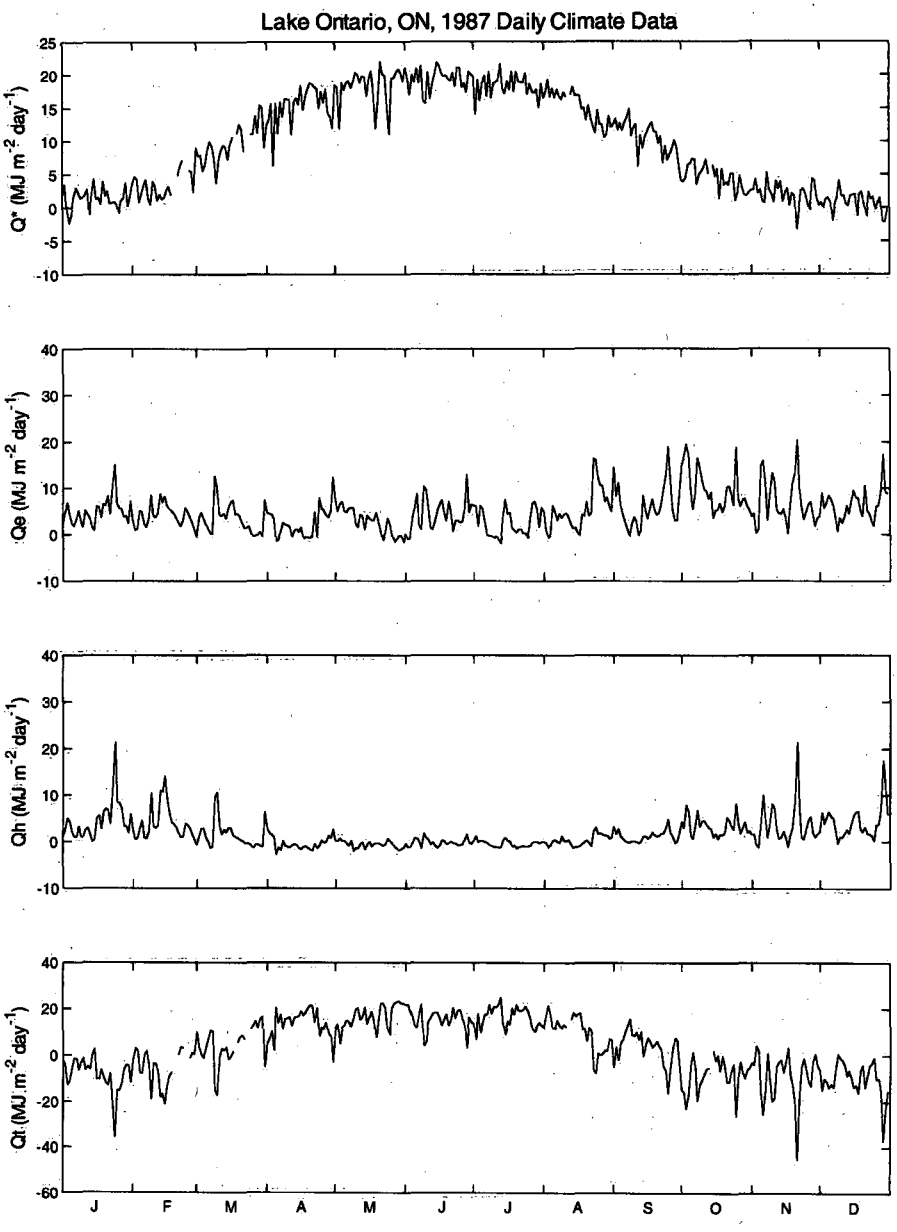
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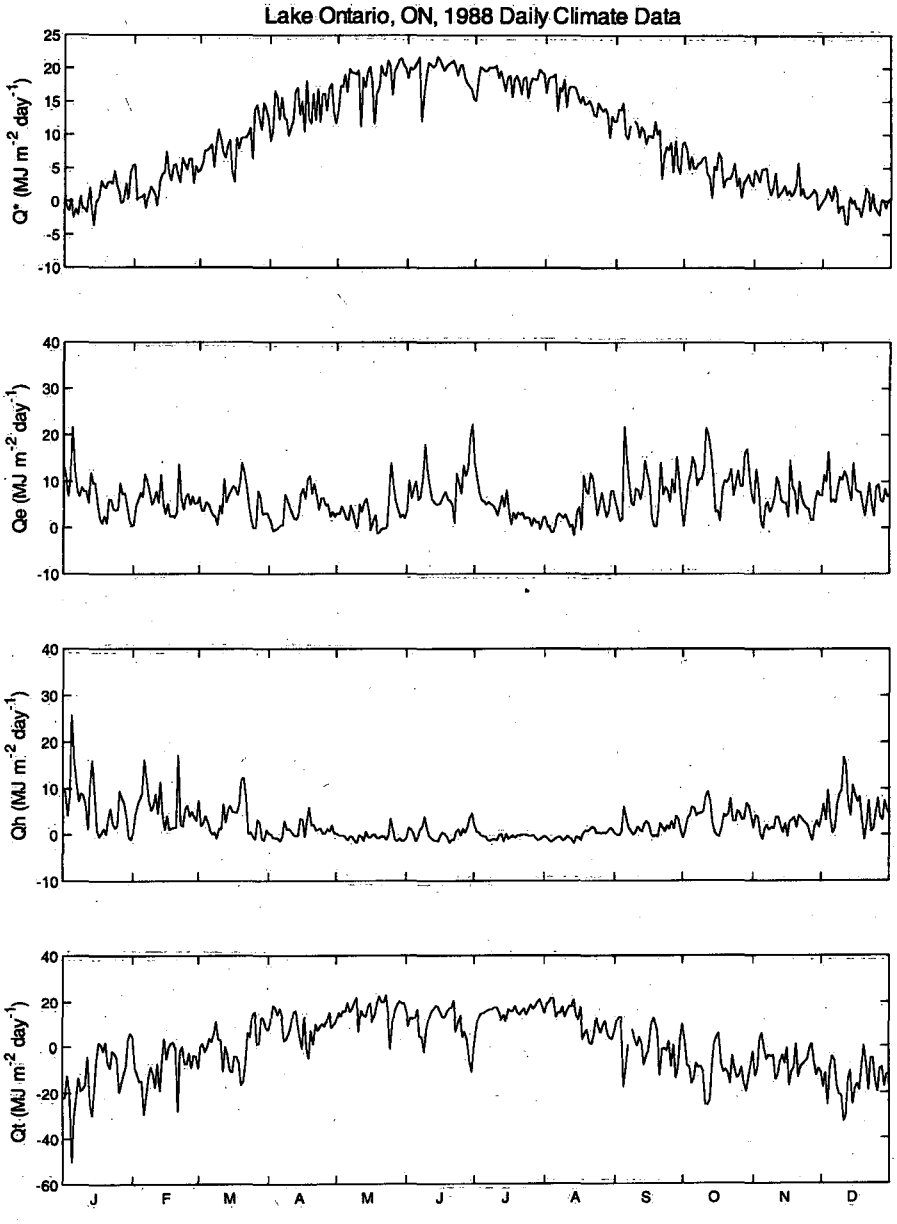
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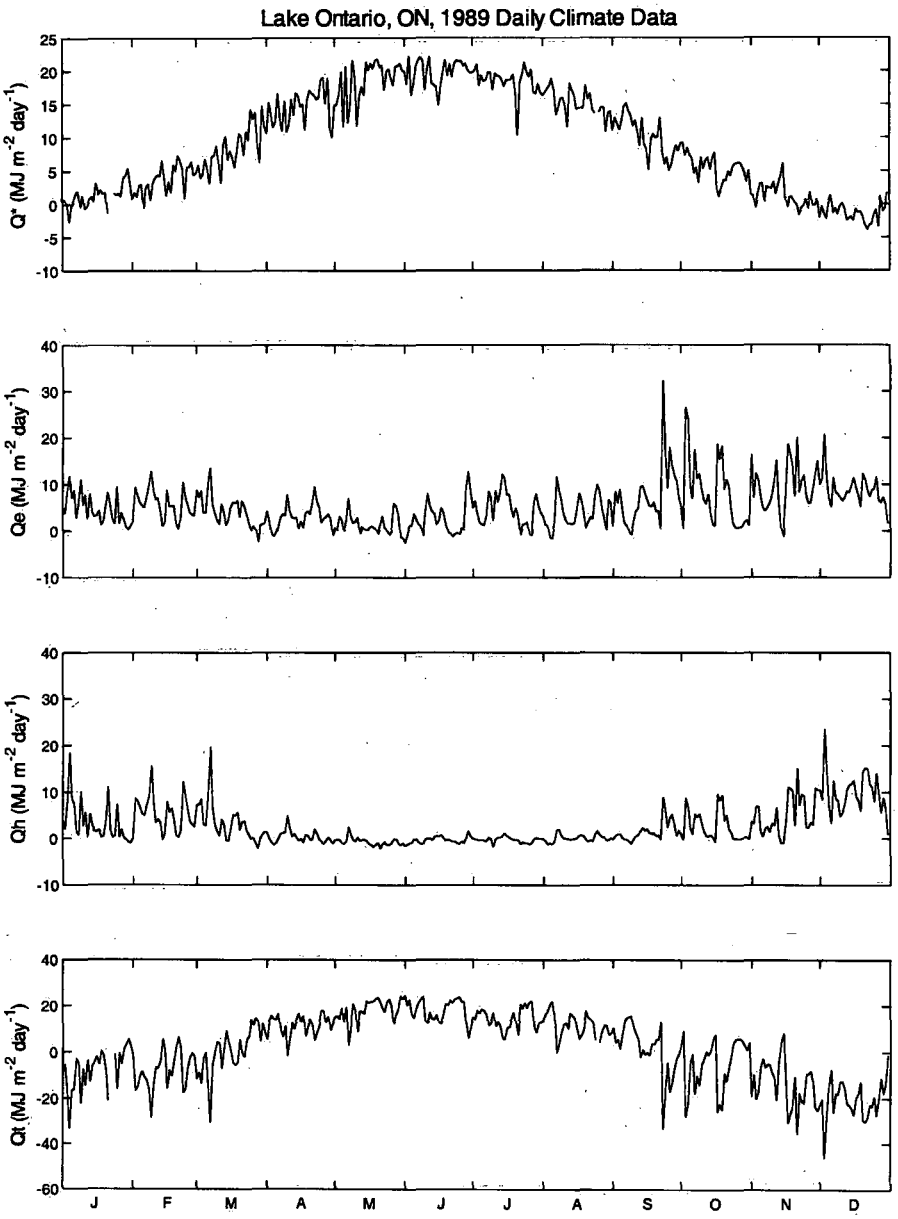
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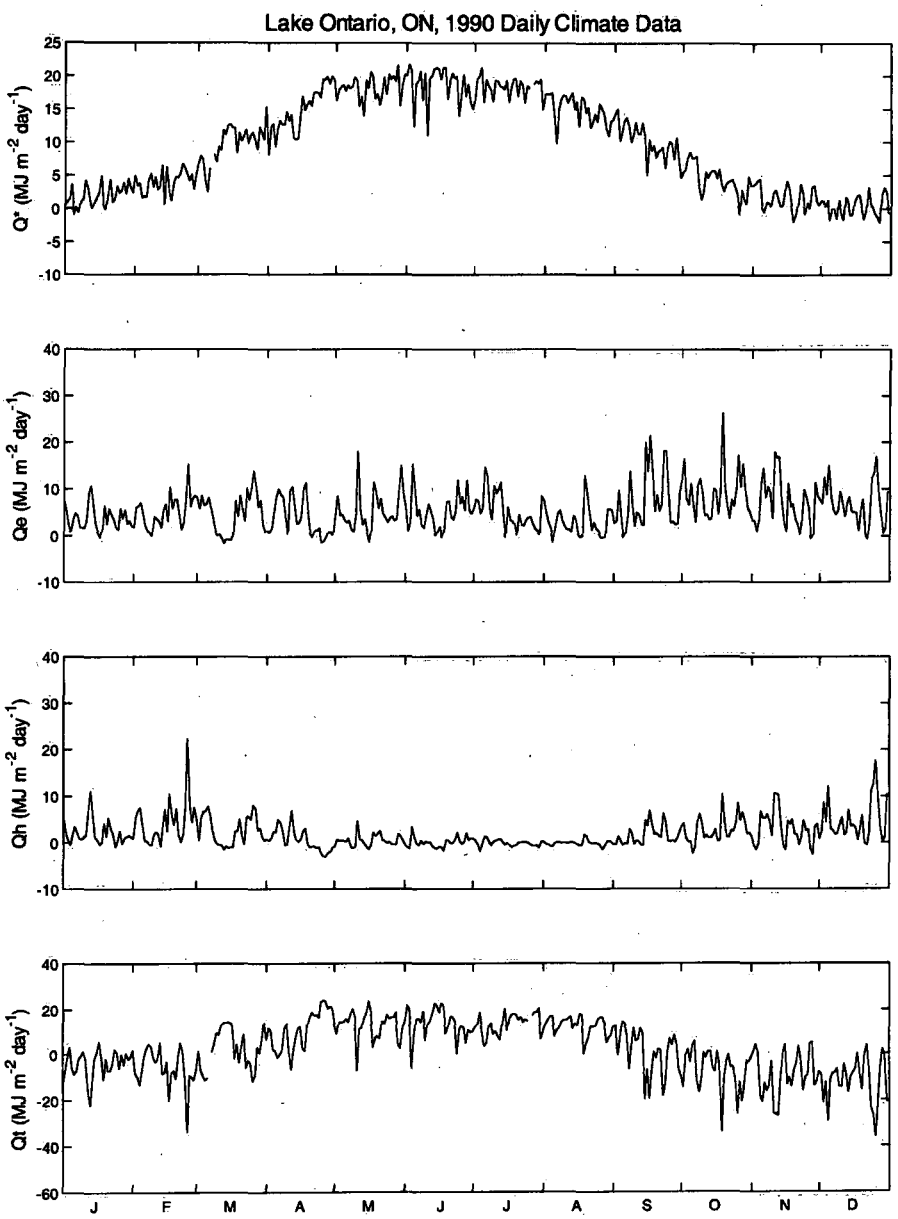
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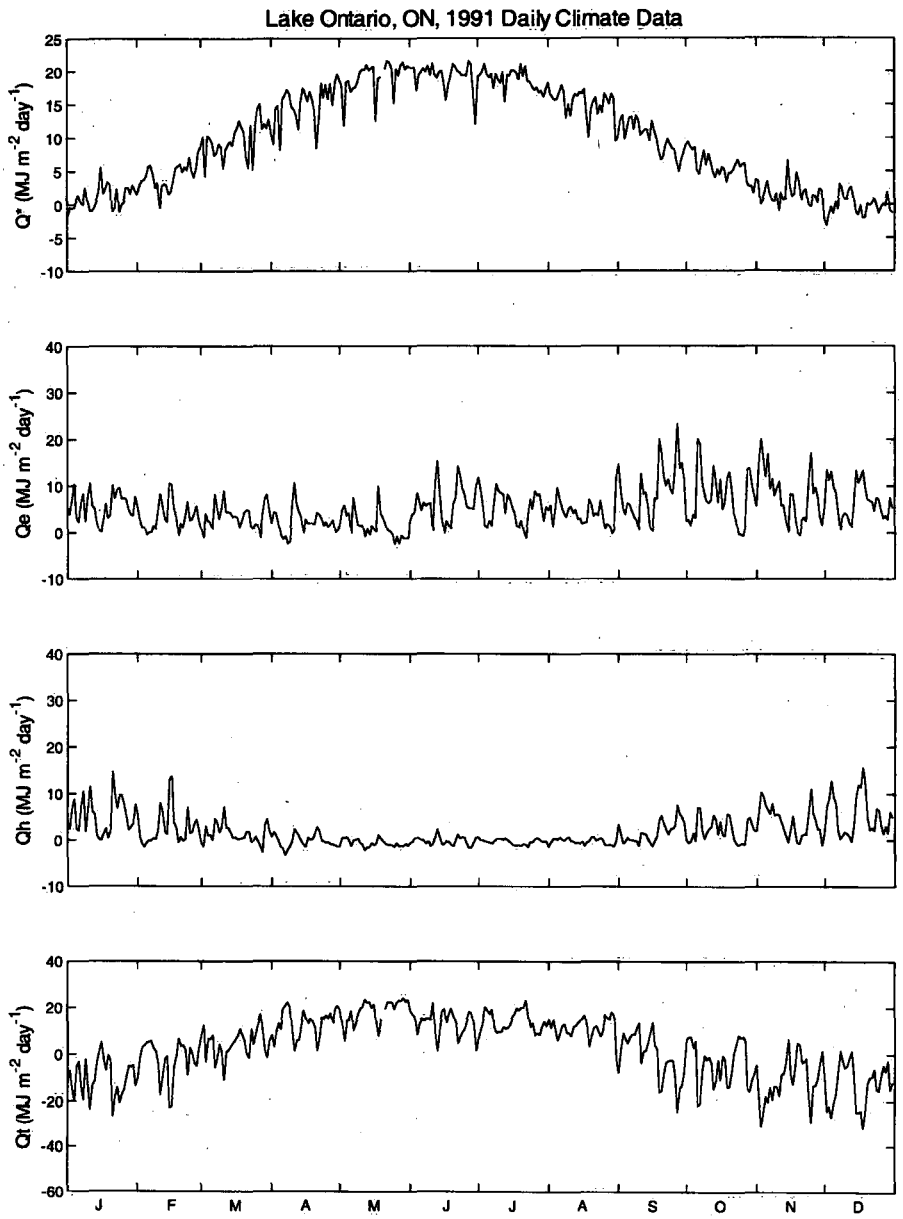
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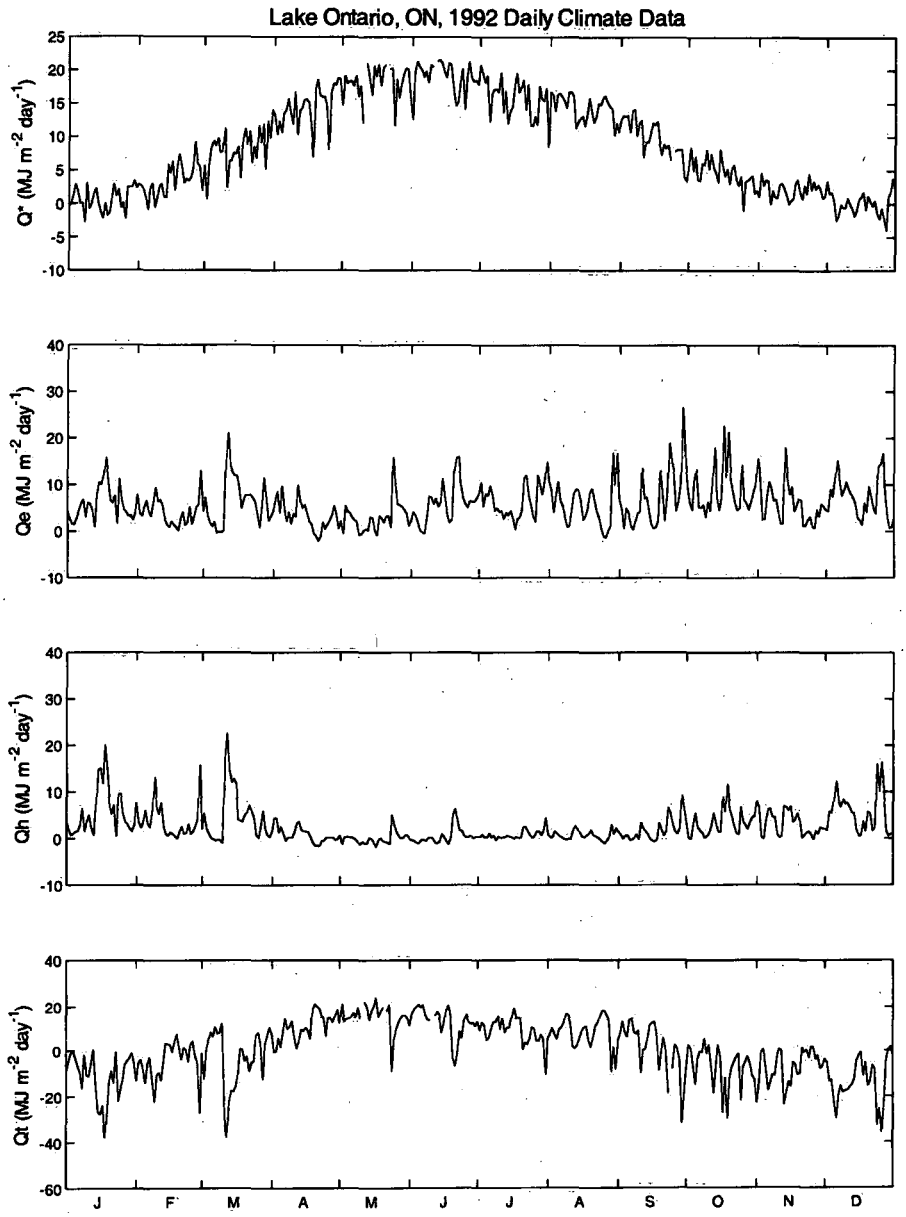
Lake Ontario, ON, 1992 Daily Climate Data
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Qt (MJ m-2 day-1)
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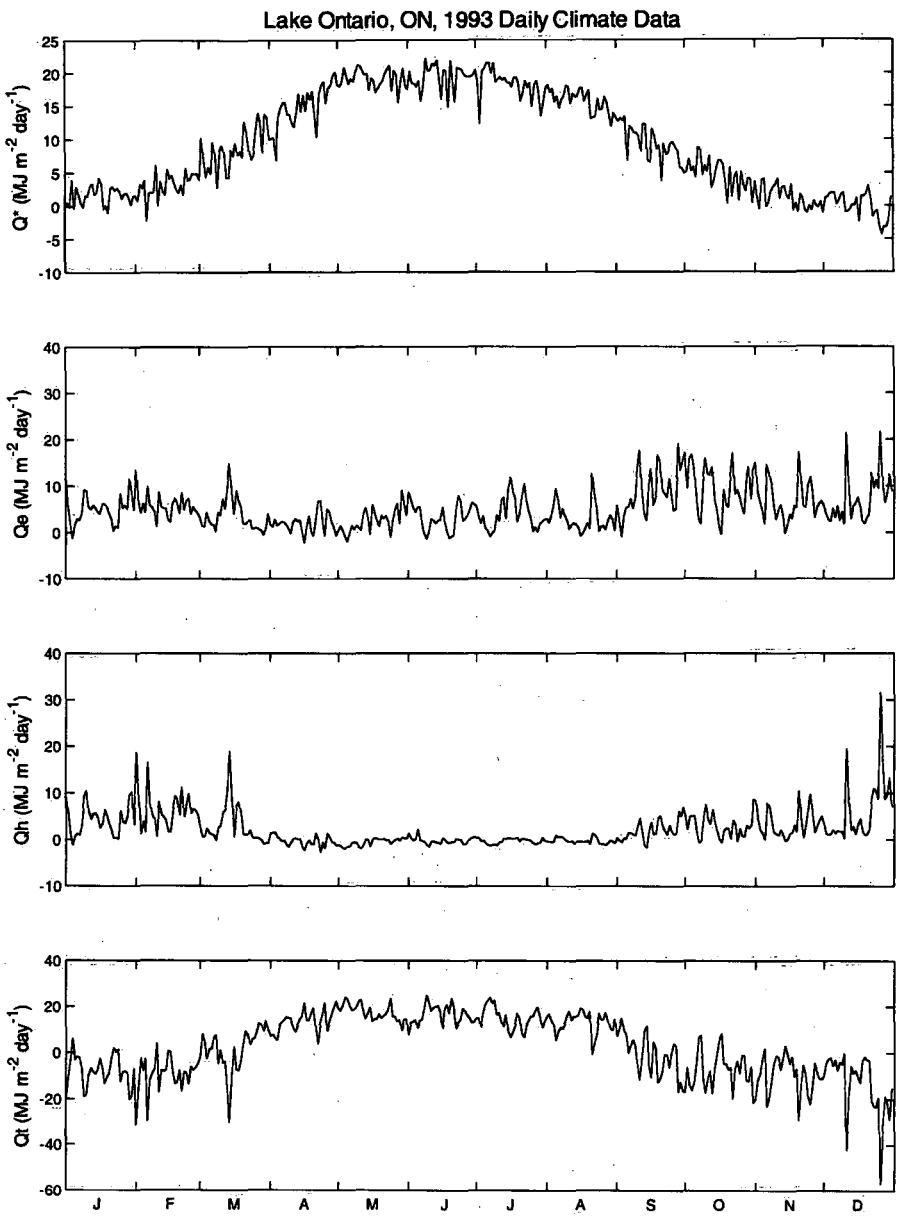
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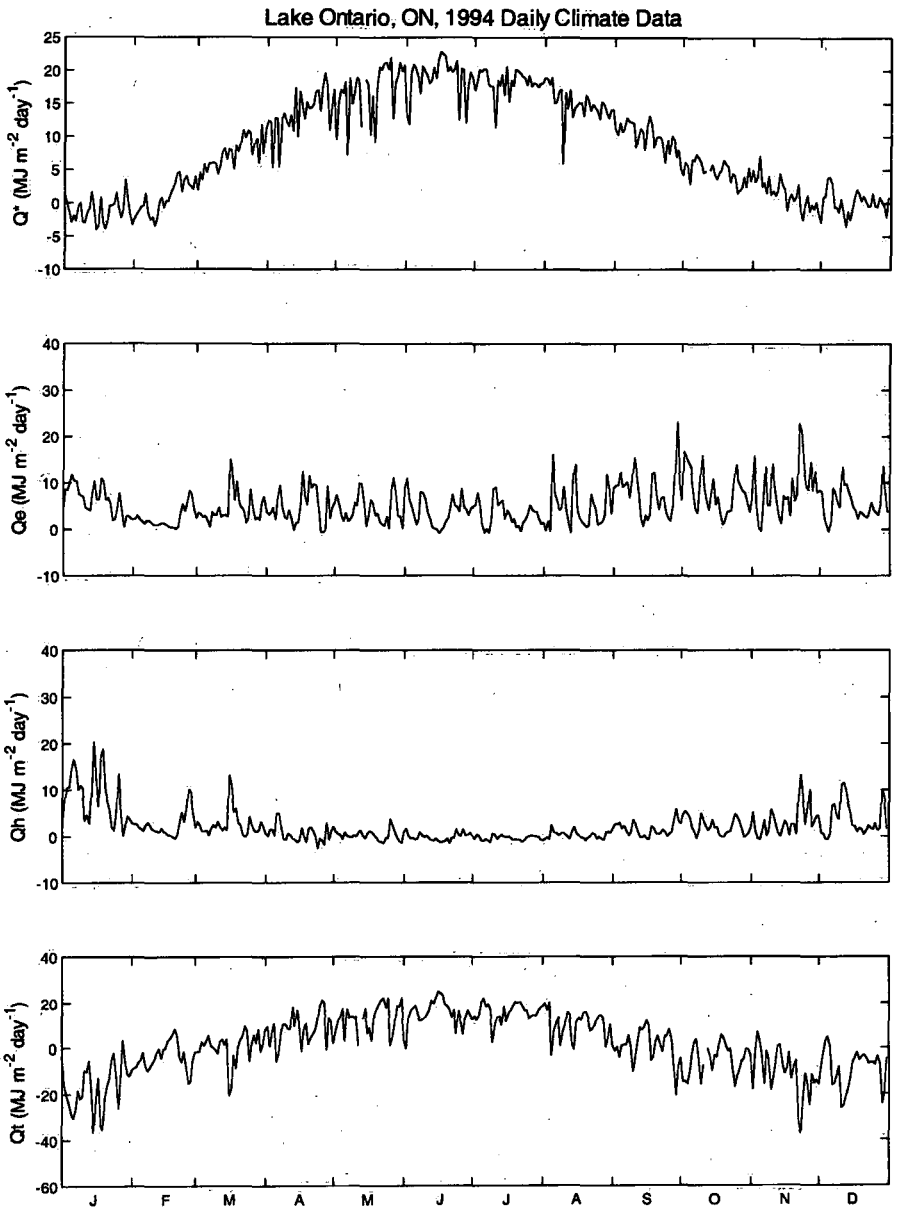
Lake Ontario, ON, 1994 Daily Climate Data
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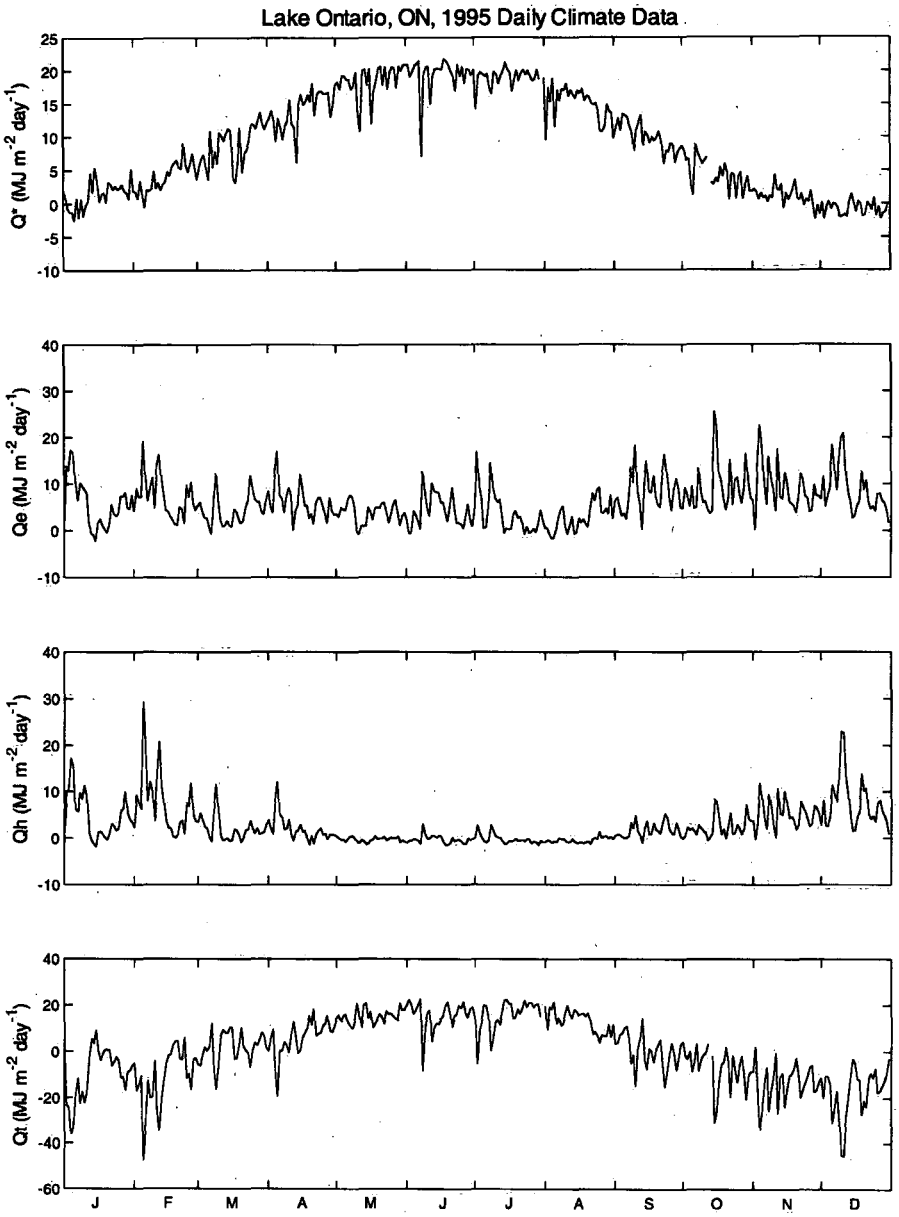
Lake Ontario, ON, 1995 Daily Climate Data
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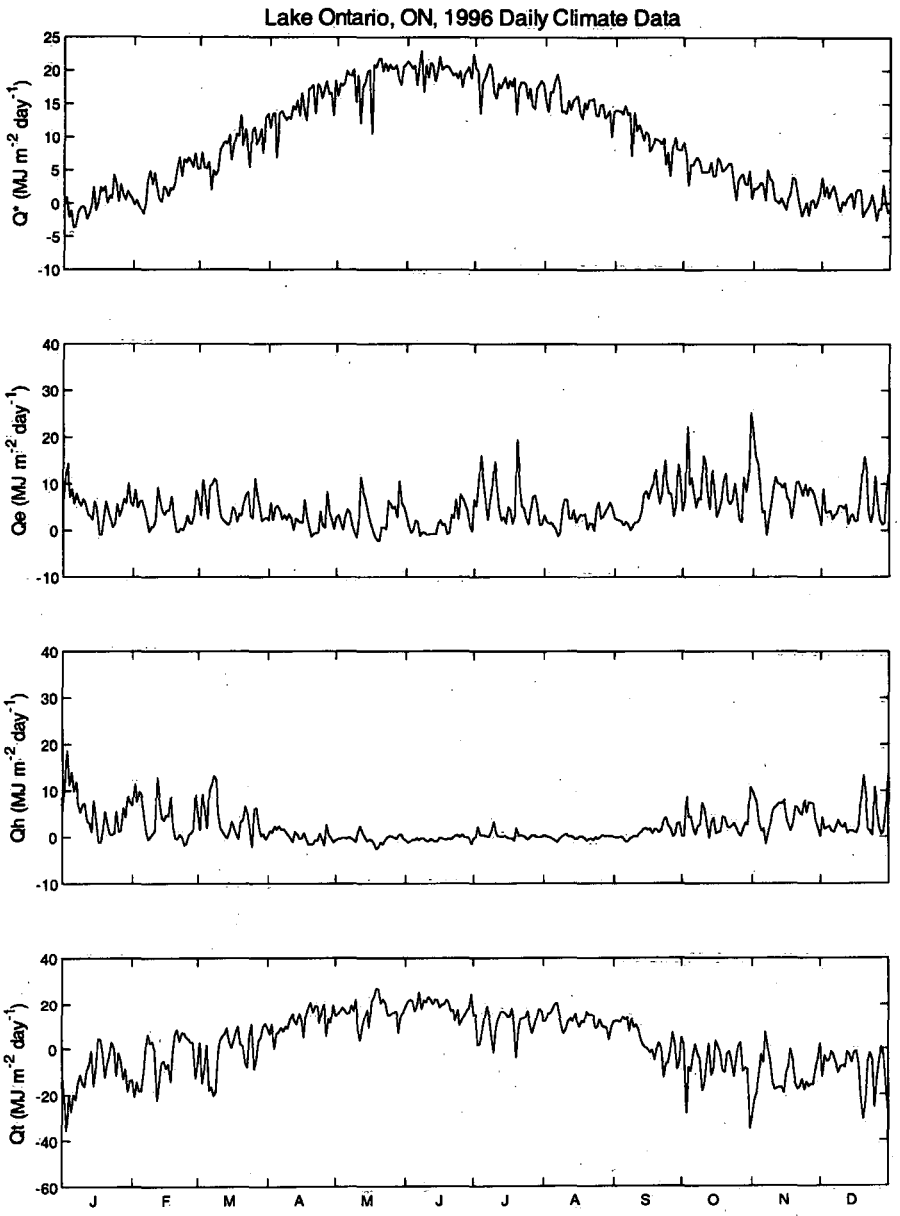
Lake Ontario, ON, 1996 Daily Climate Data
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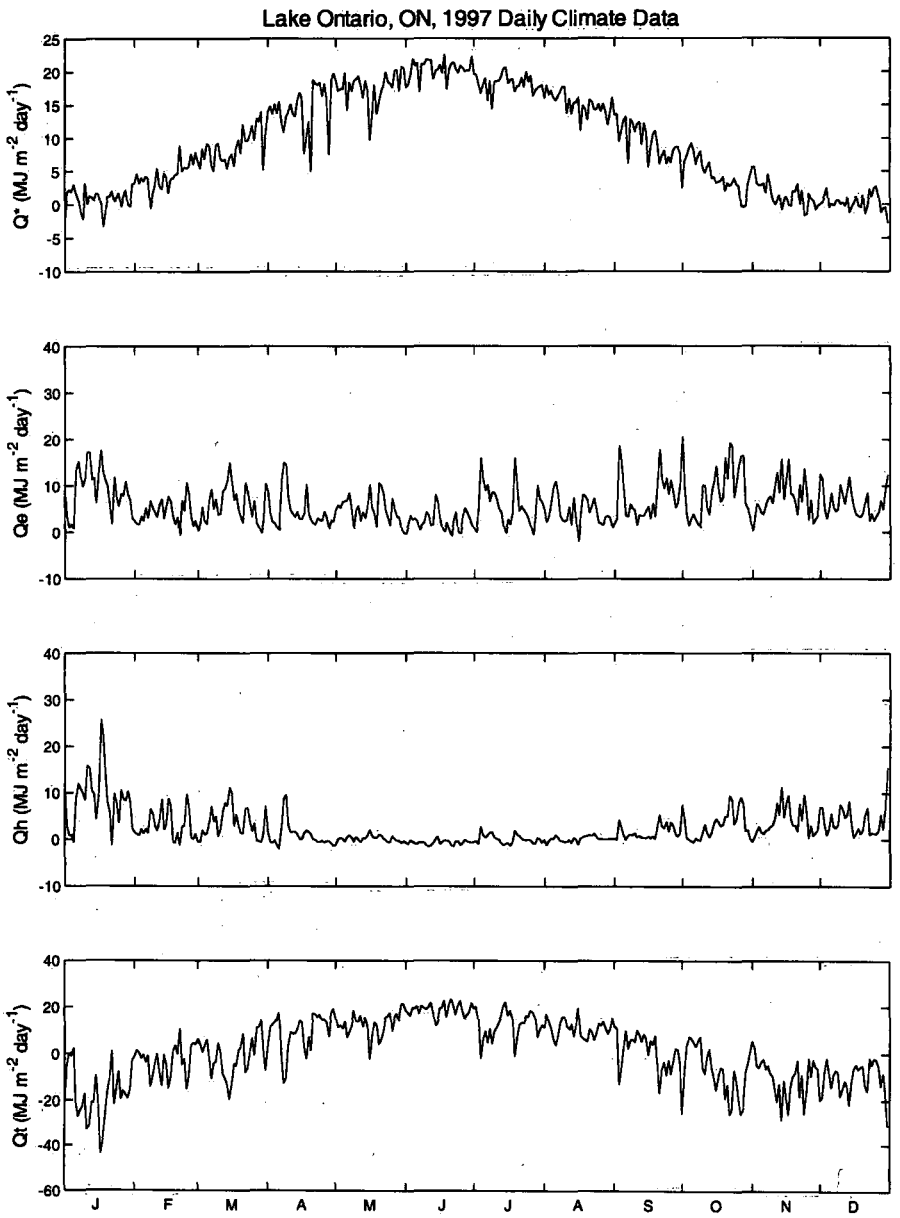
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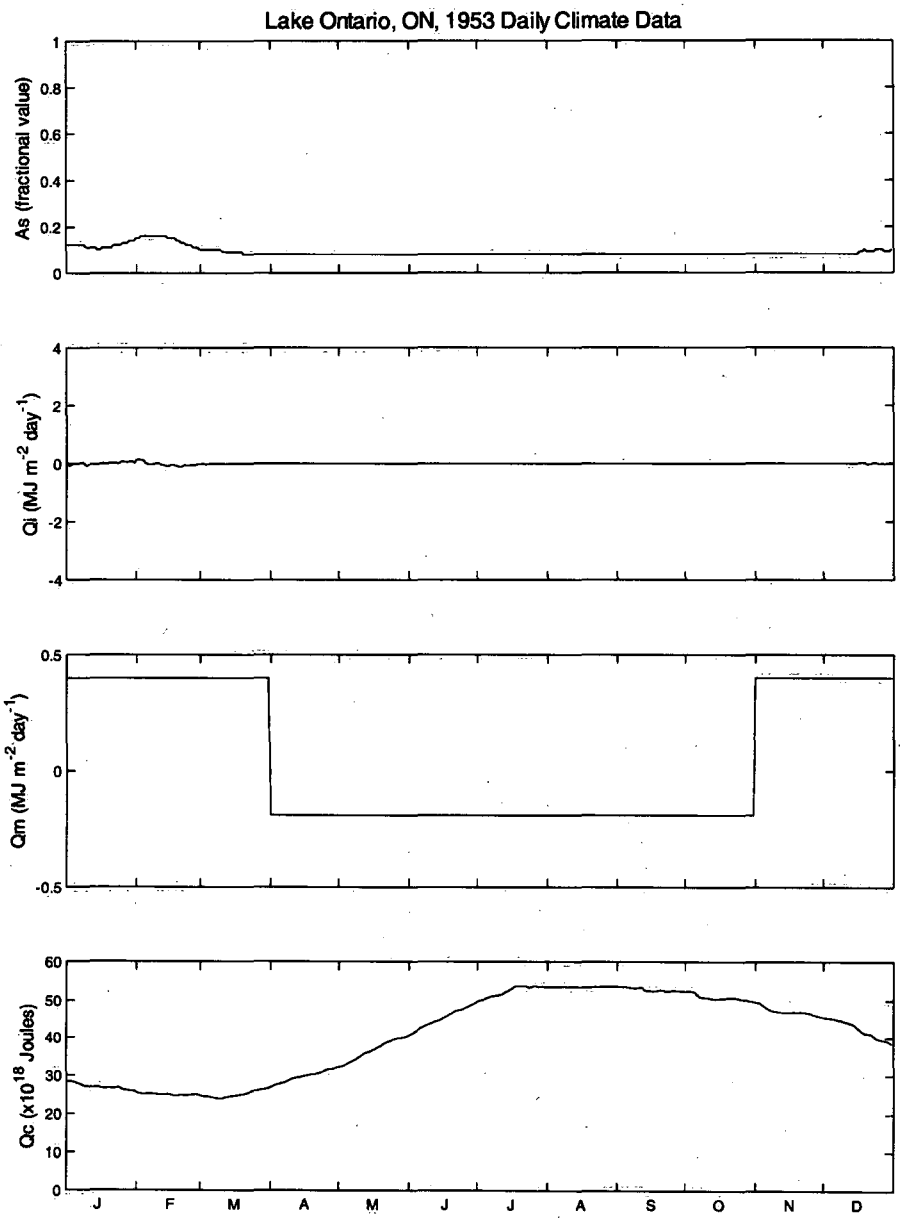
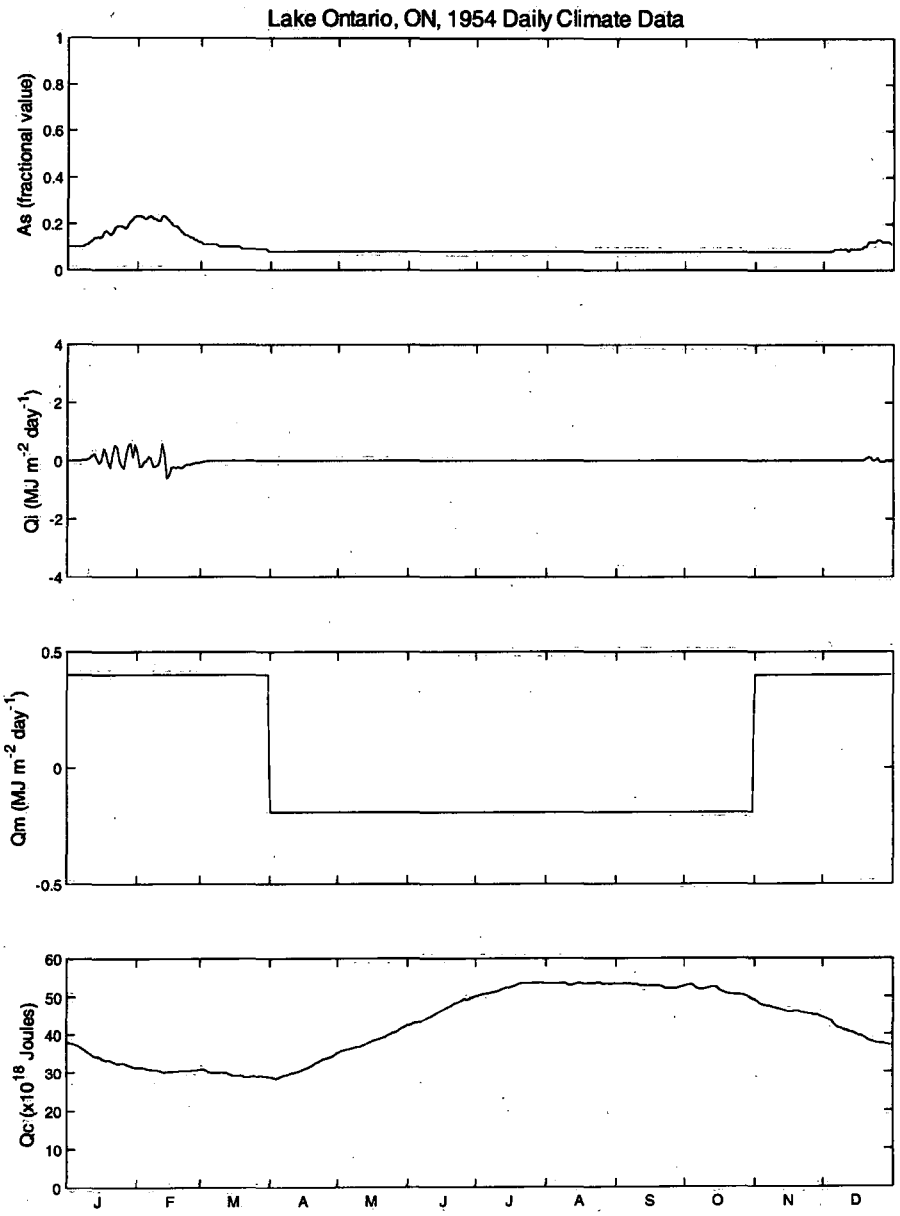
Appendix 3
Other Fluxes




Lake Ontario, ON, 1954 Daily Climate Data
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Qc (x10^18 Joules)
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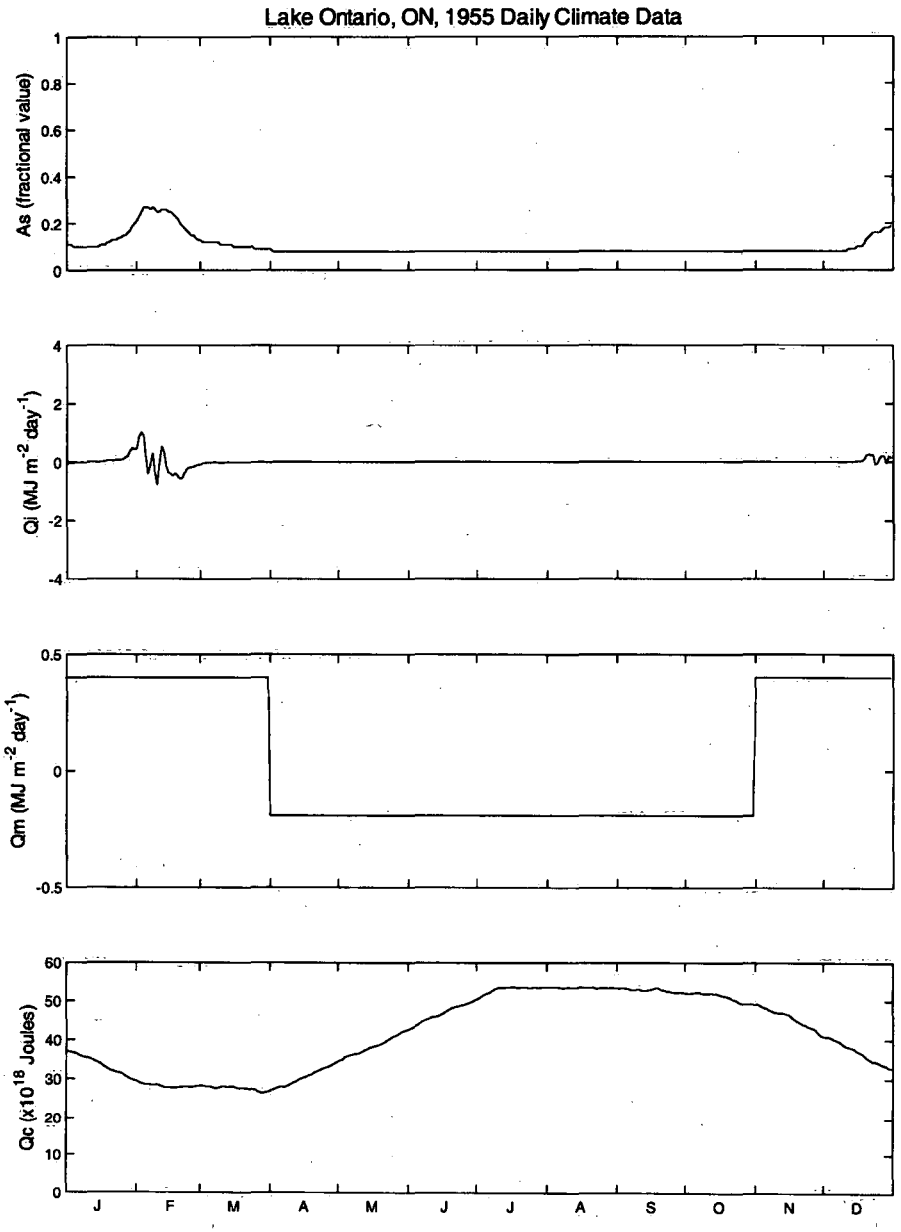
Lake Ontario, ON, 1955 Daily Climate Data
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Qc (x10 18 Joules)
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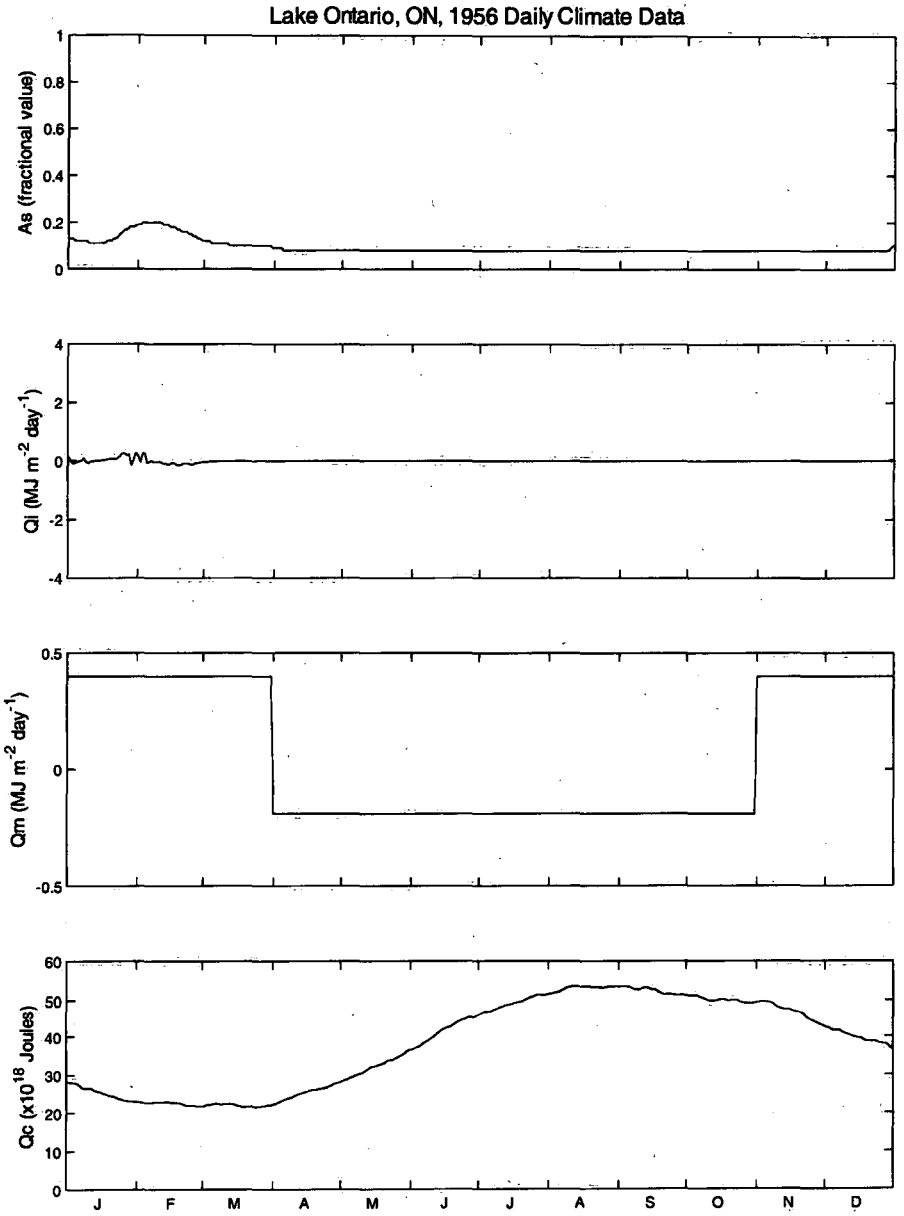
Lake Ontario, ON, 1956 Daily Climate Data
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Qc (x10^18 Joules)
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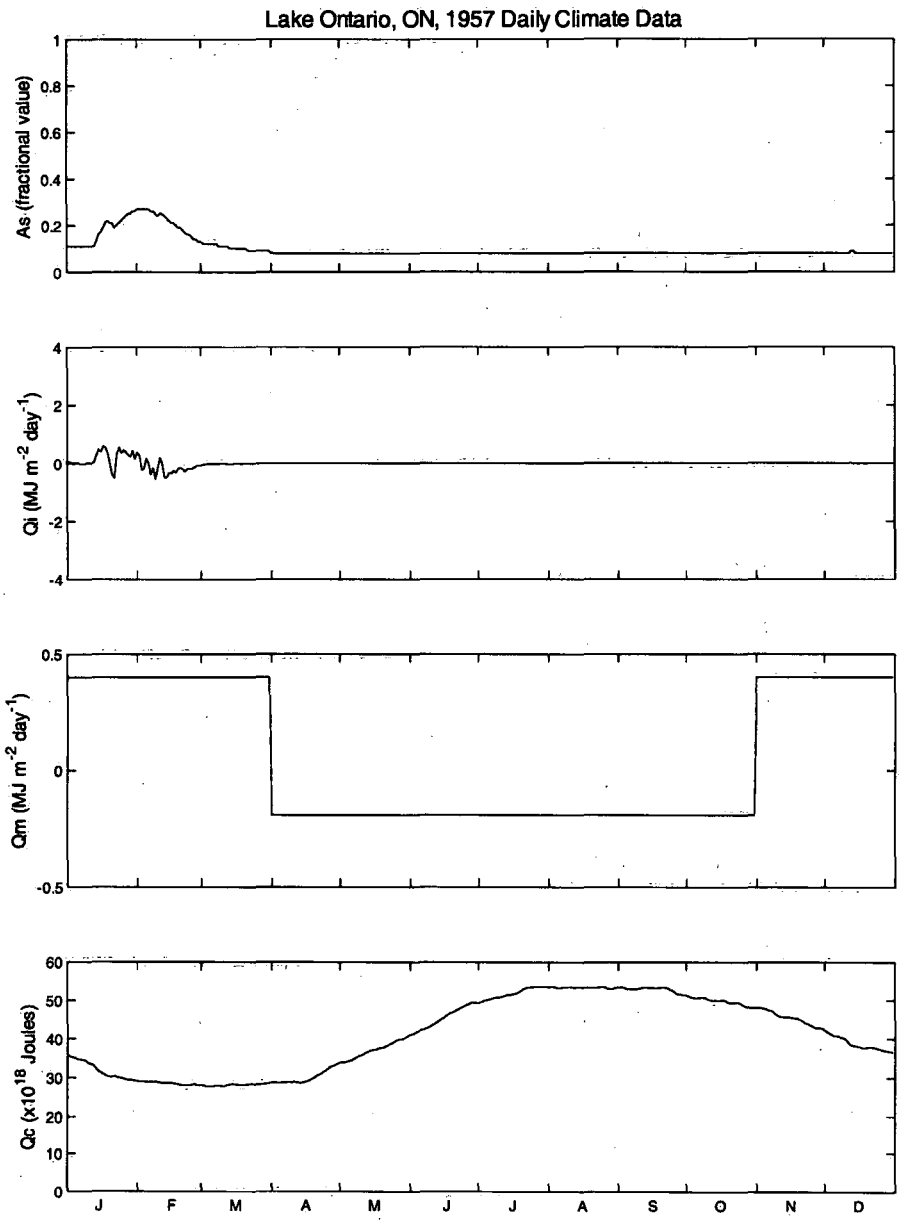
Lake Ontario, ON, 1957 Daily Climate Data
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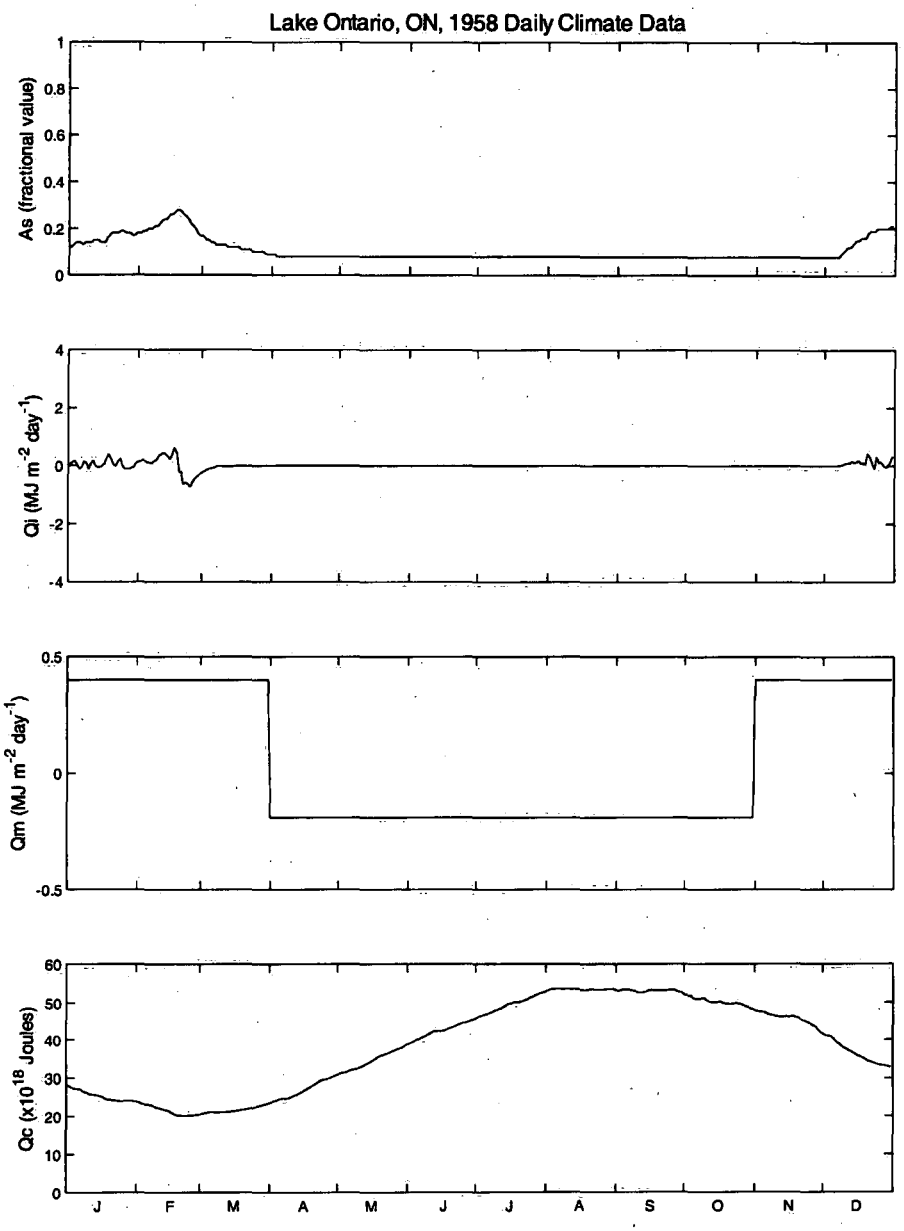
Lake Ontario, ON, 1958 Daily Climate Data
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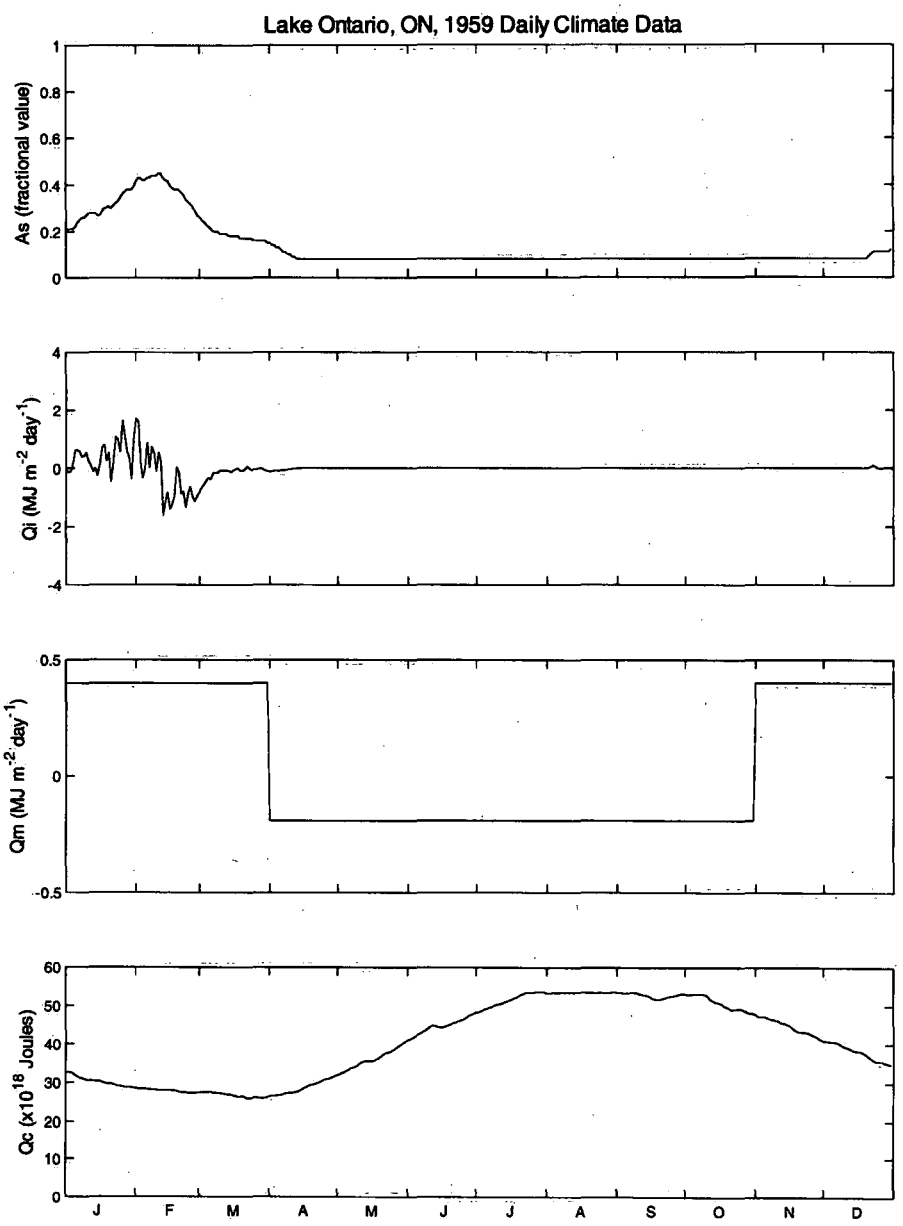
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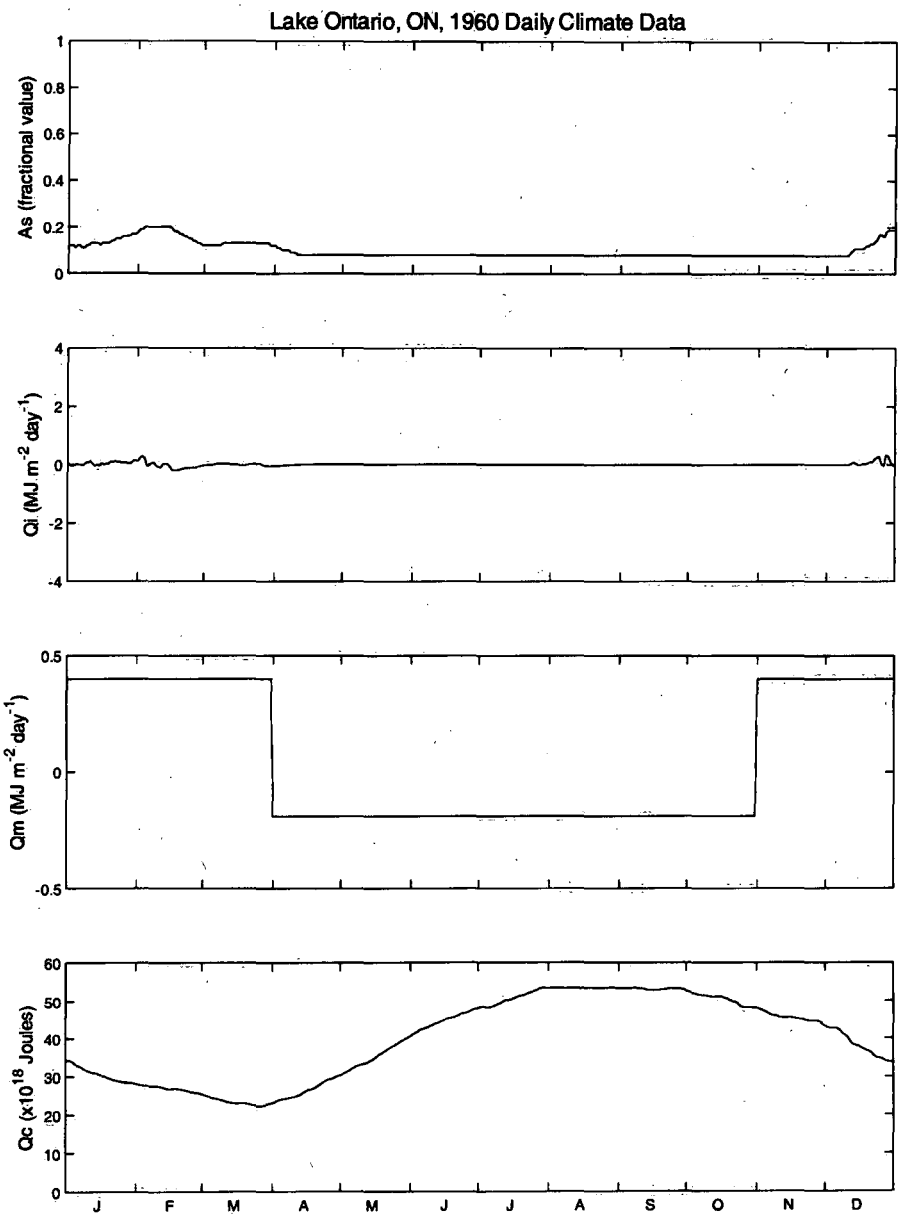
Lake Ontario, ON, 1960 Daily Climate Data
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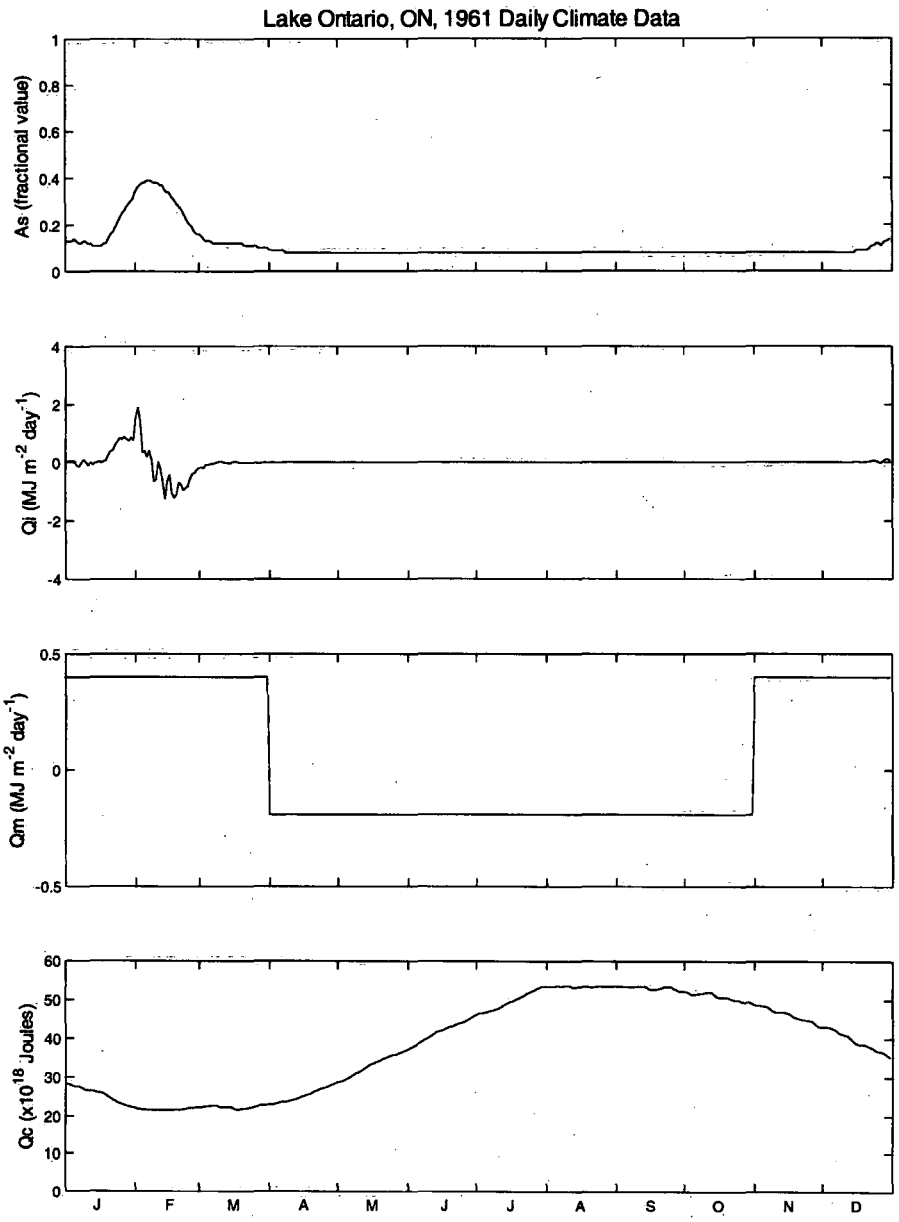
Lake Ontario, ON, 1961 Daily Climate Data
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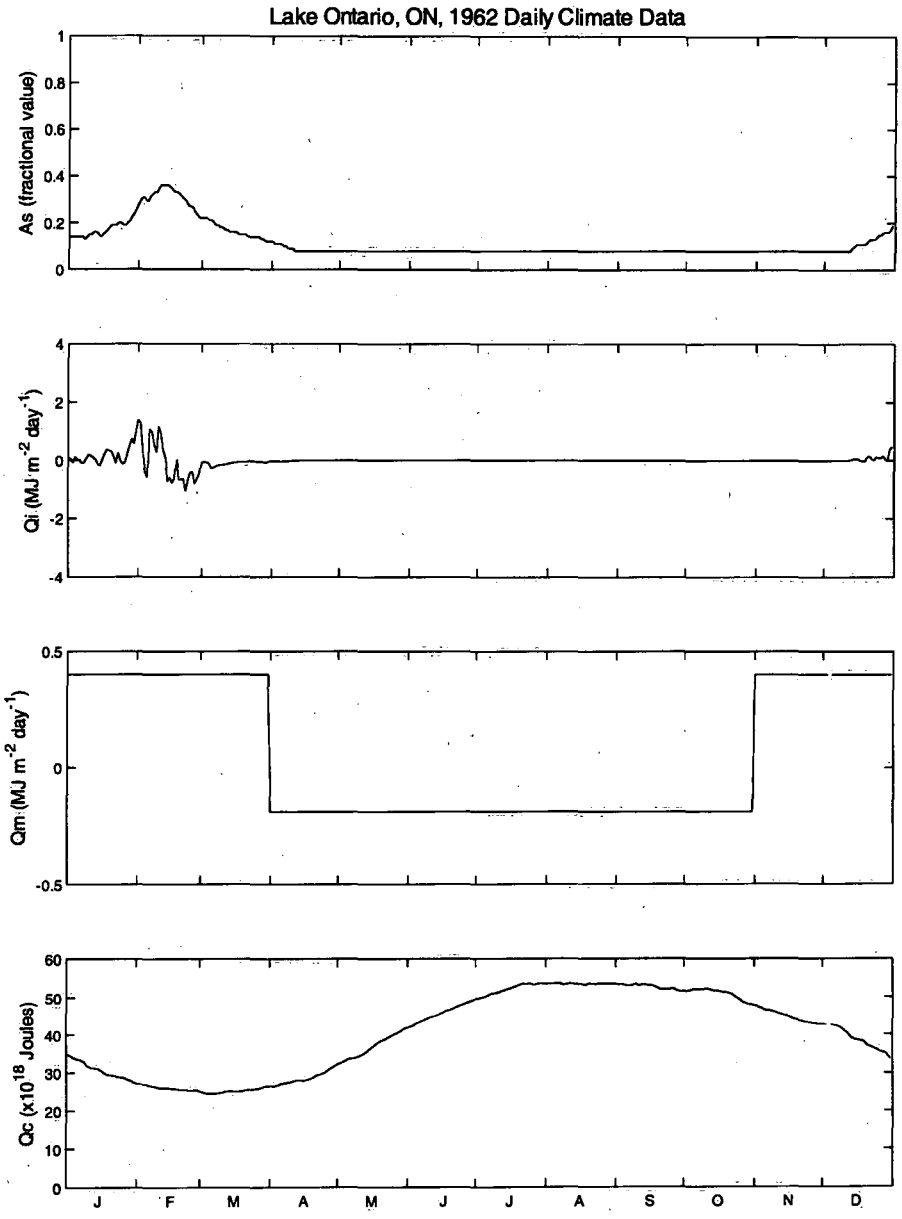
Lake Ontario, ON, 1962 Daily Climate Data
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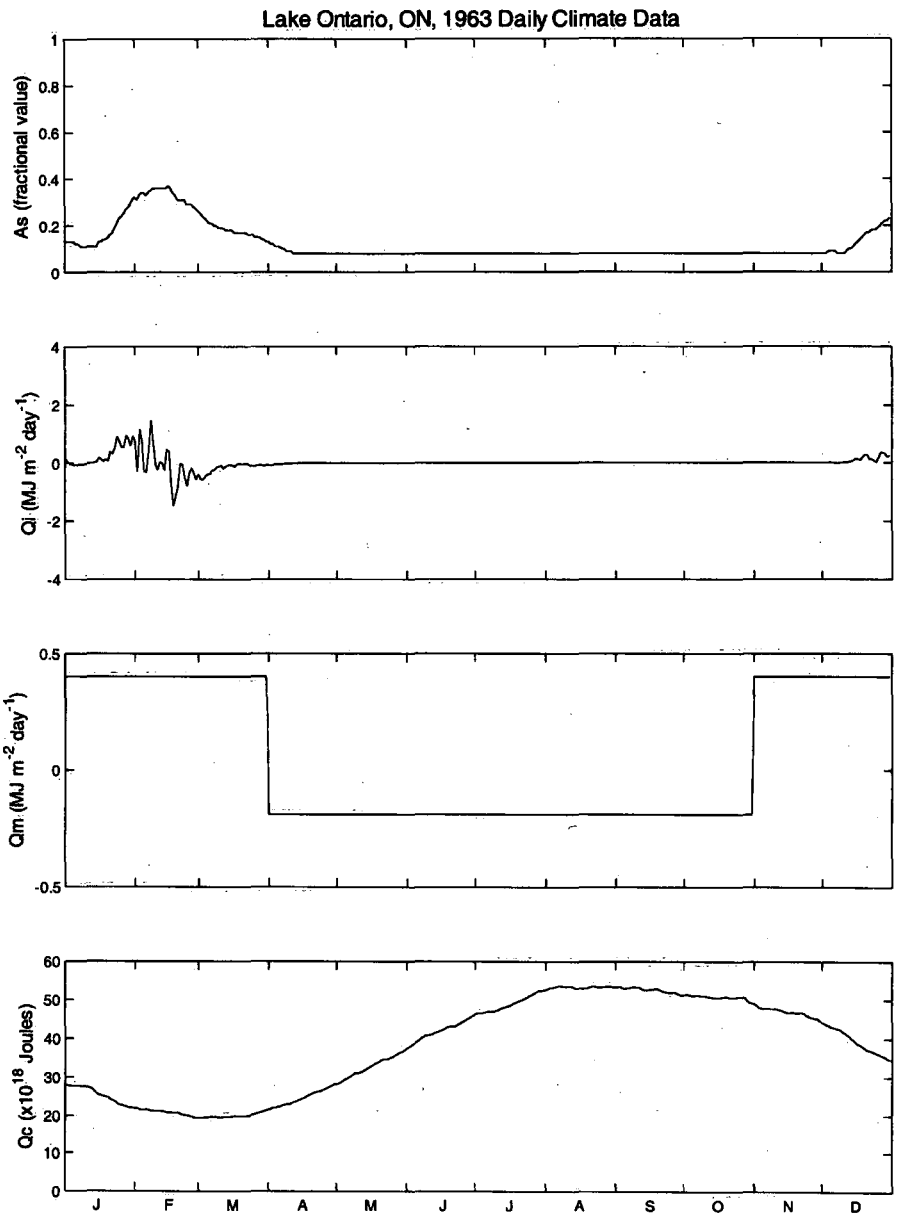
Lake Ontario, ON, 1963 Daily Climate Data
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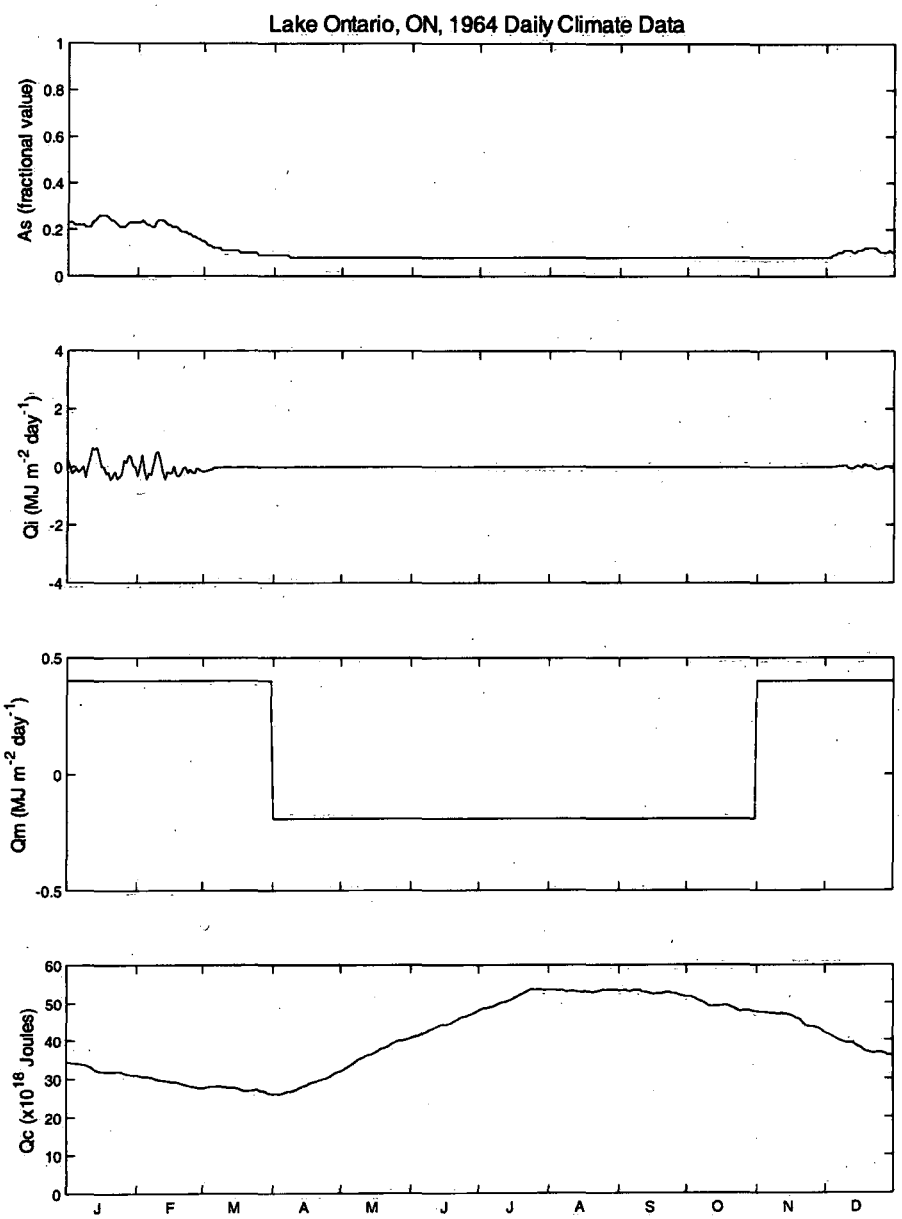
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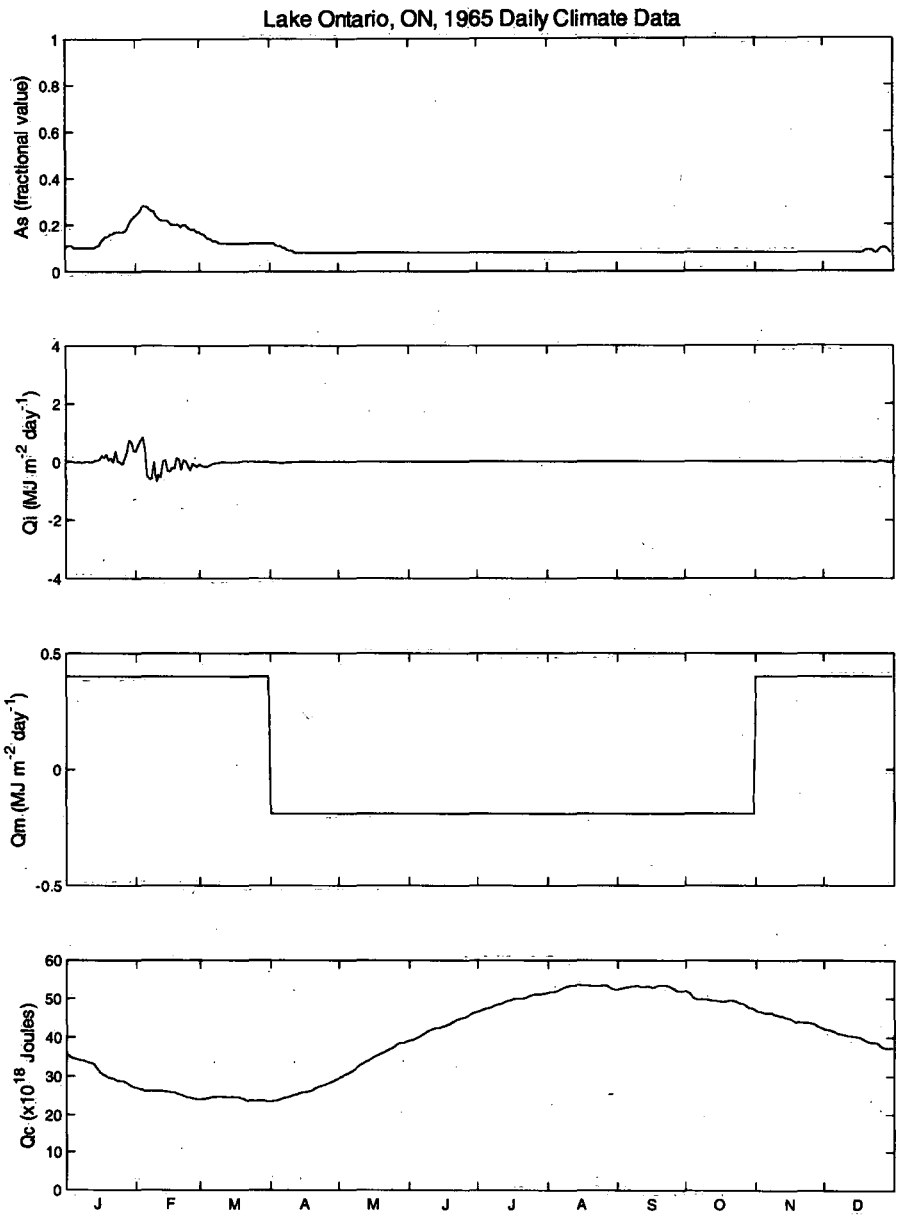
Lake Ontario, ON, 1965 Daily Climate Data
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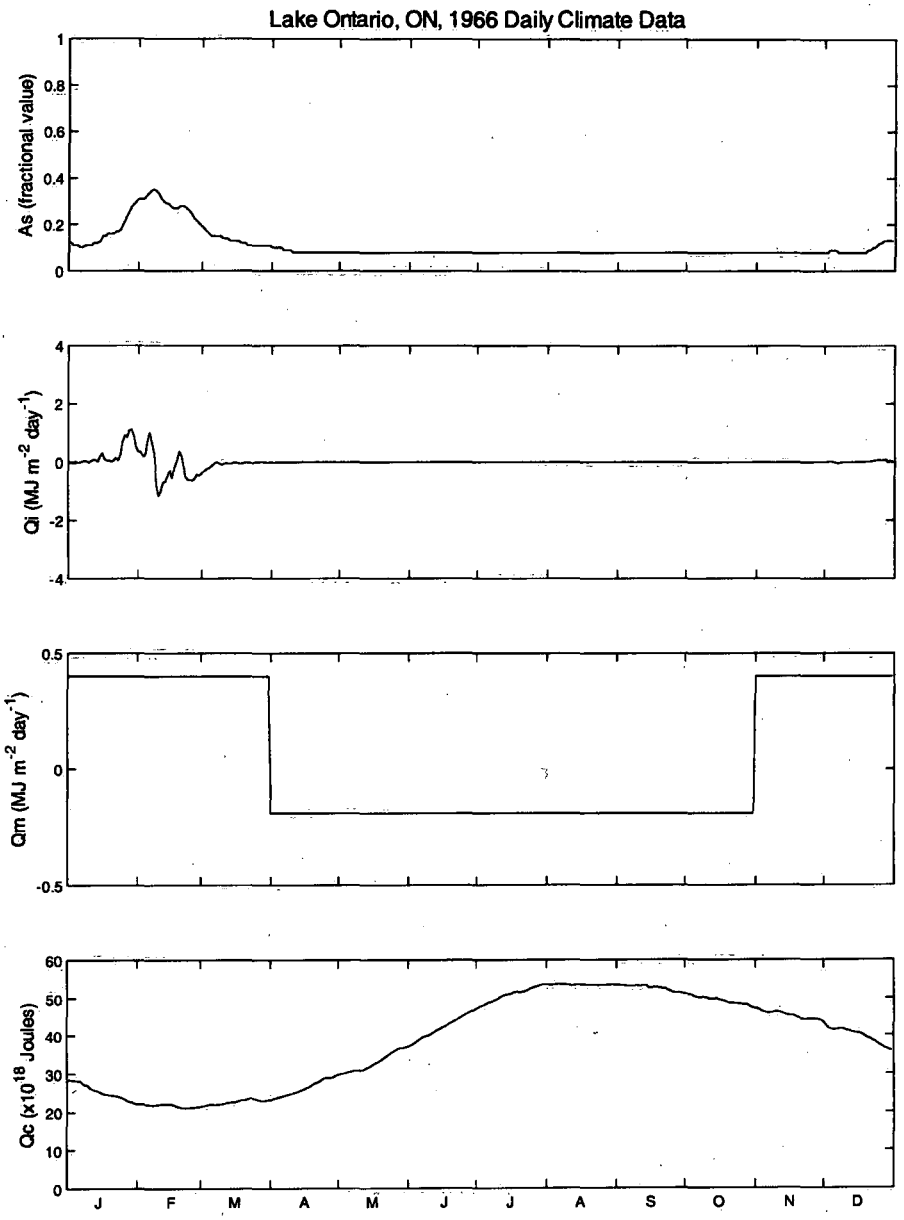
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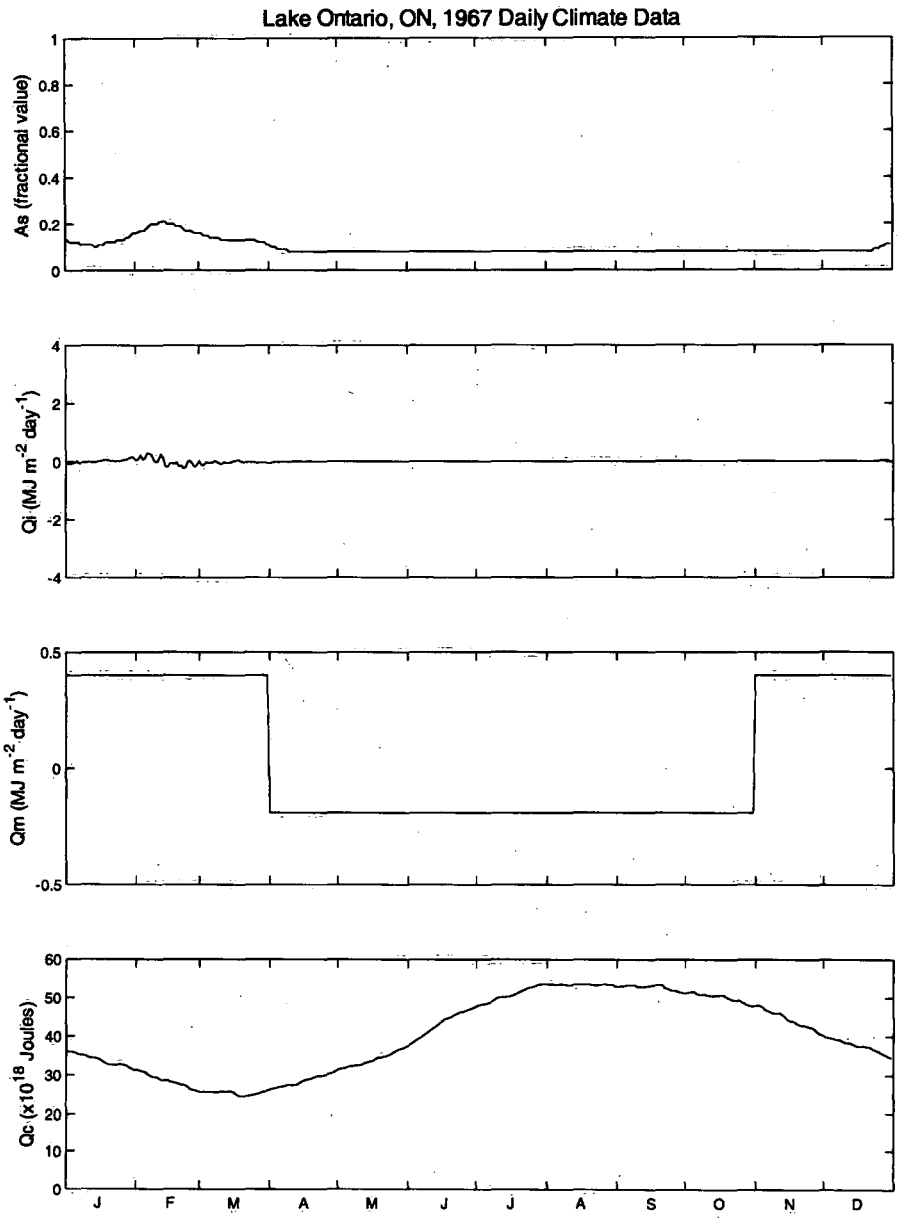
Lake Ontario, ON, 1967 Daily Climate Data
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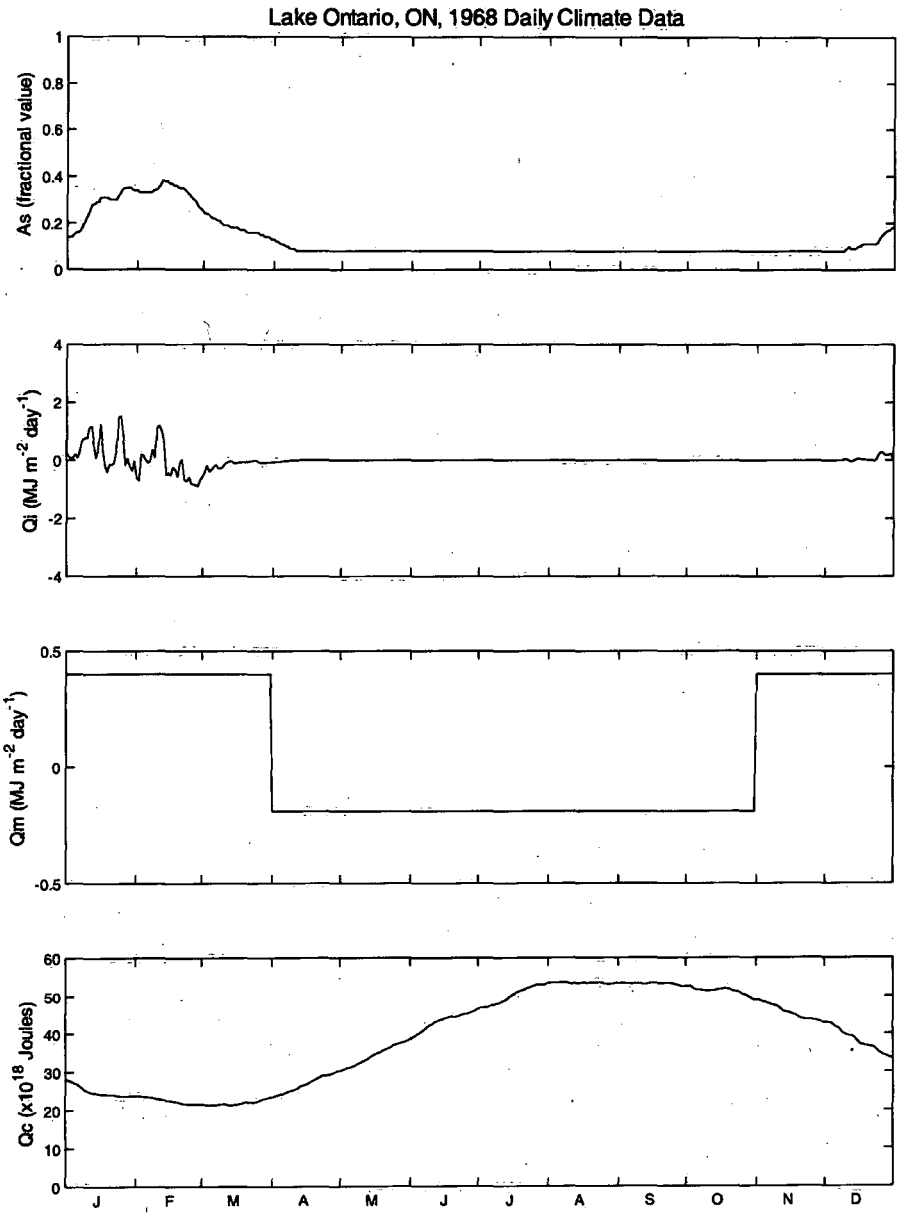
Lake Ontario, ON, 1968 Daily Climate Data
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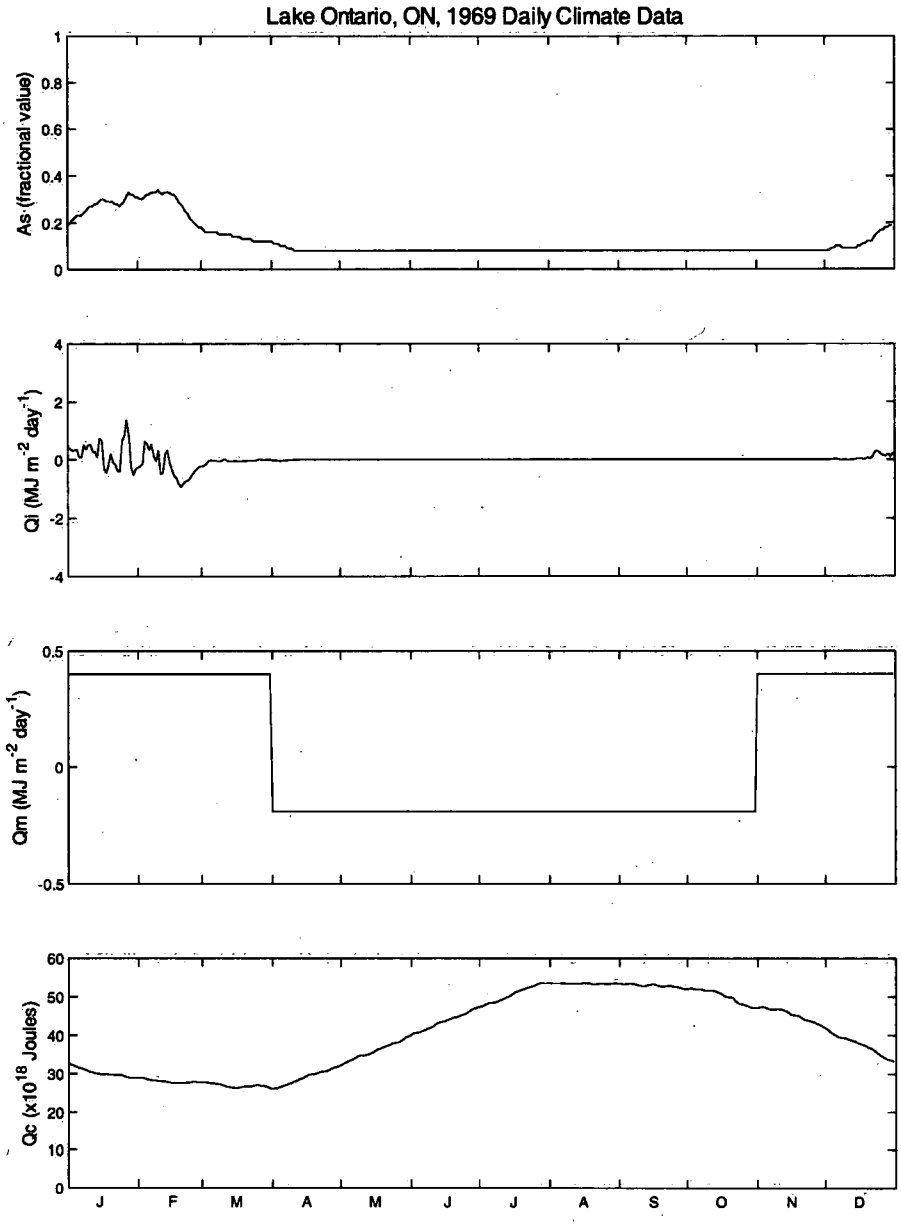
Lake Ontario, ON, 1969 Daily Climate Data
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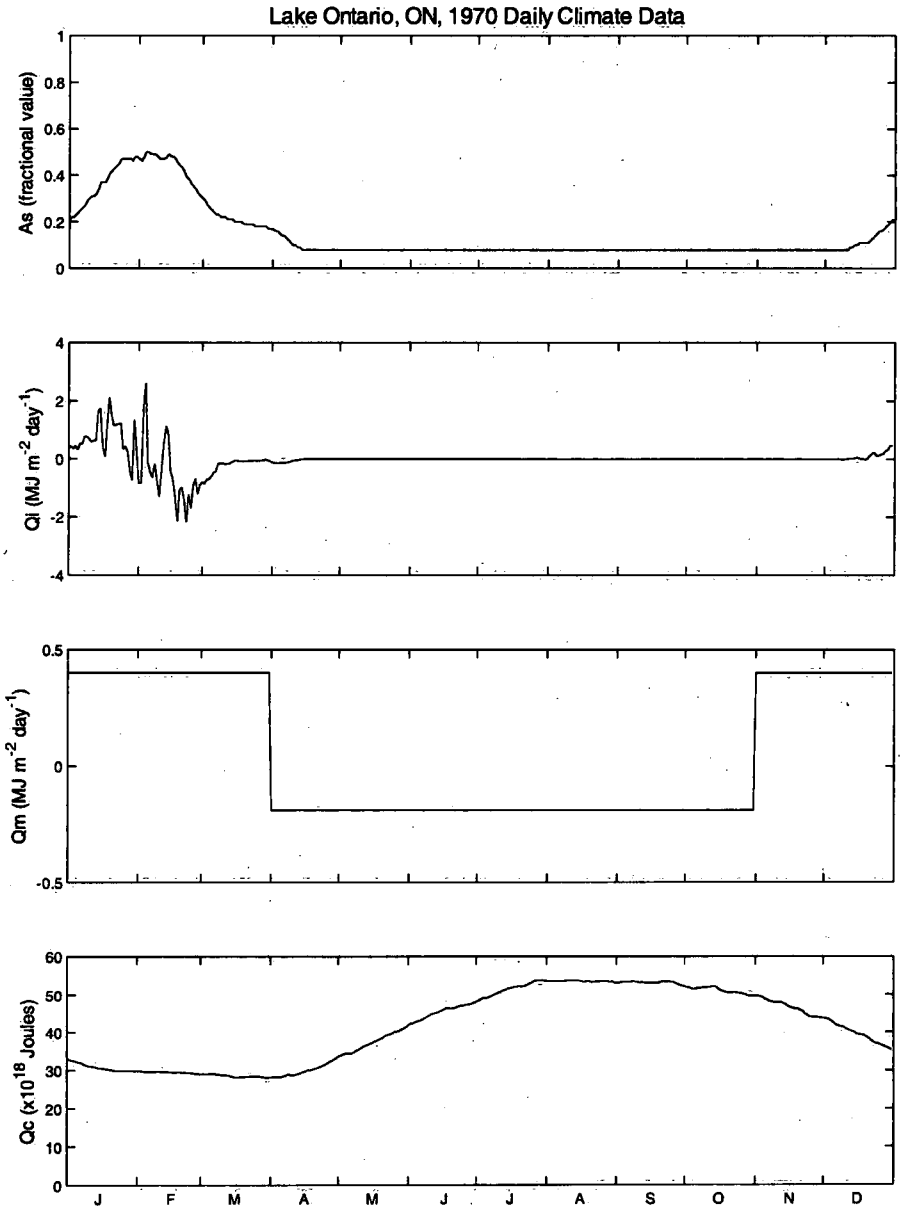
Lake Ontario, ON, 1970 Daily Climate Data
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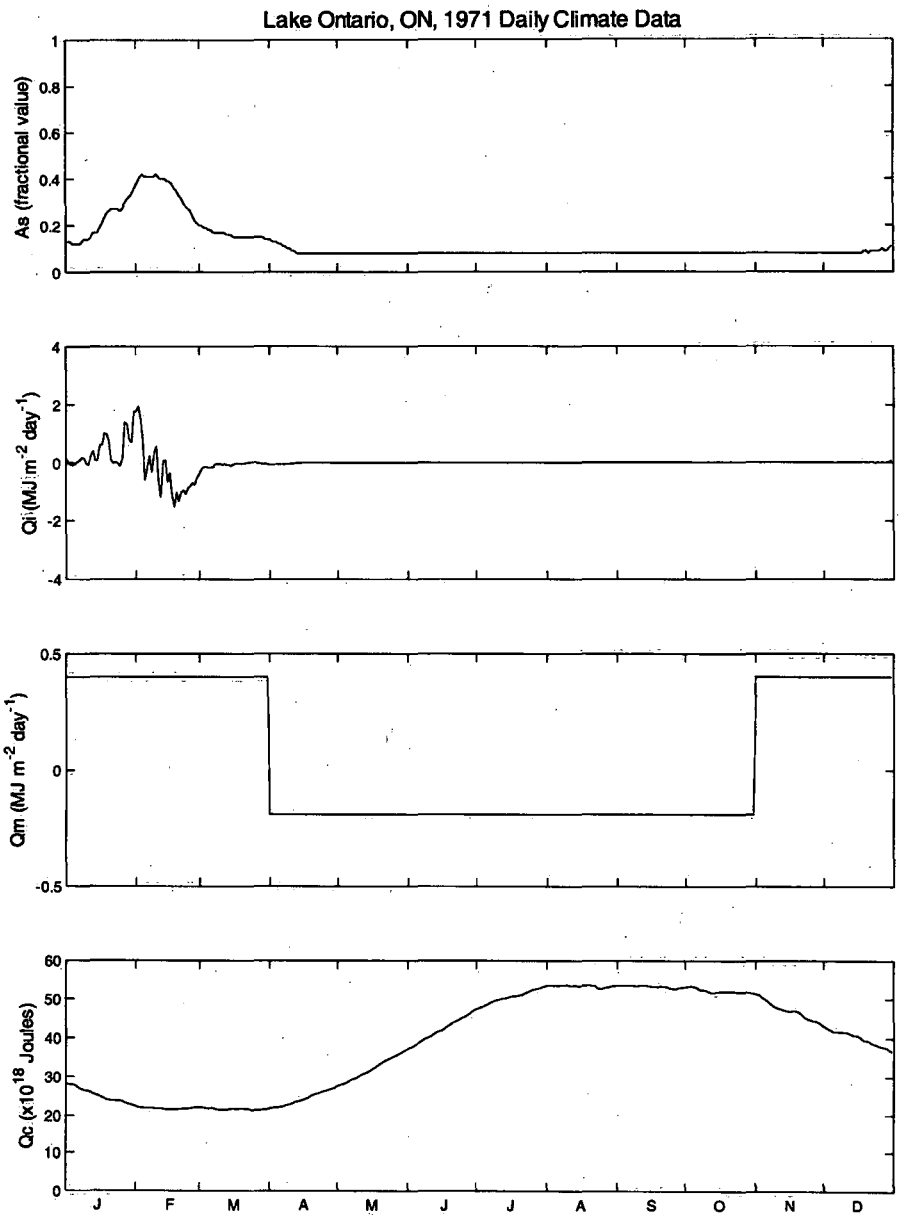
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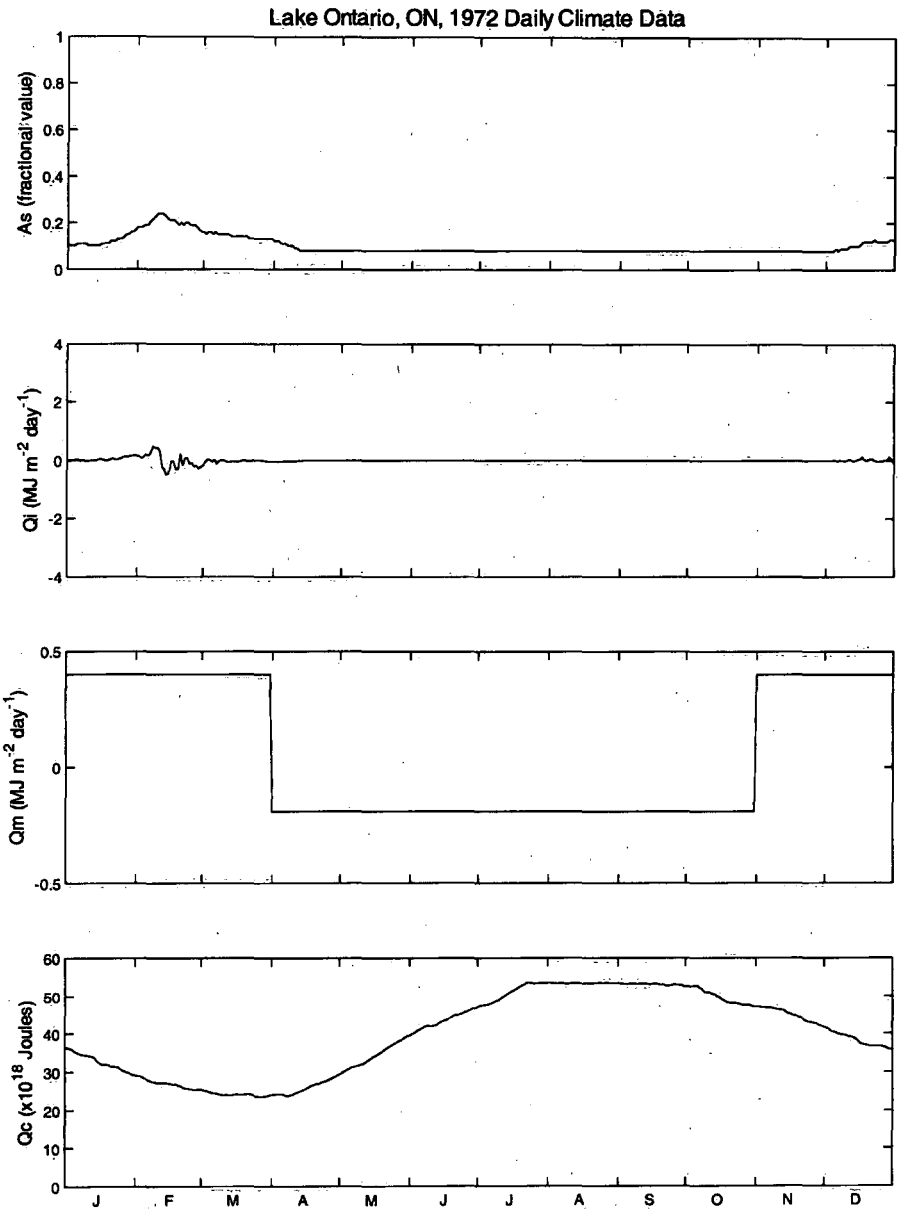
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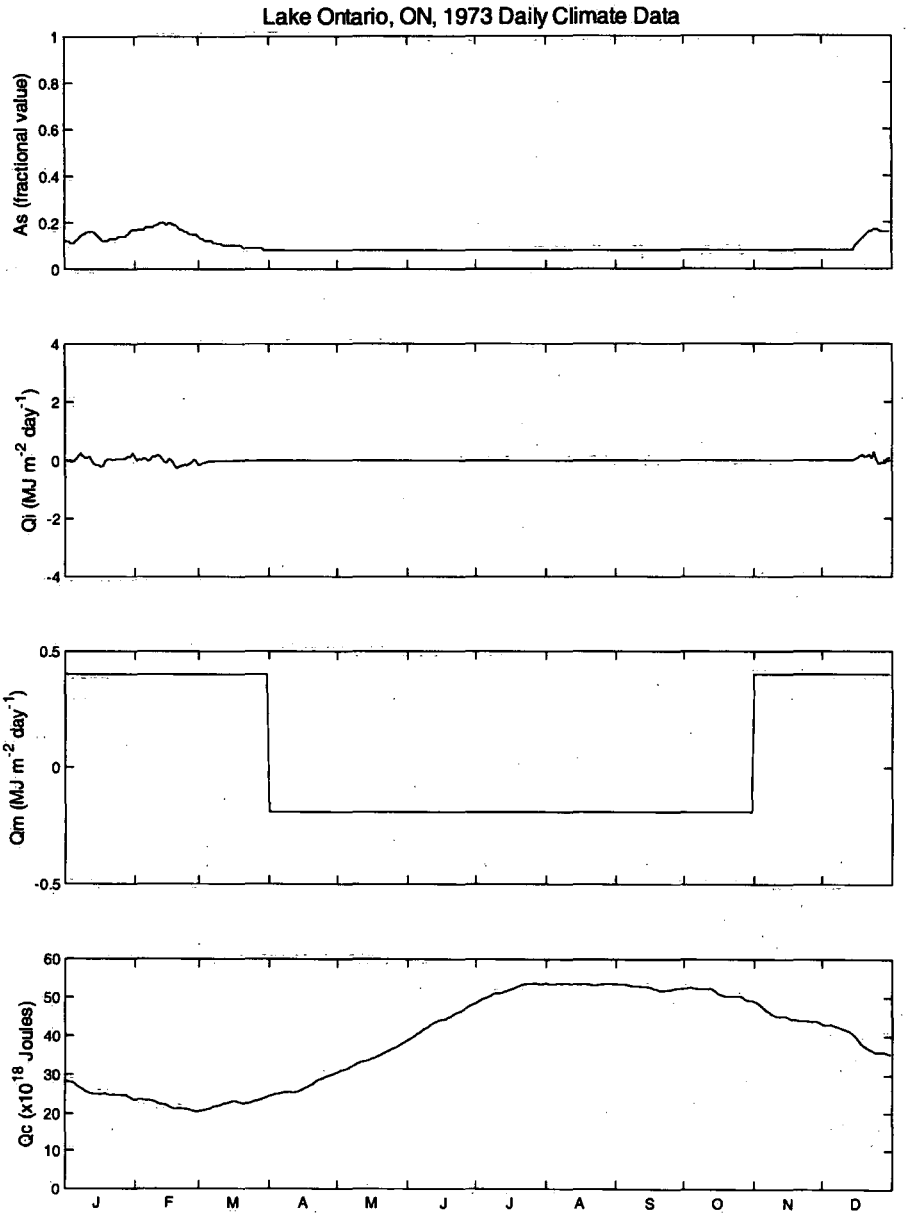
Lake Ontario, ON, 1973 Daily Climate Data
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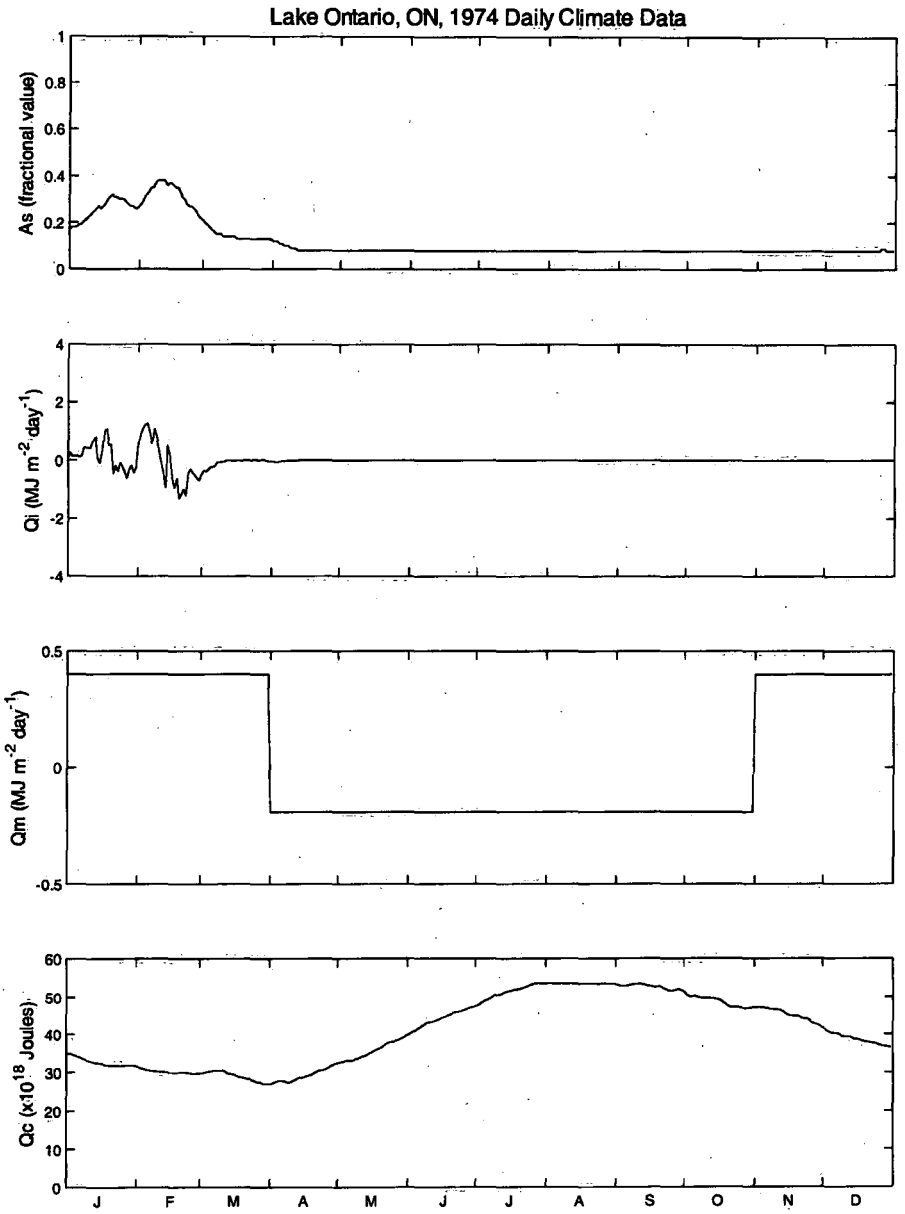
Lake Ontario, ON, 1974 Daily Climate Data
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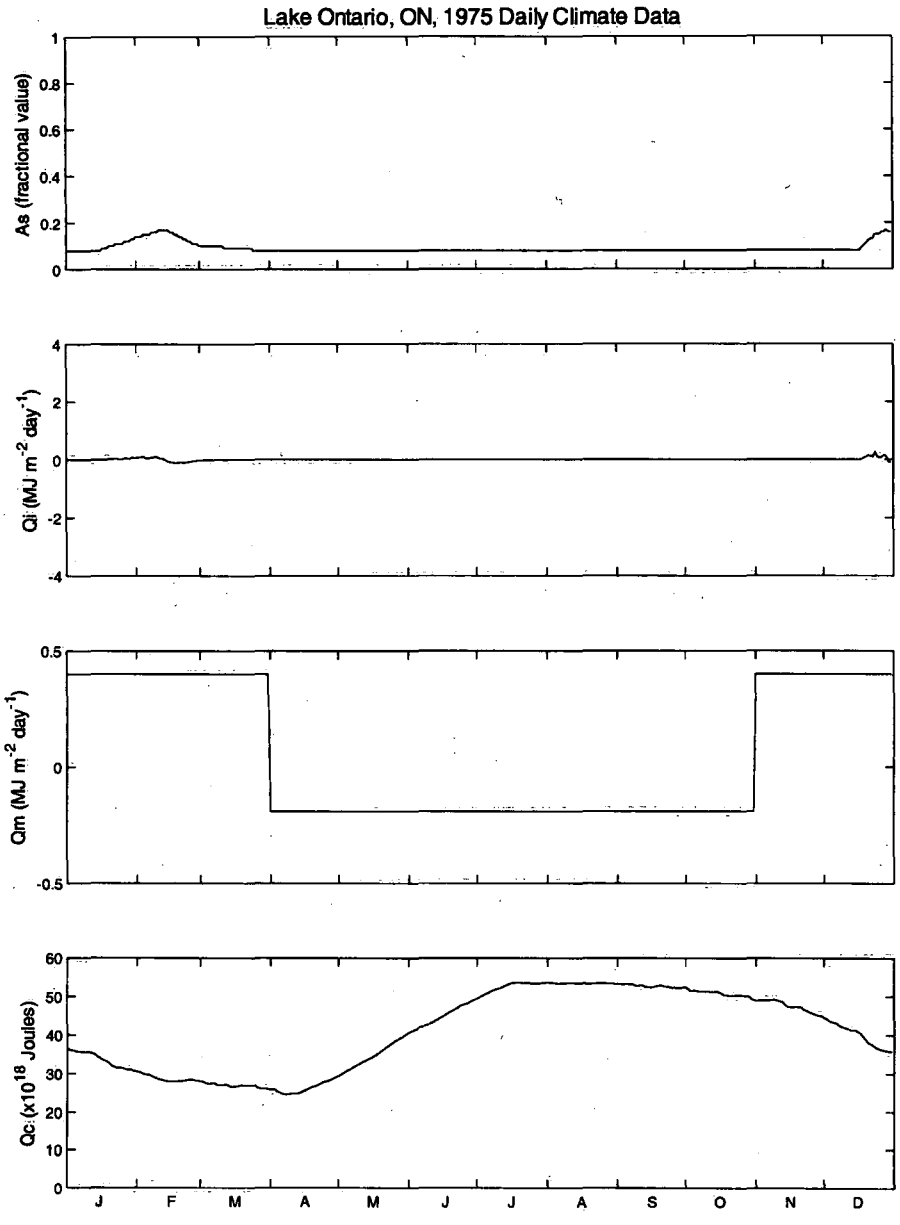
Lake Ontario, ON, 1975 Daily Climate Data
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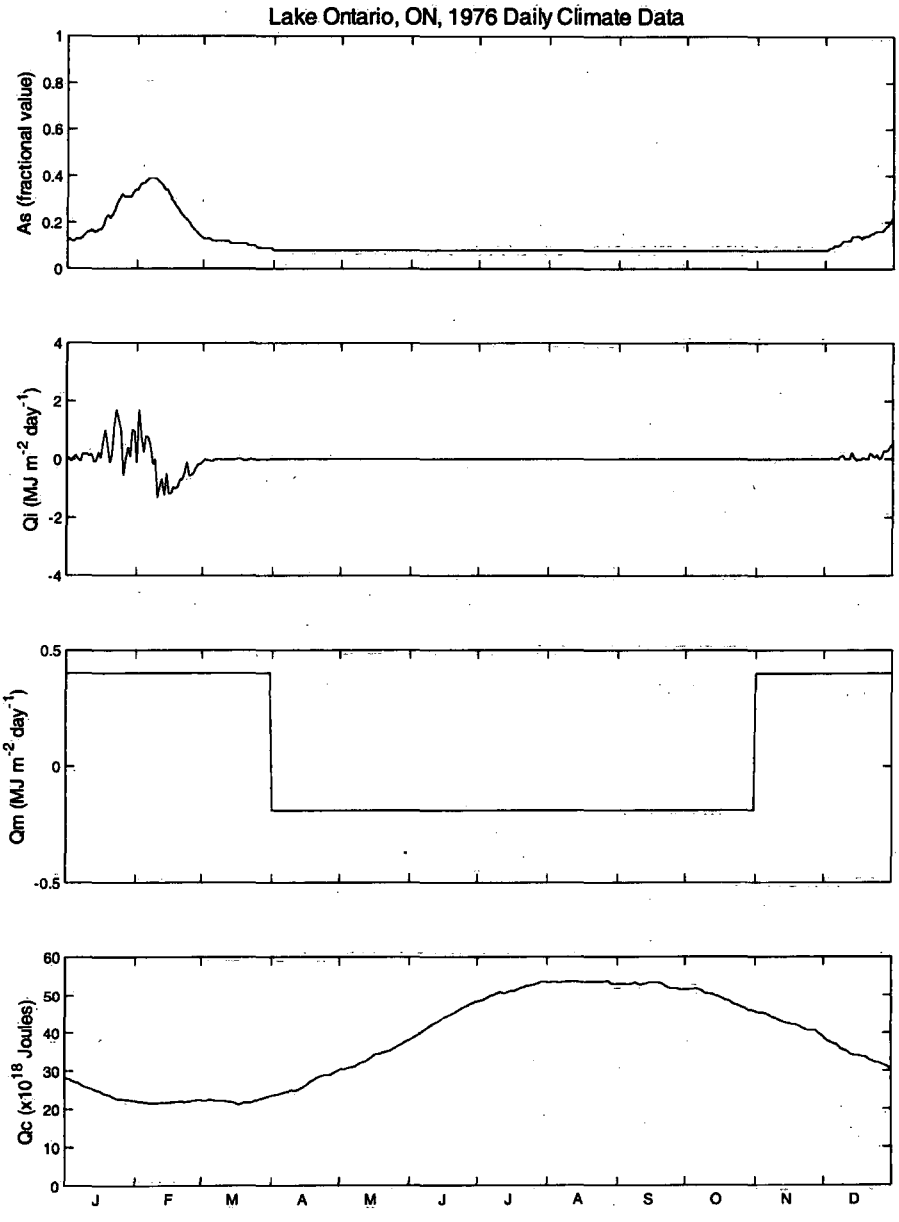
Lake Ontario, ON, 1976 Daily Climate Data
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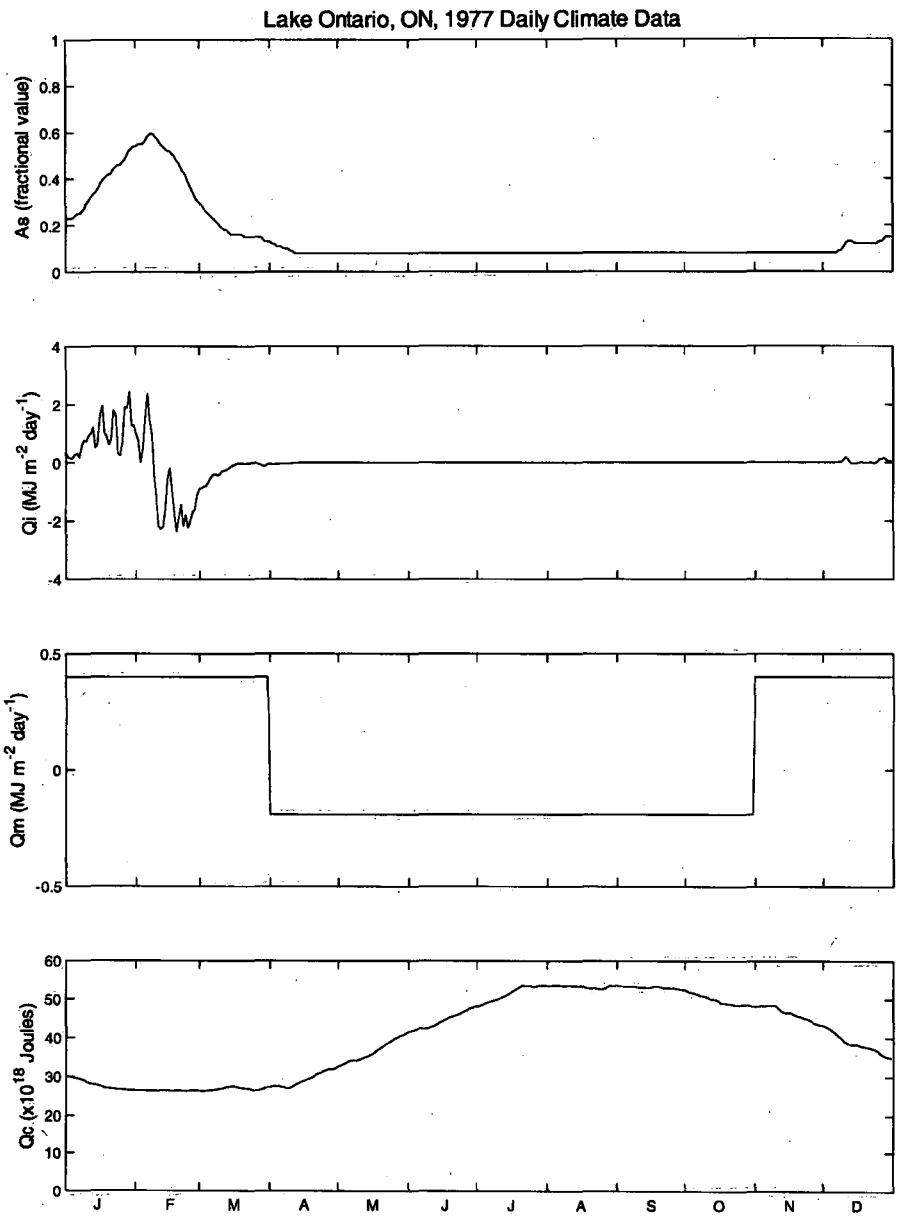
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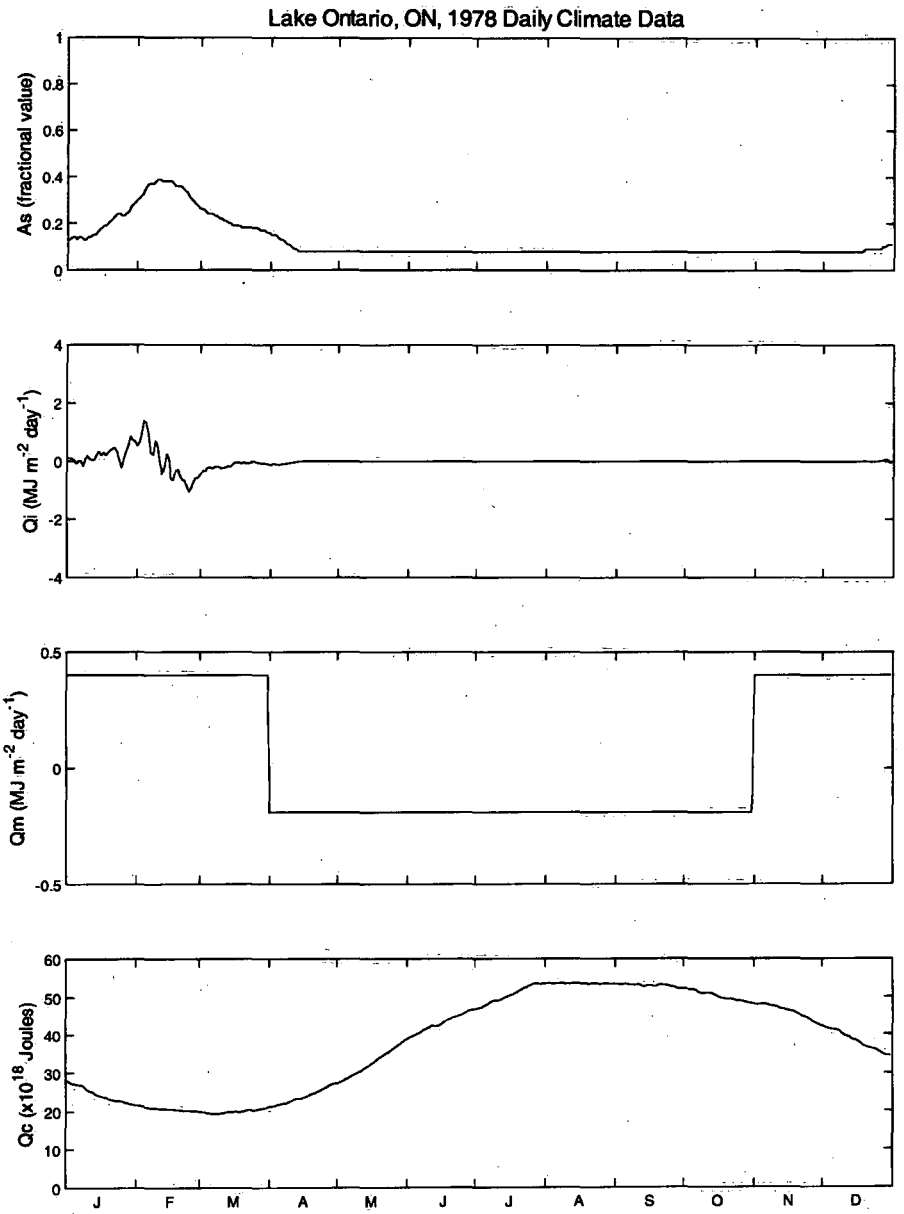
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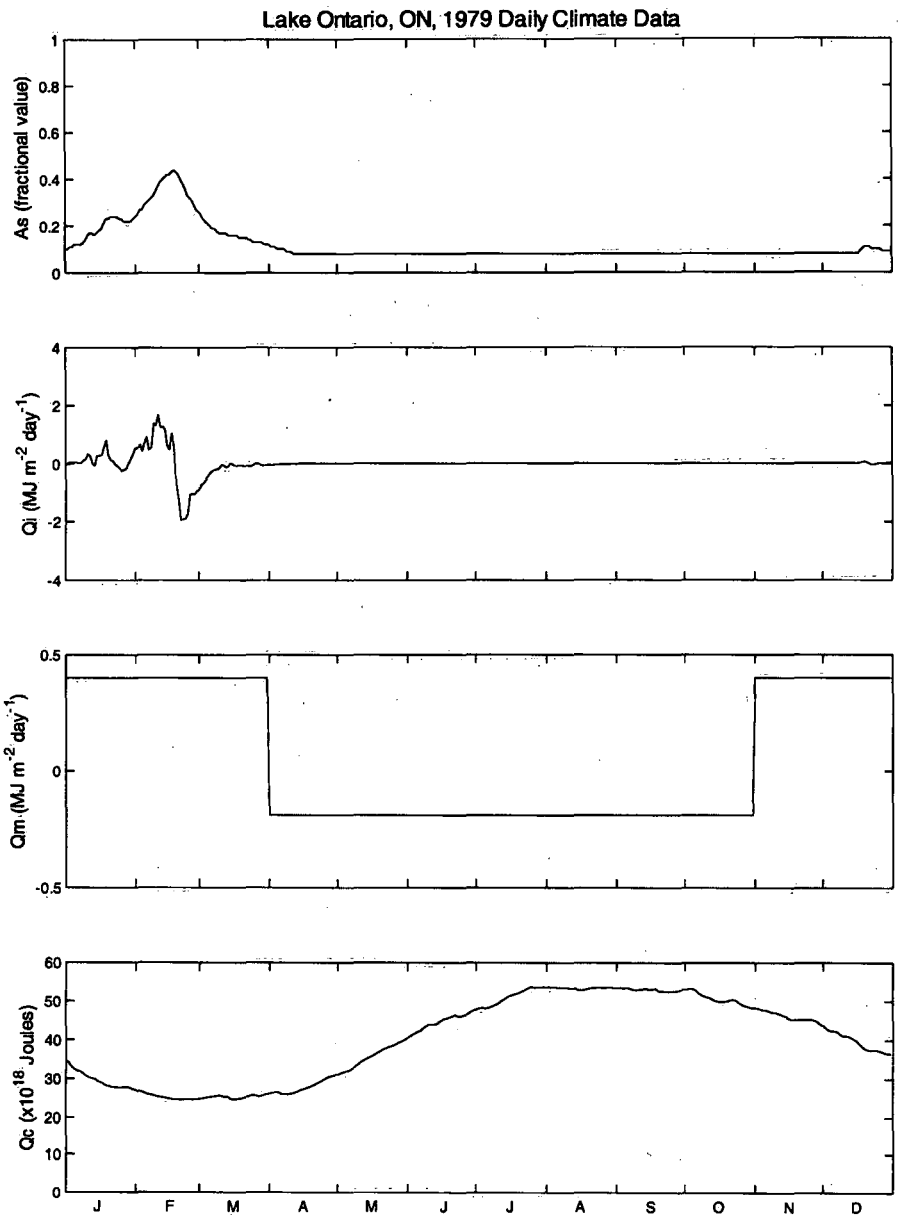
Lake Ontario, ON, 1979 Daily Climate Data
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Qc (x10^18 Joules)
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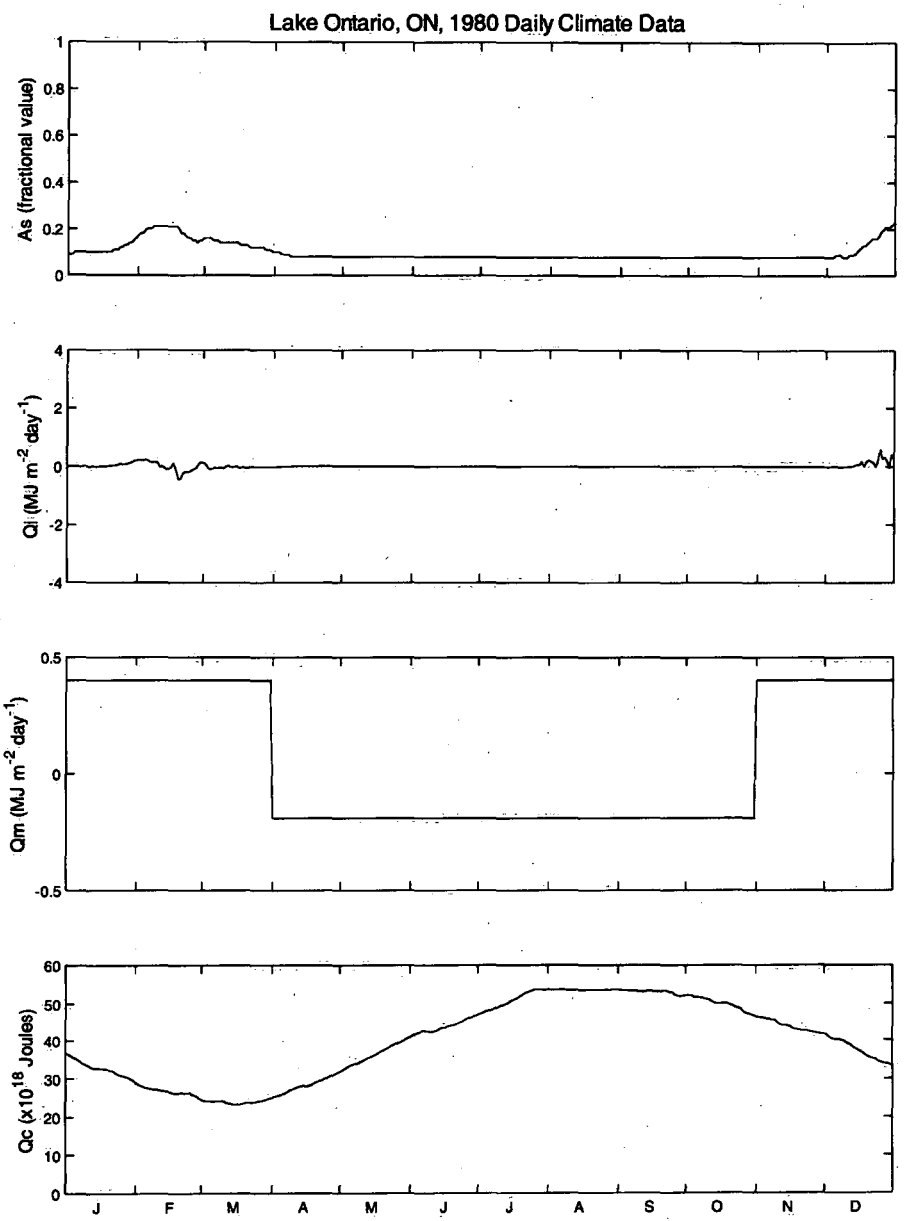
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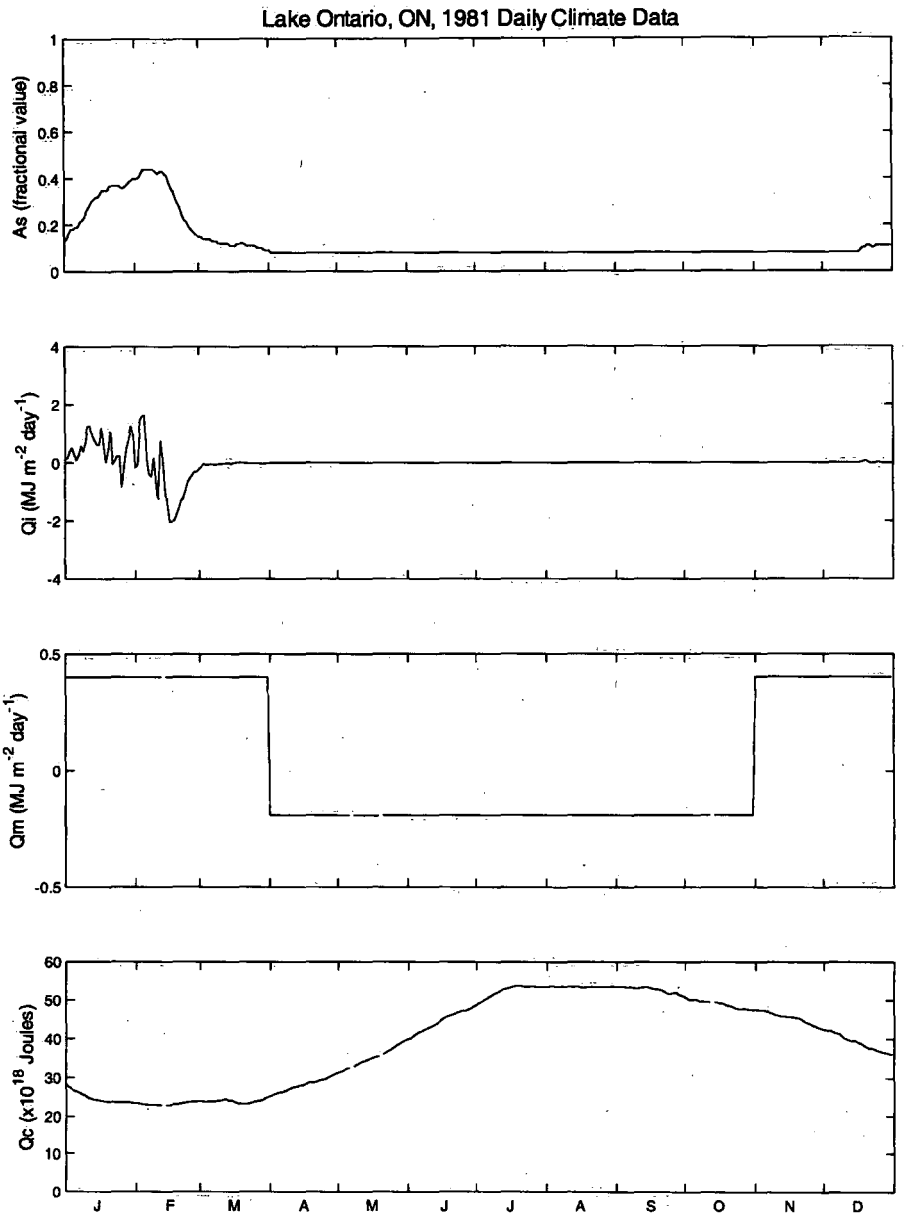
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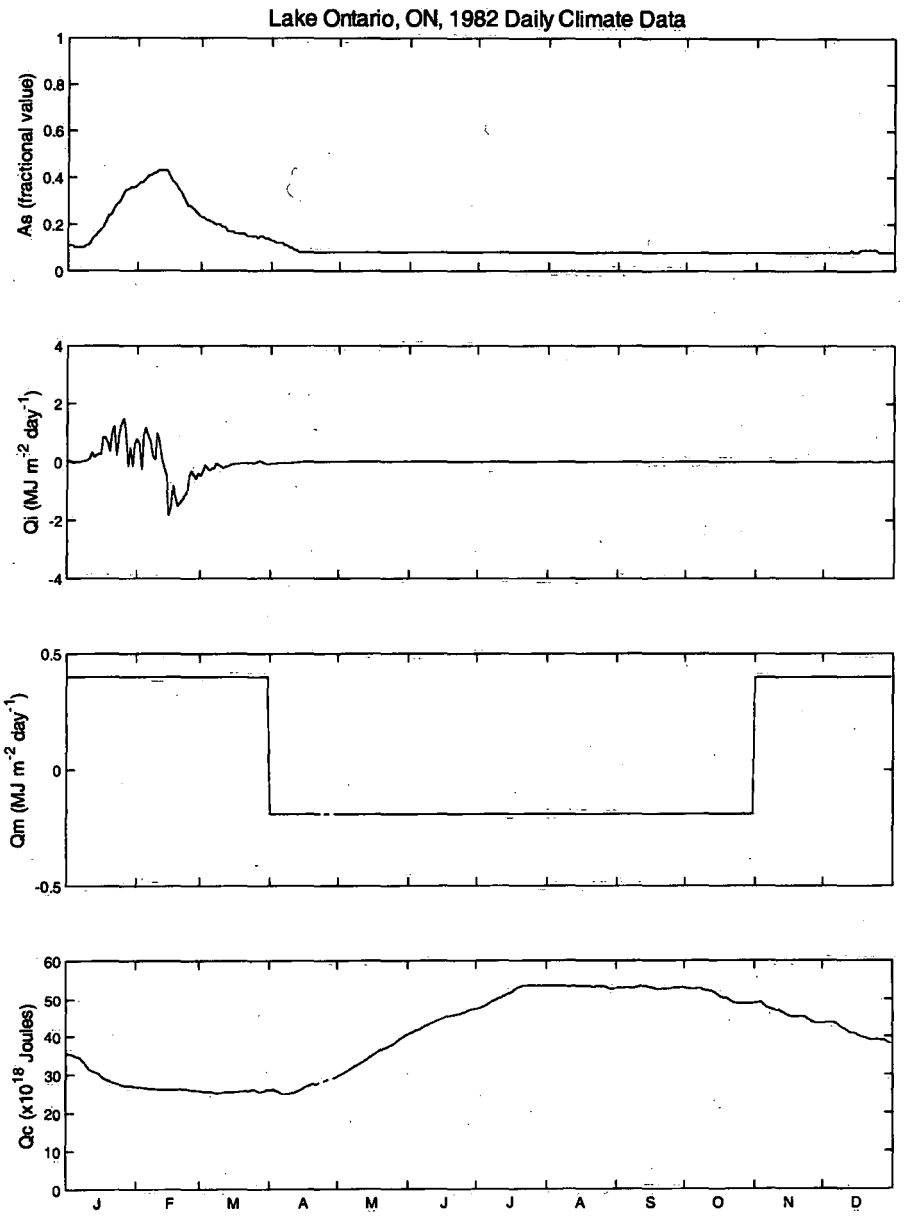
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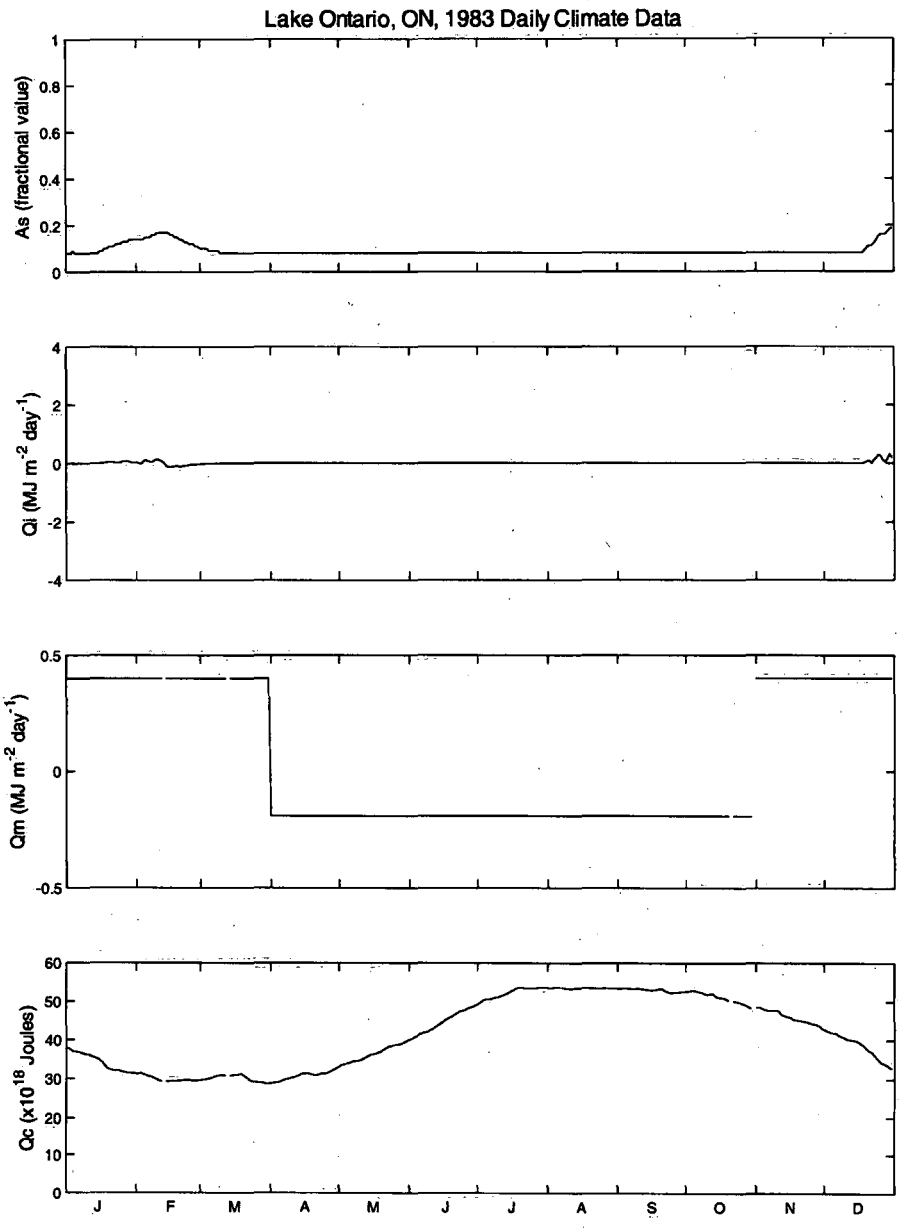
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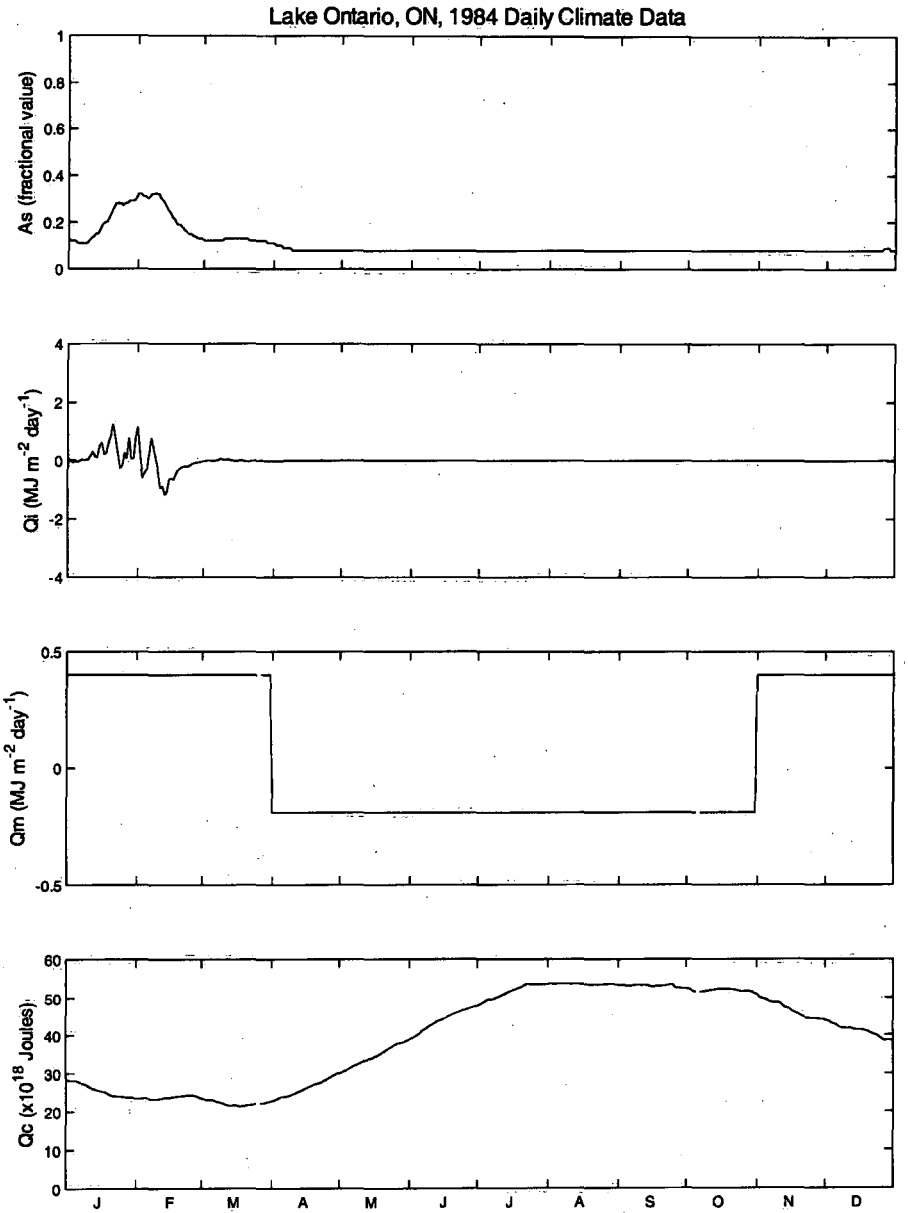
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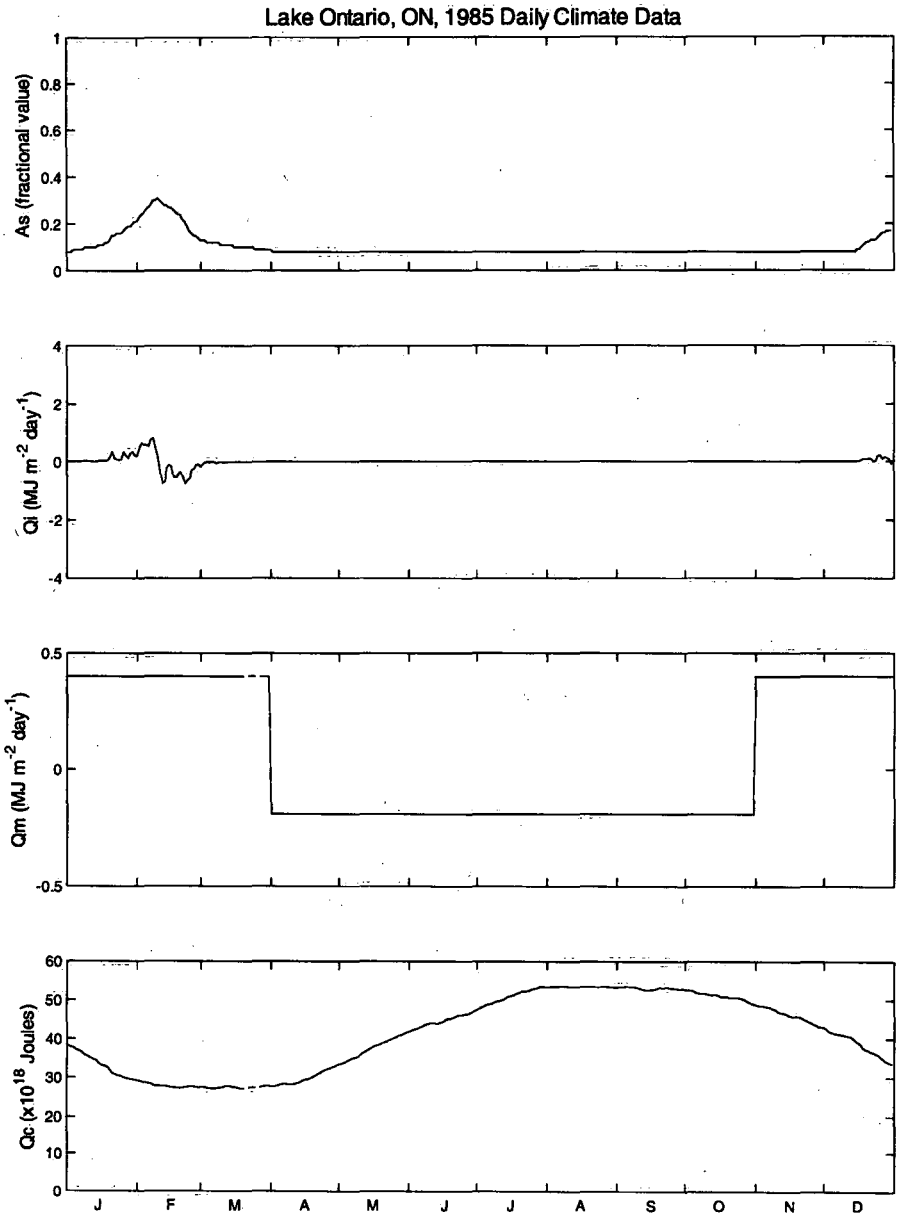
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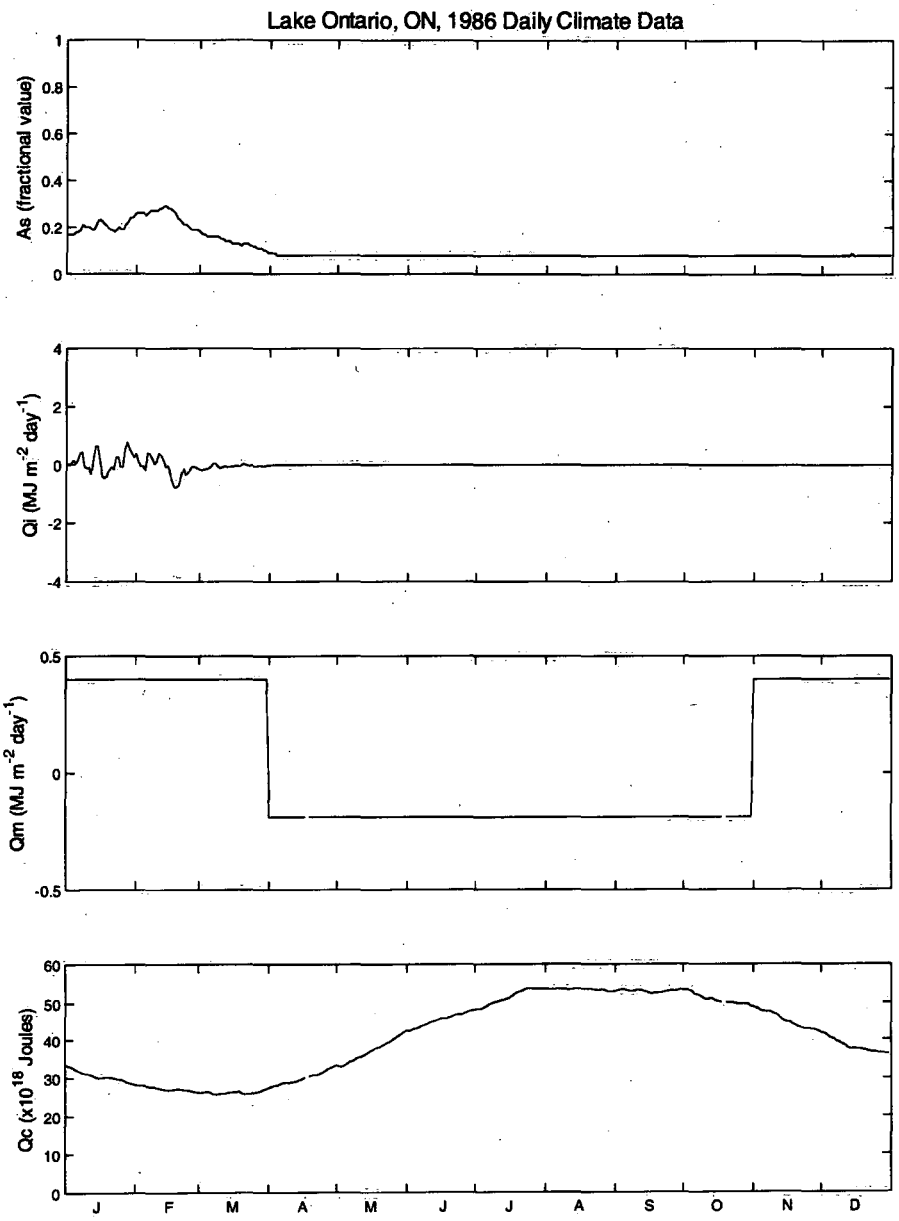
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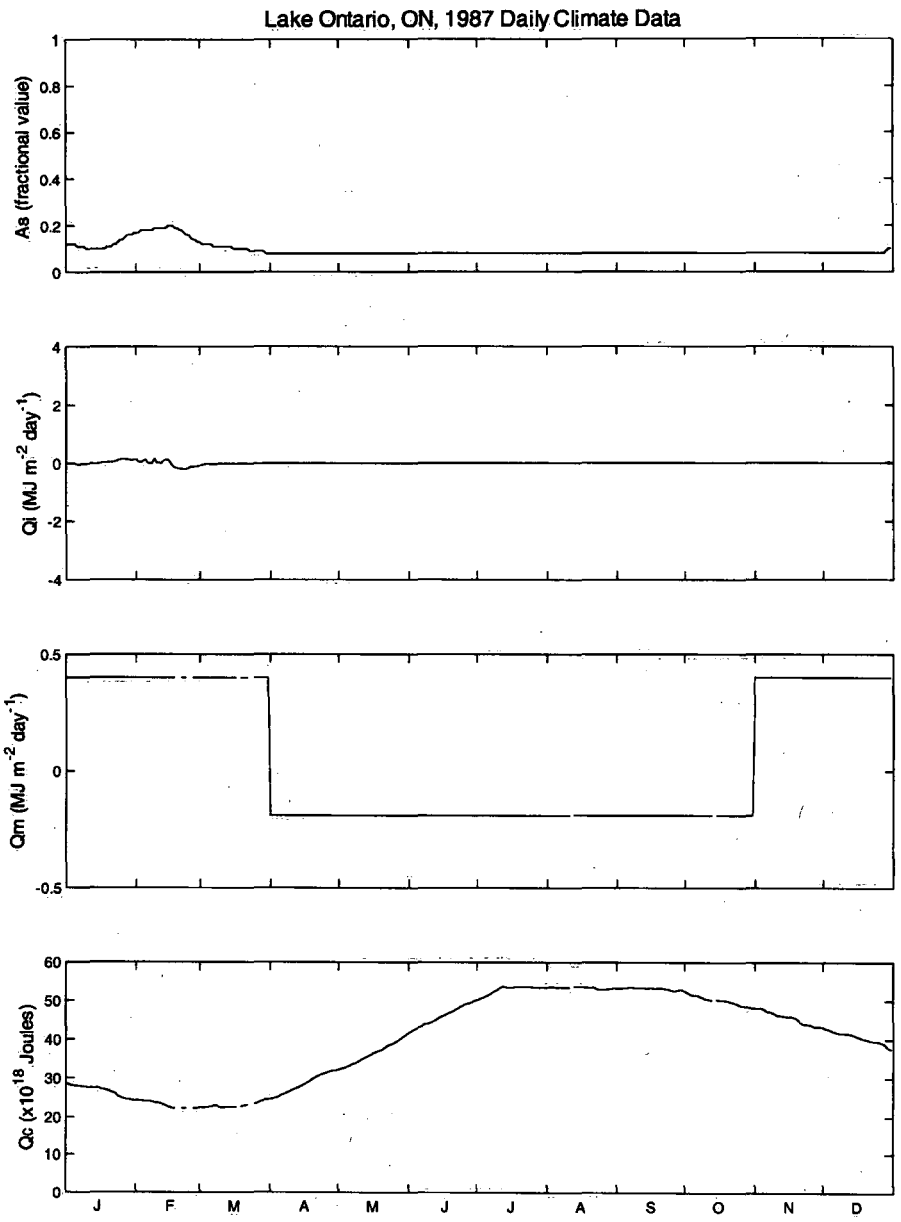
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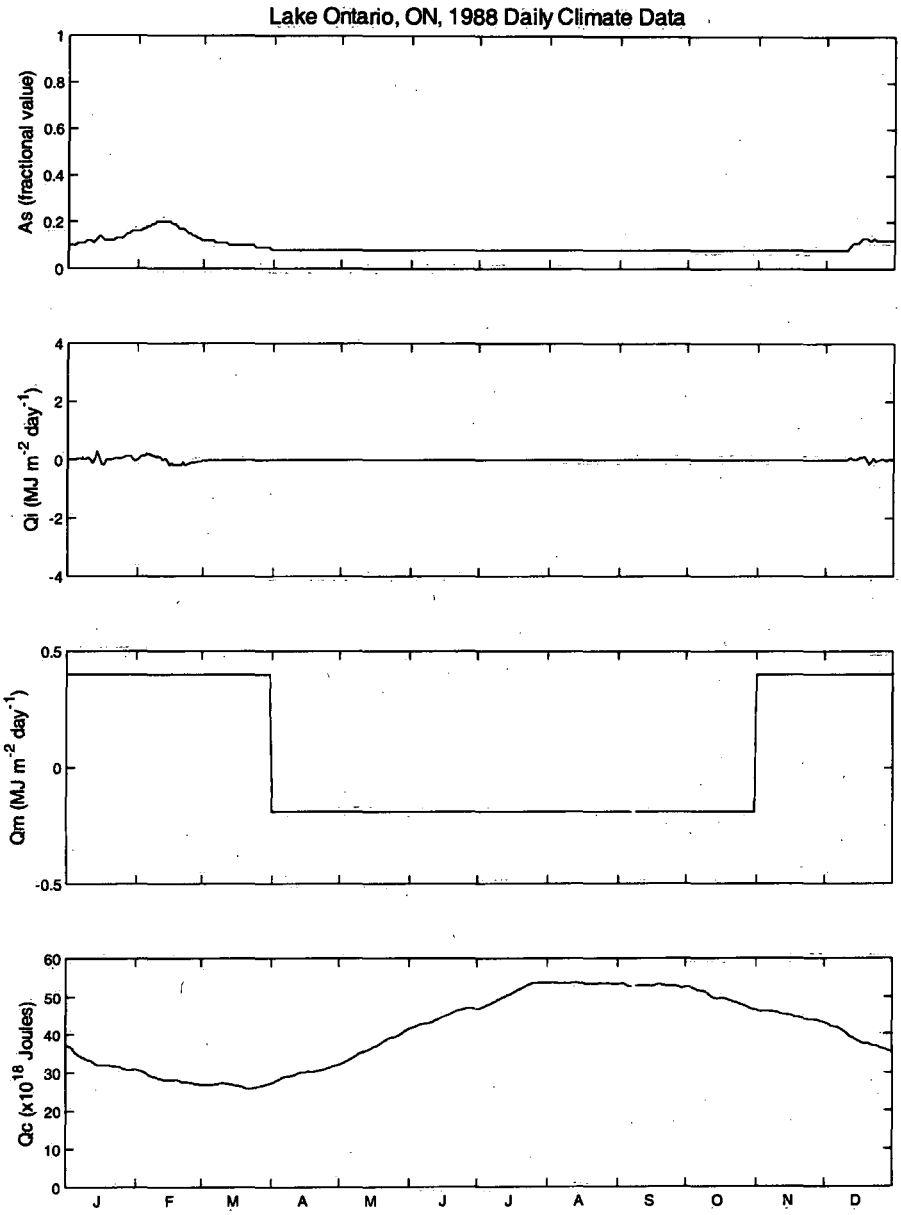
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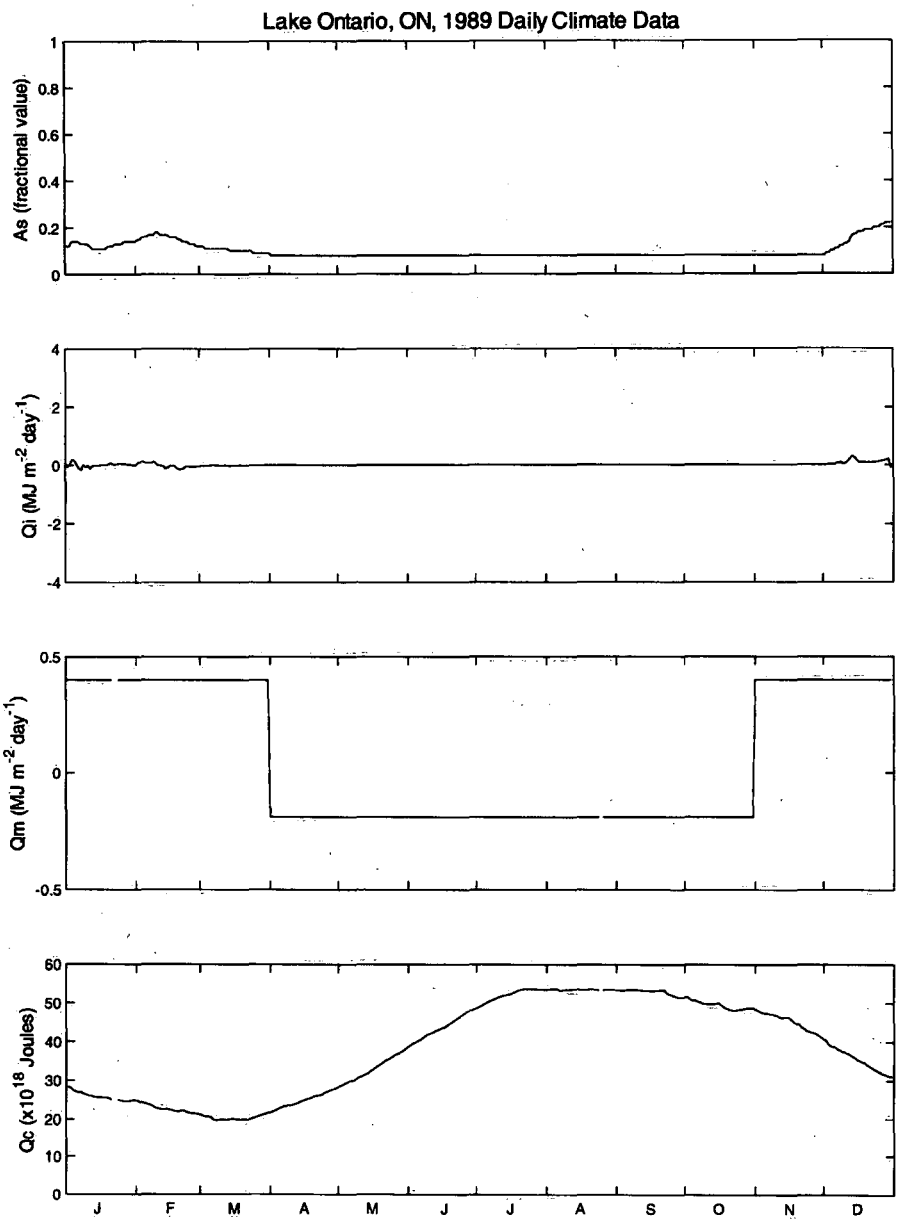
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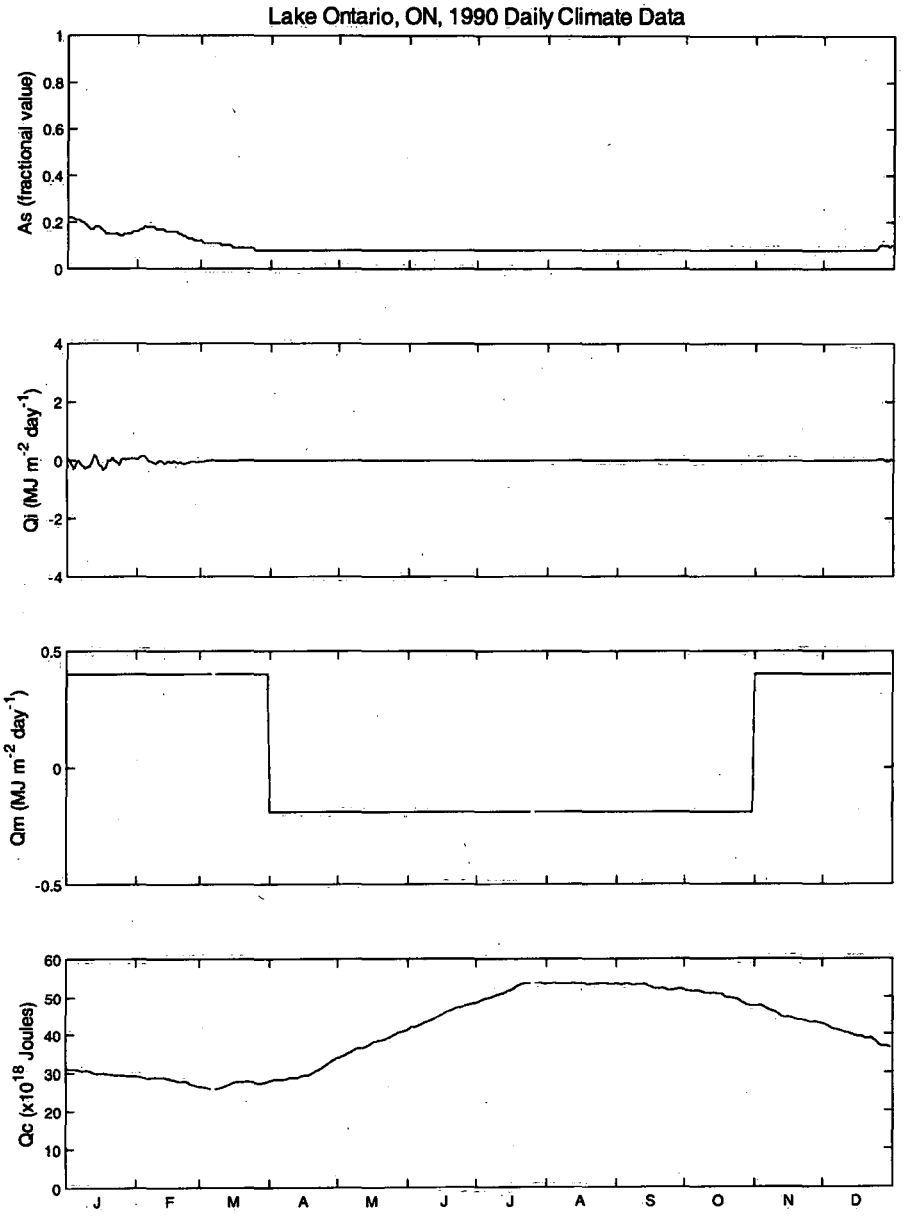
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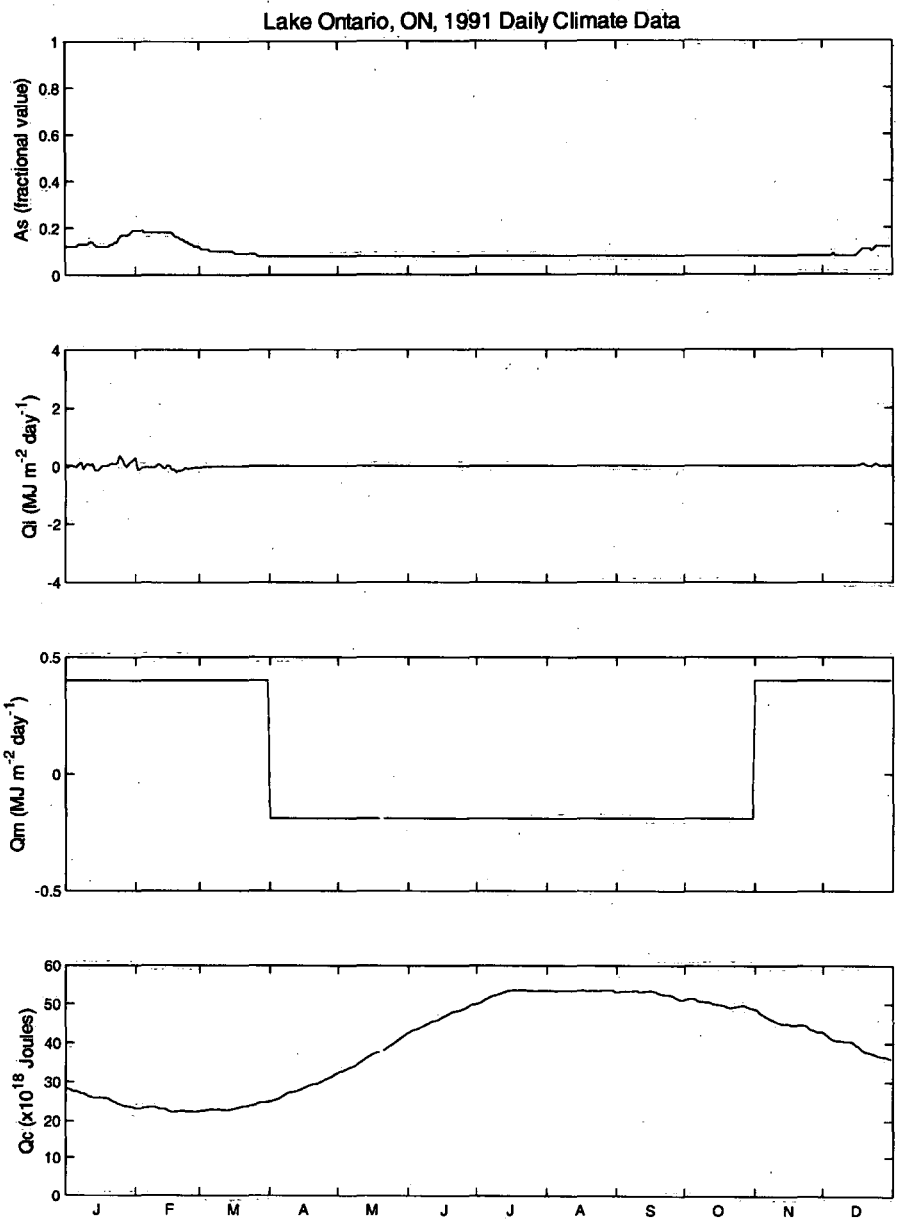
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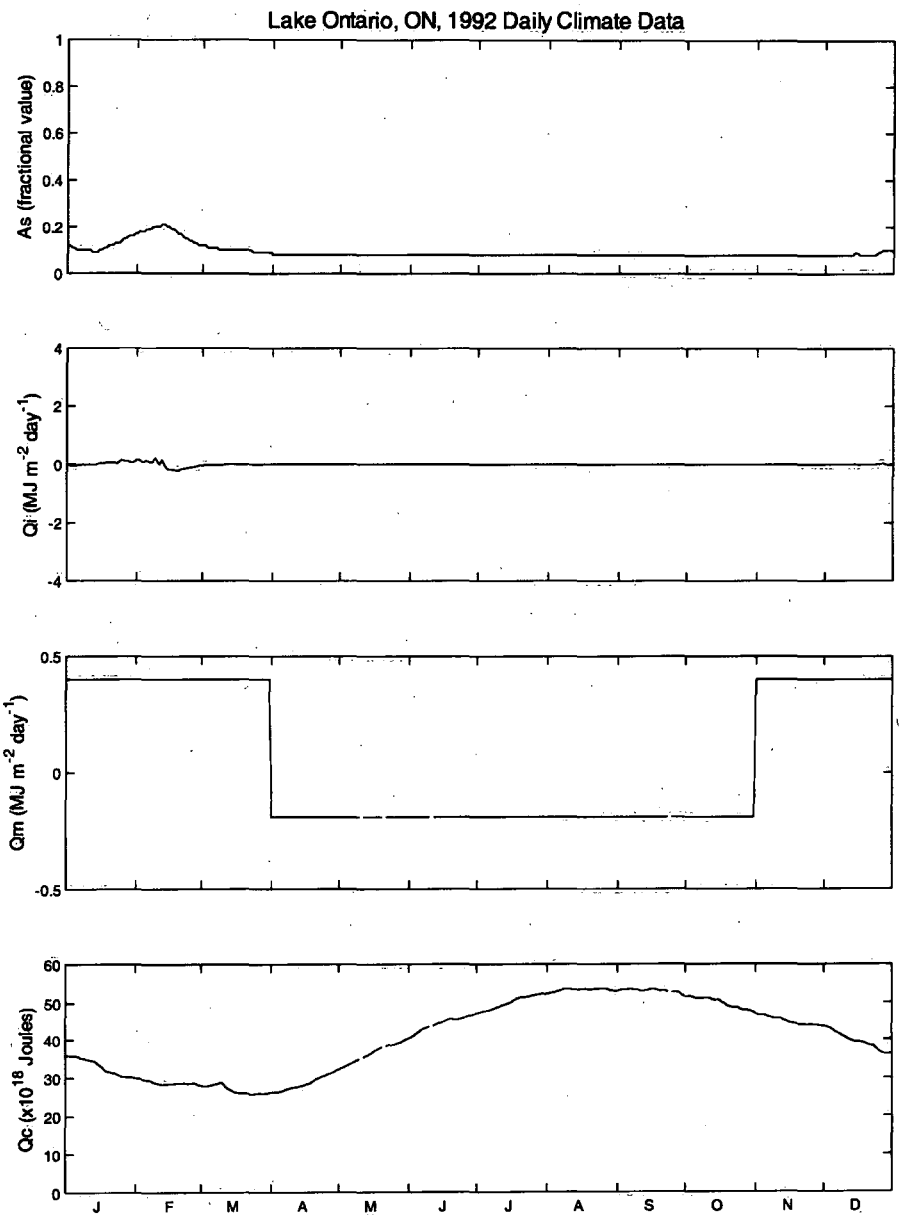
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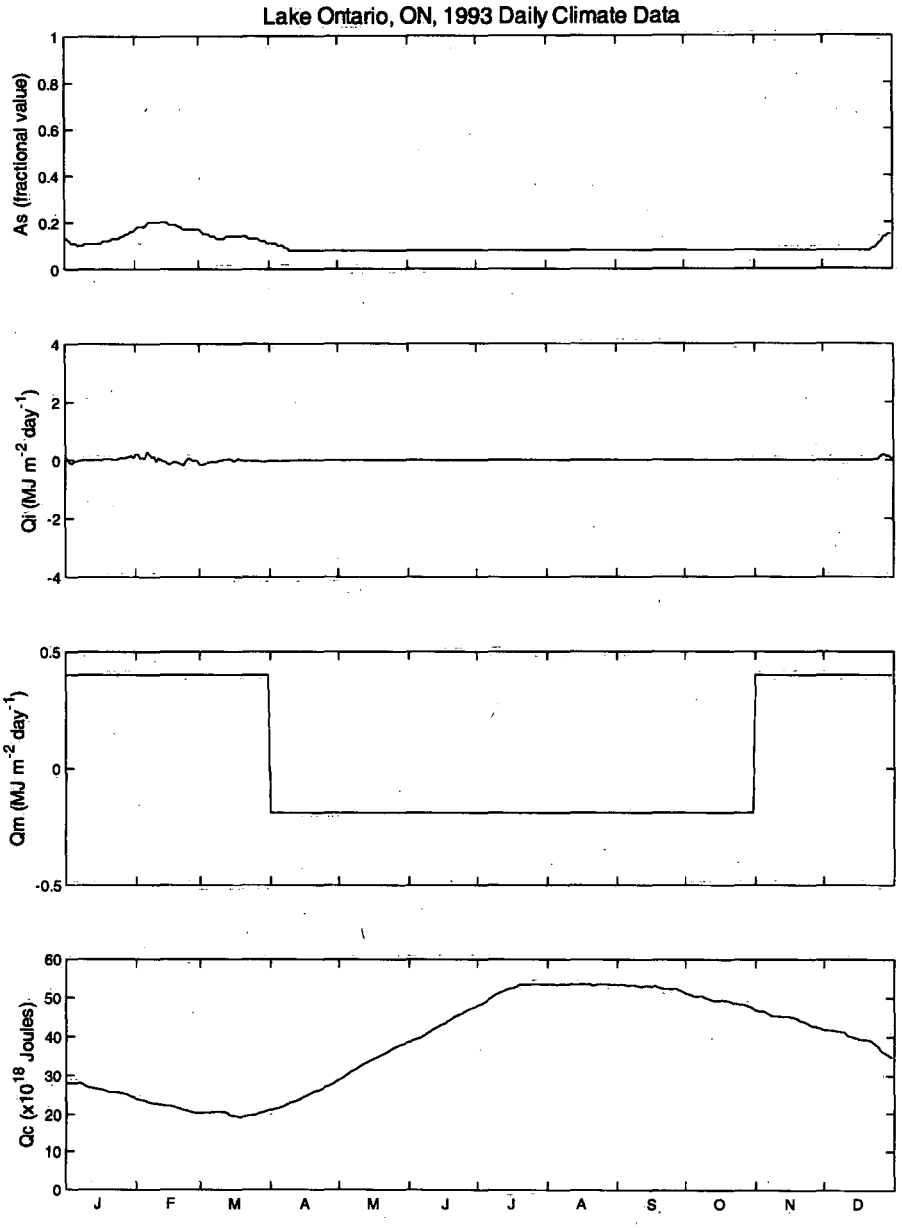
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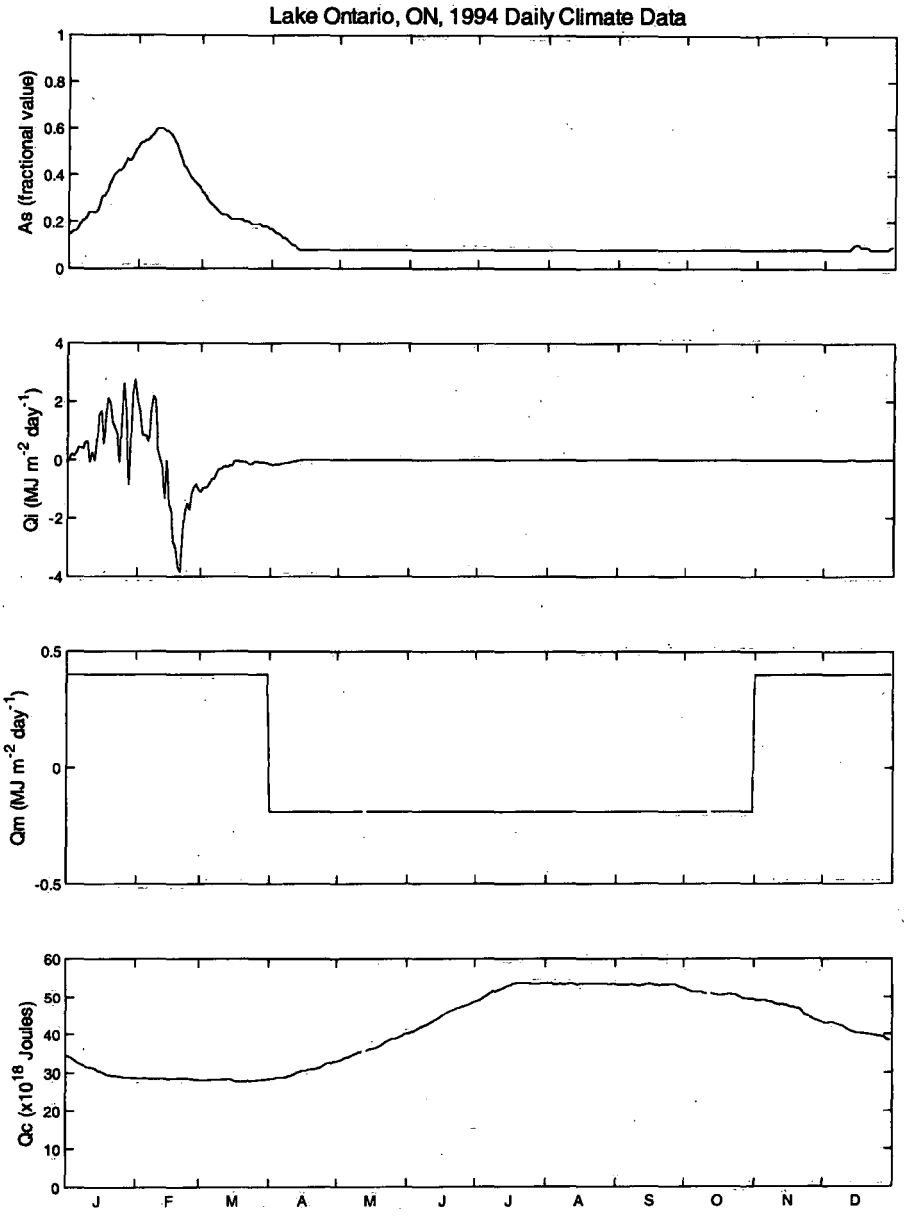
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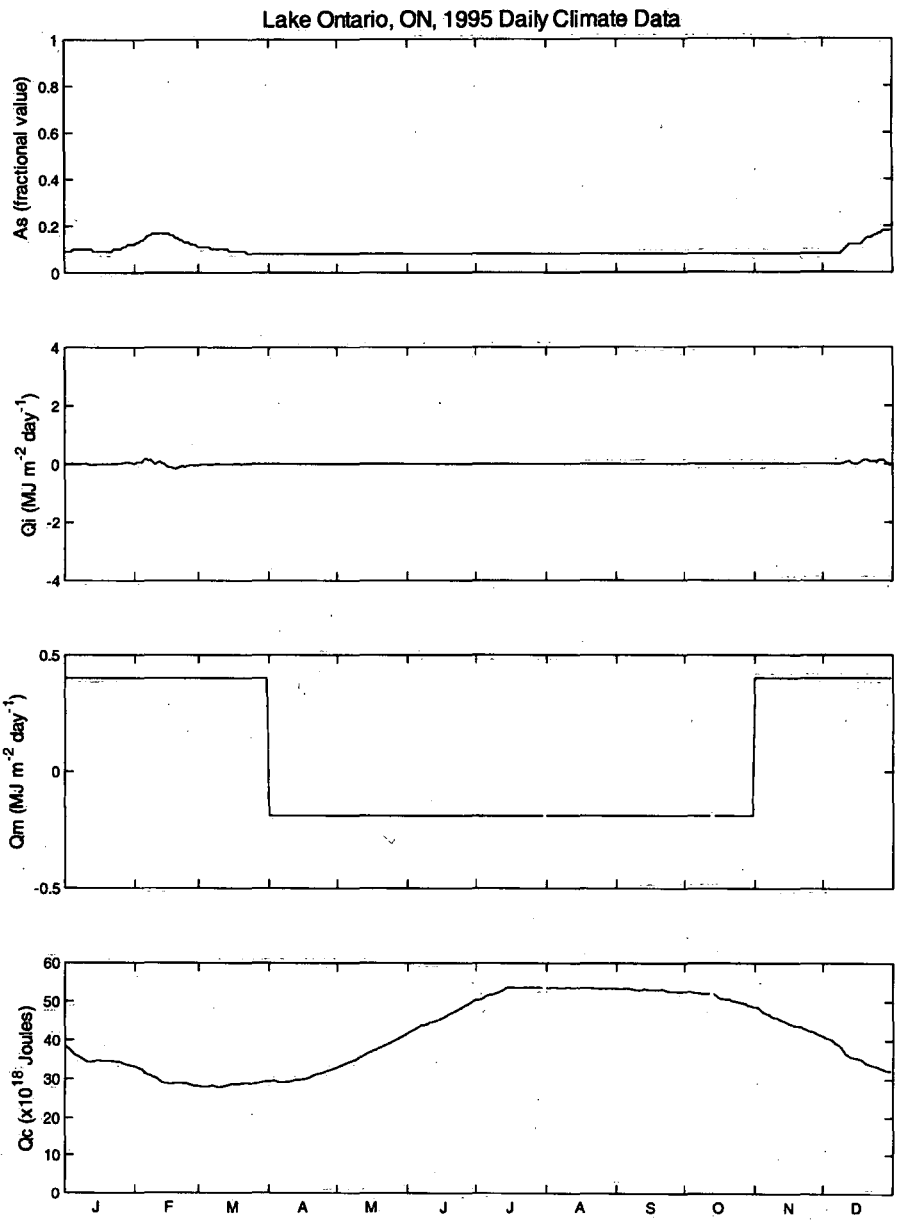
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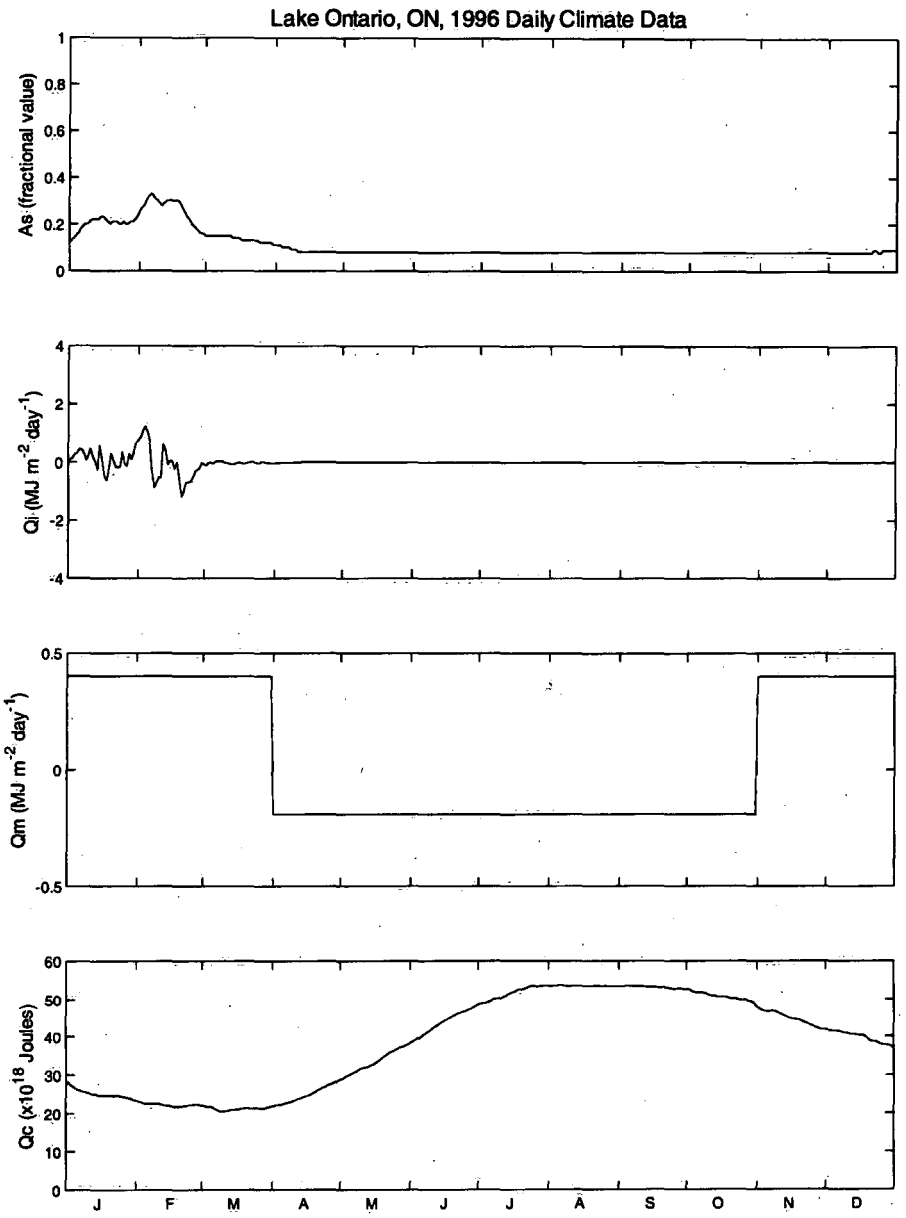
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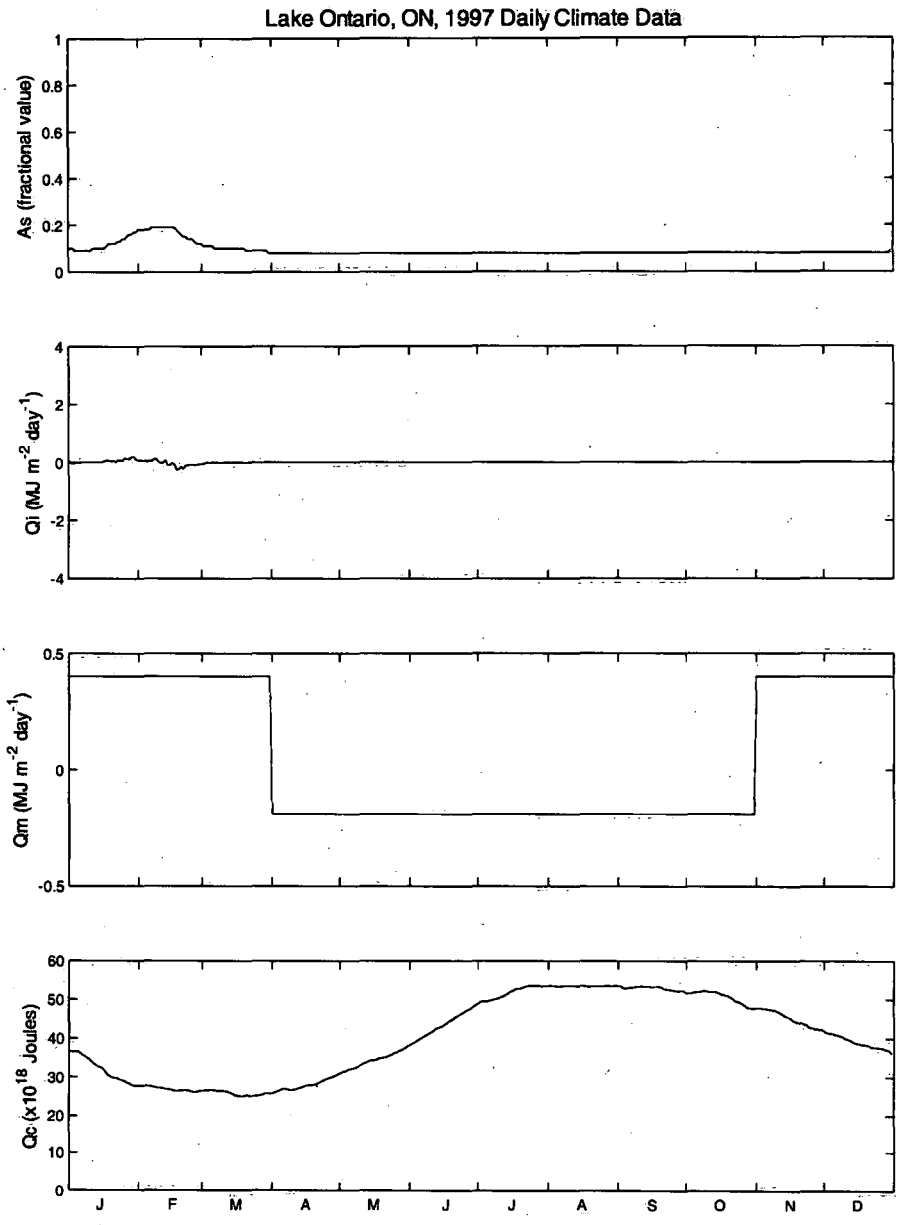
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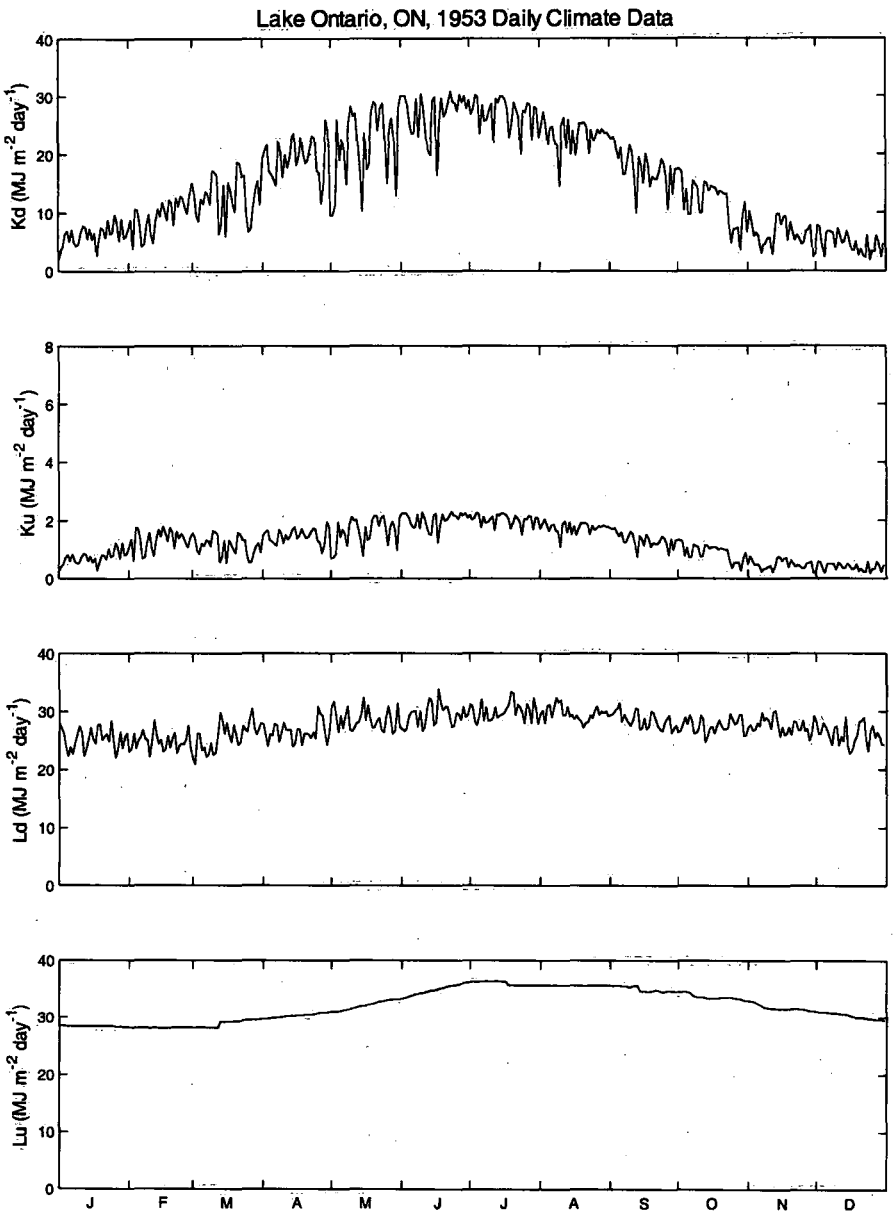
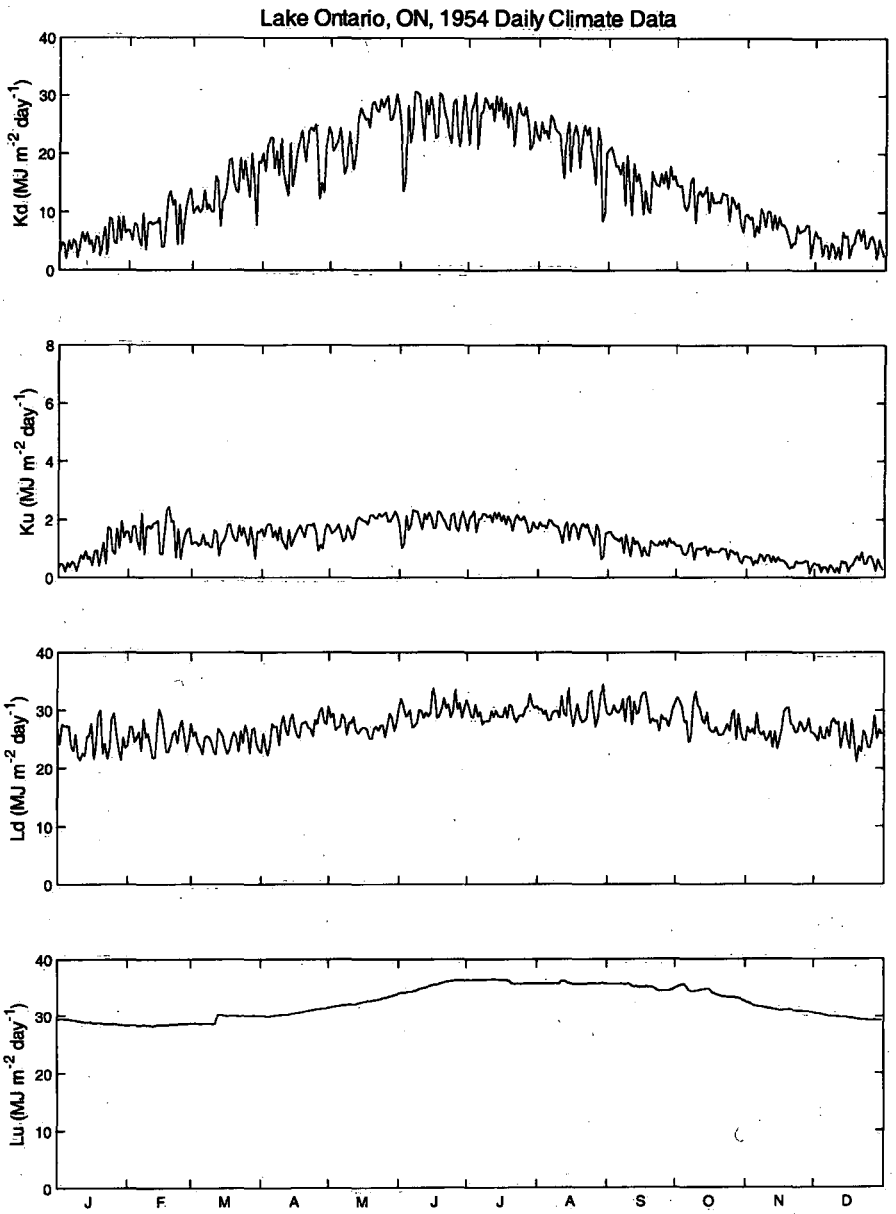
Appendix 4
Radiative

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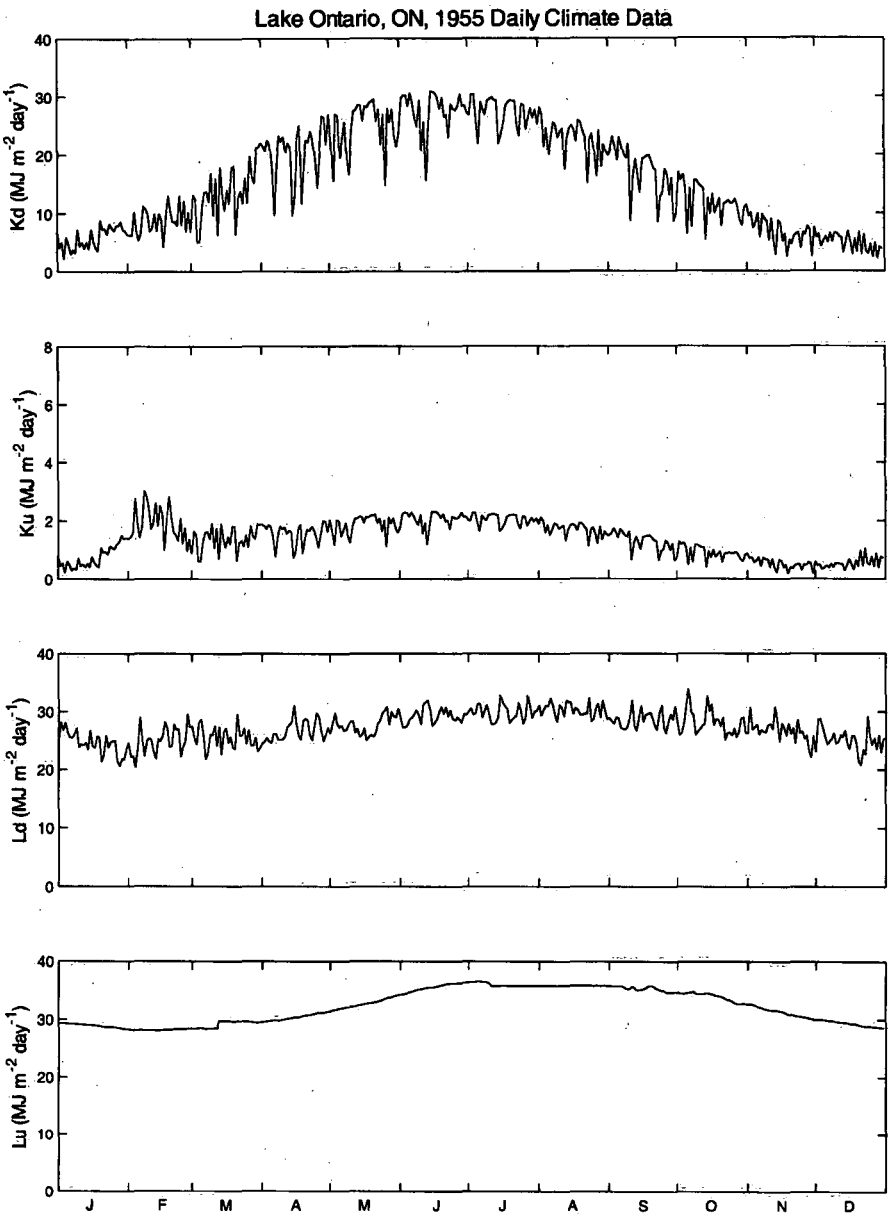
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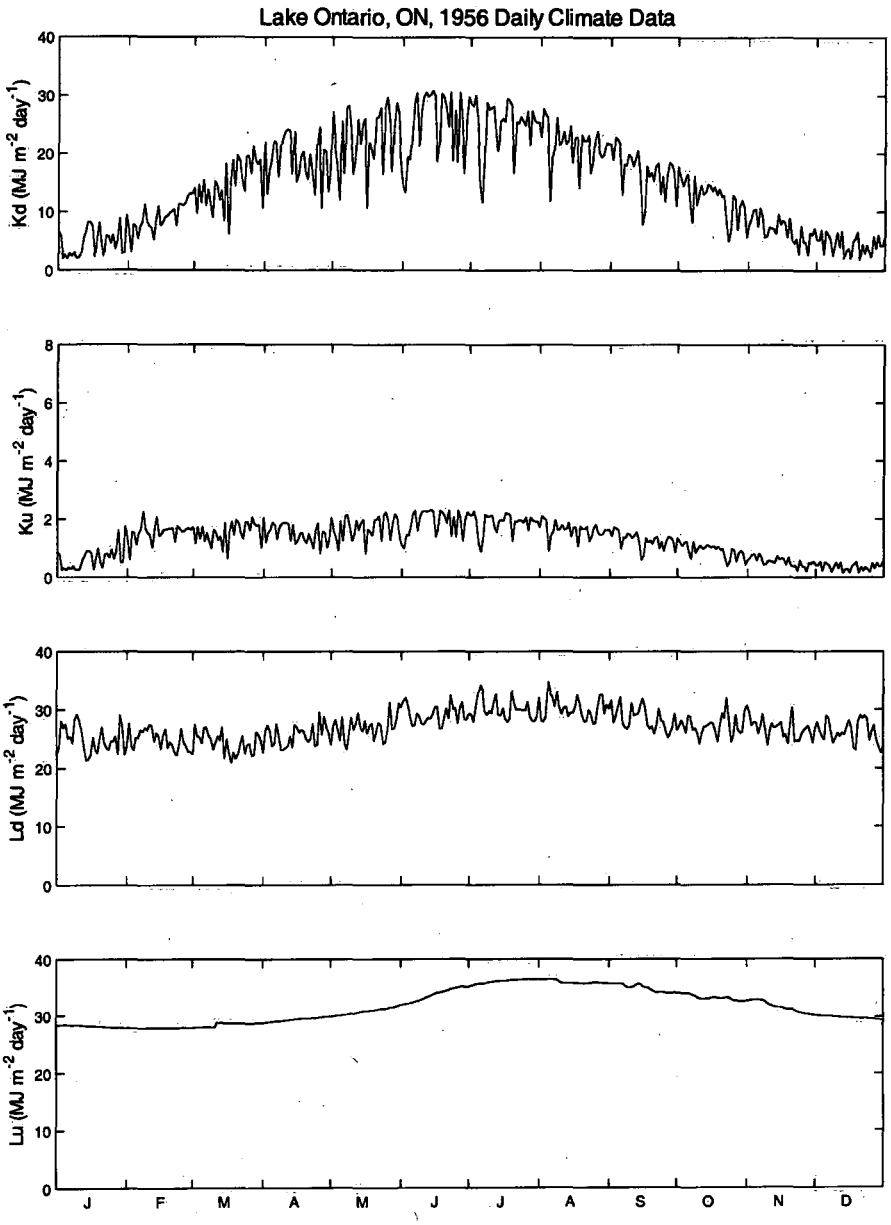
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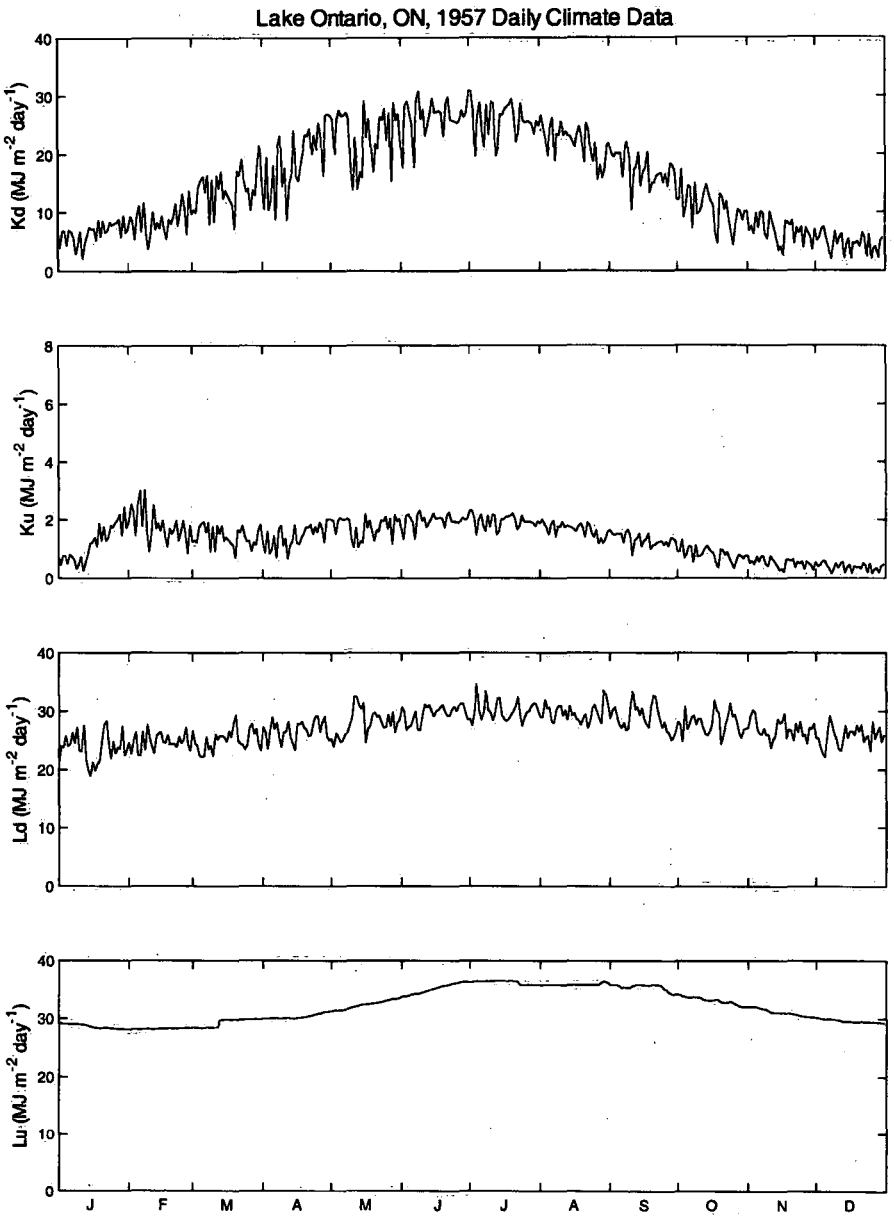
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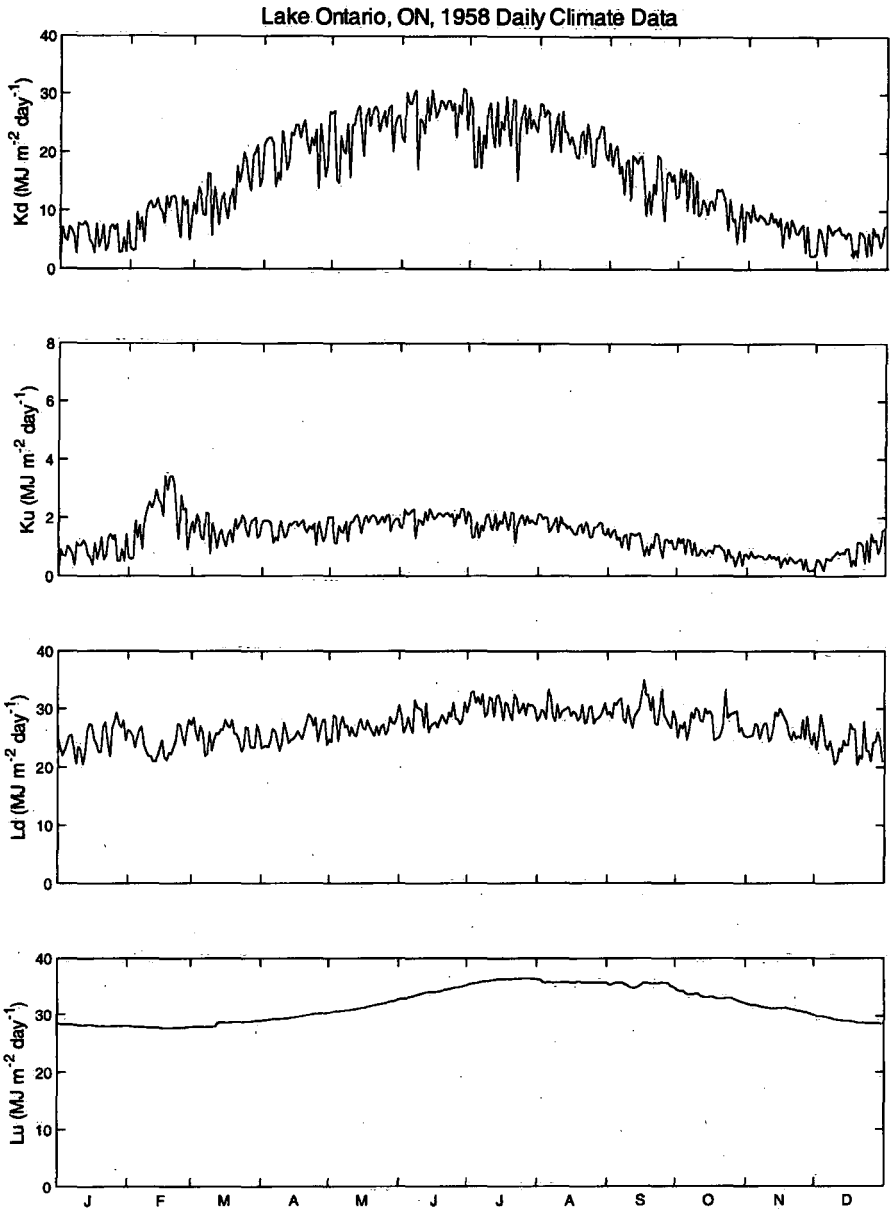
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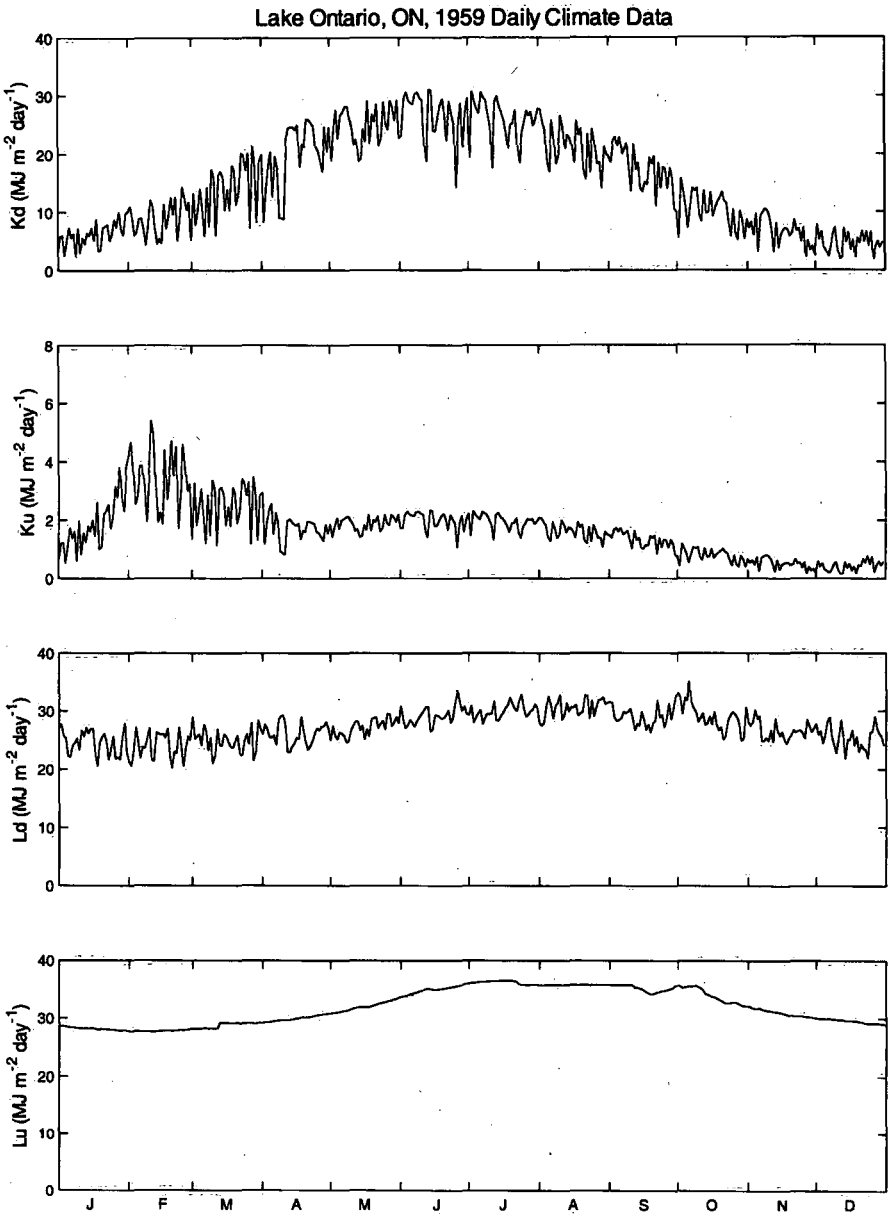
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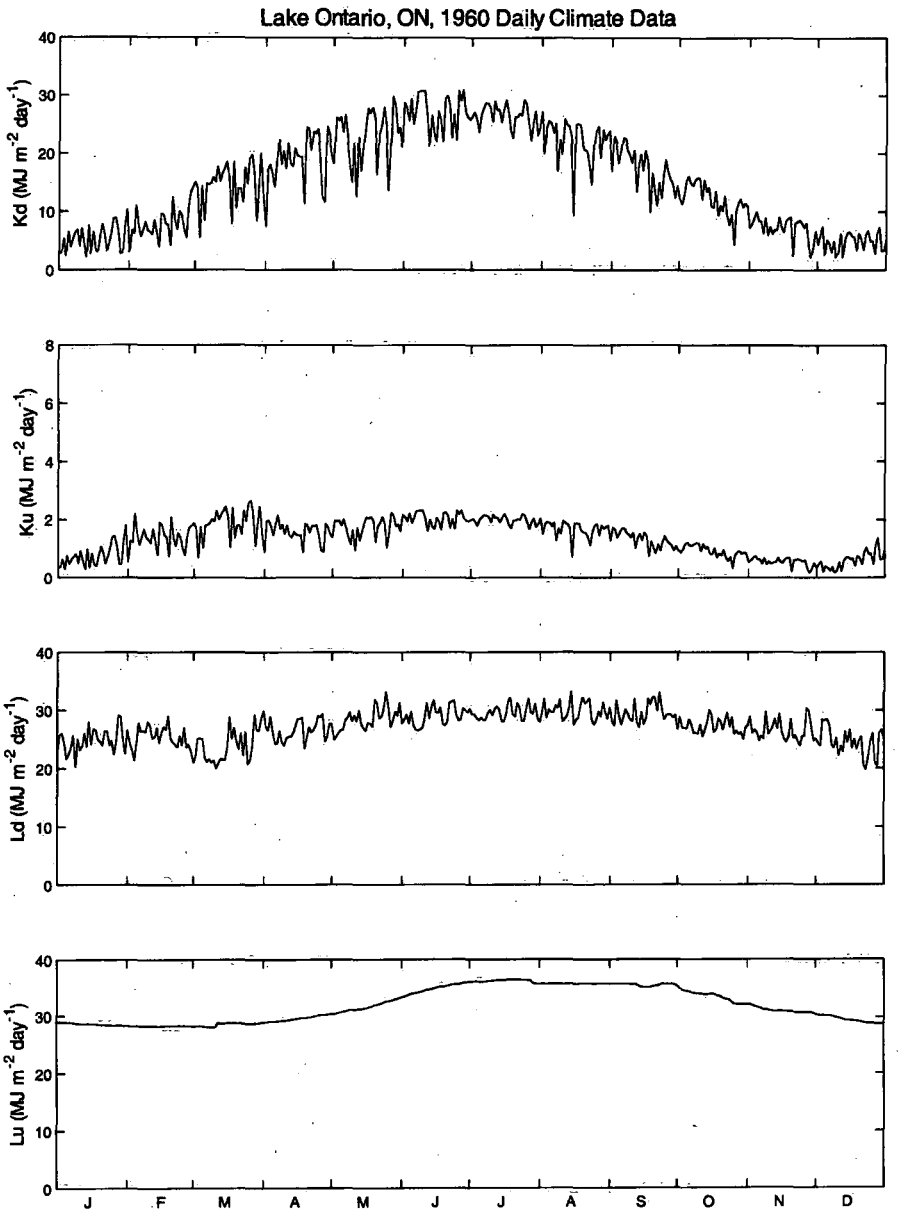
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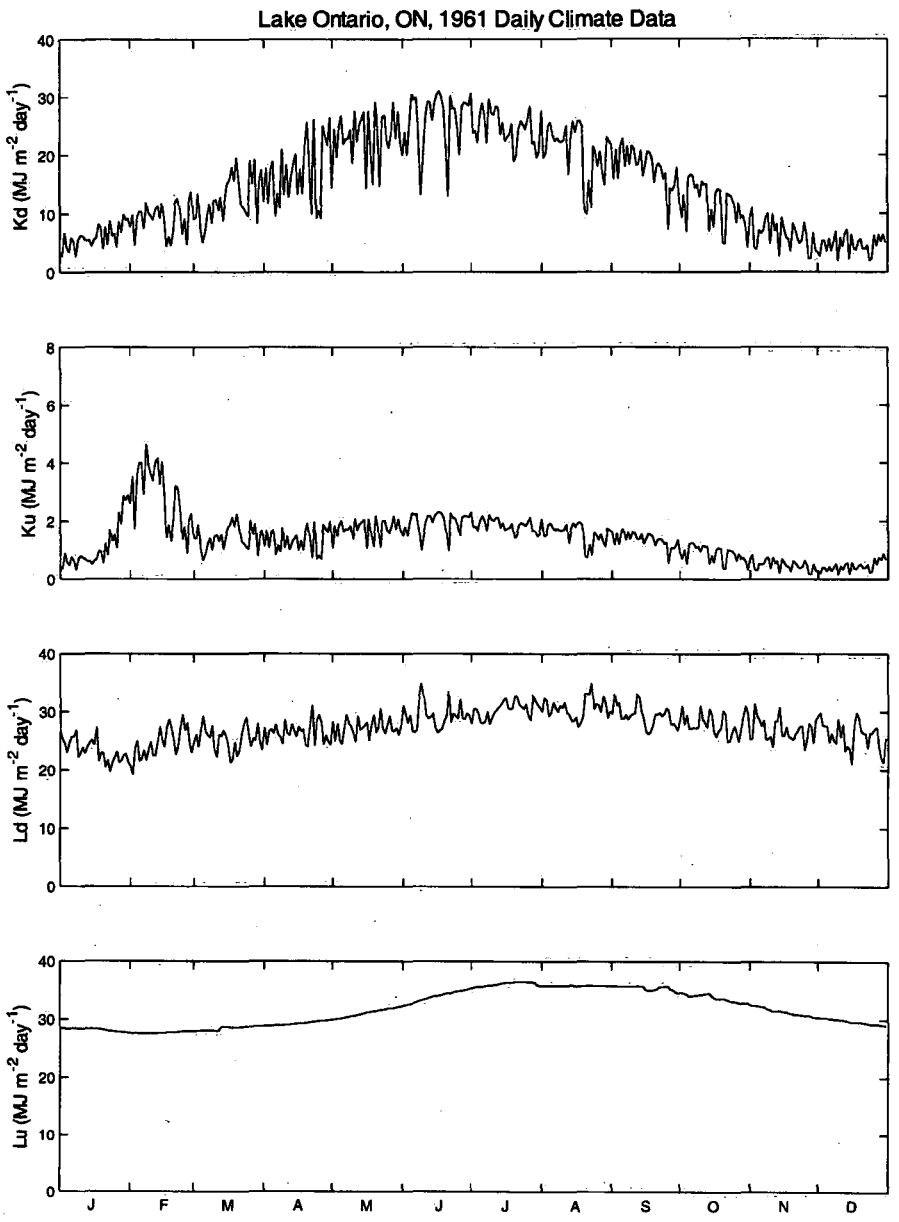
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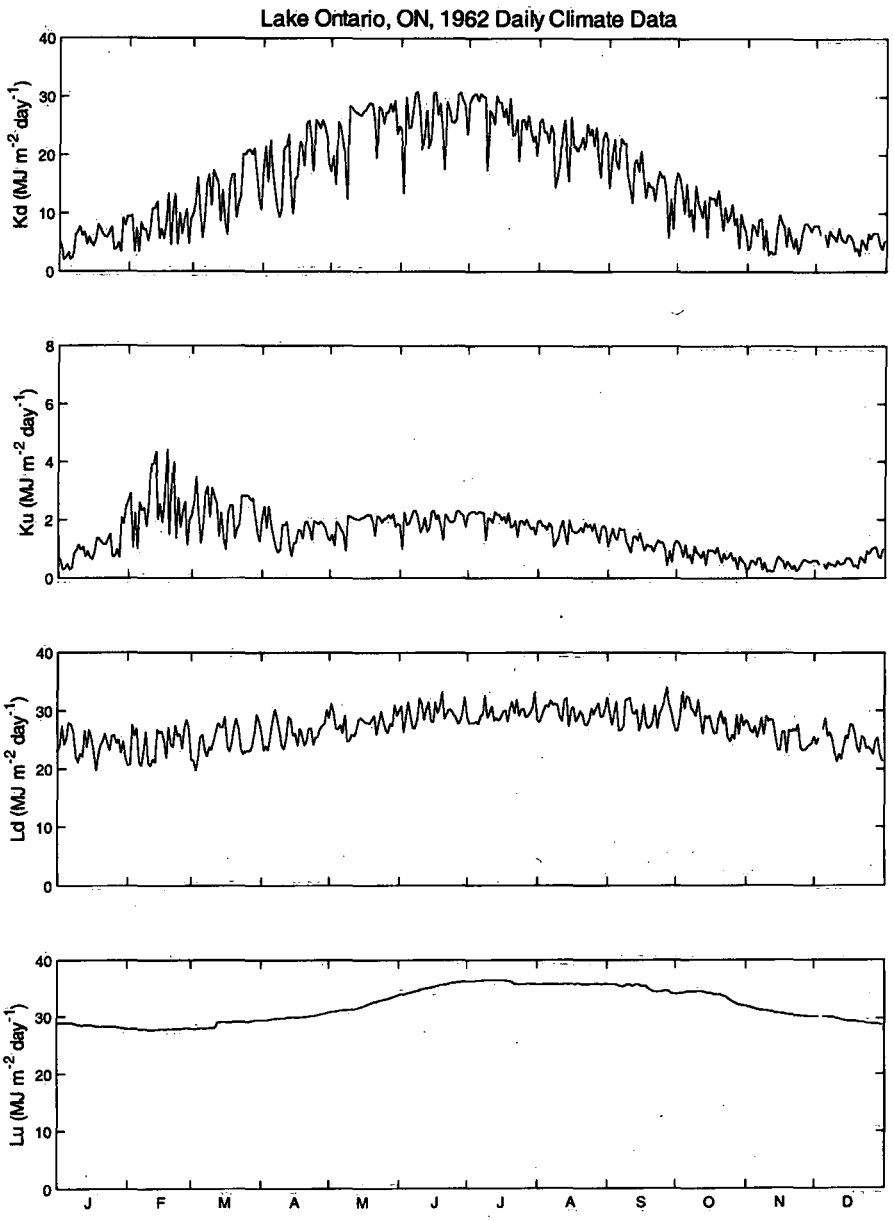
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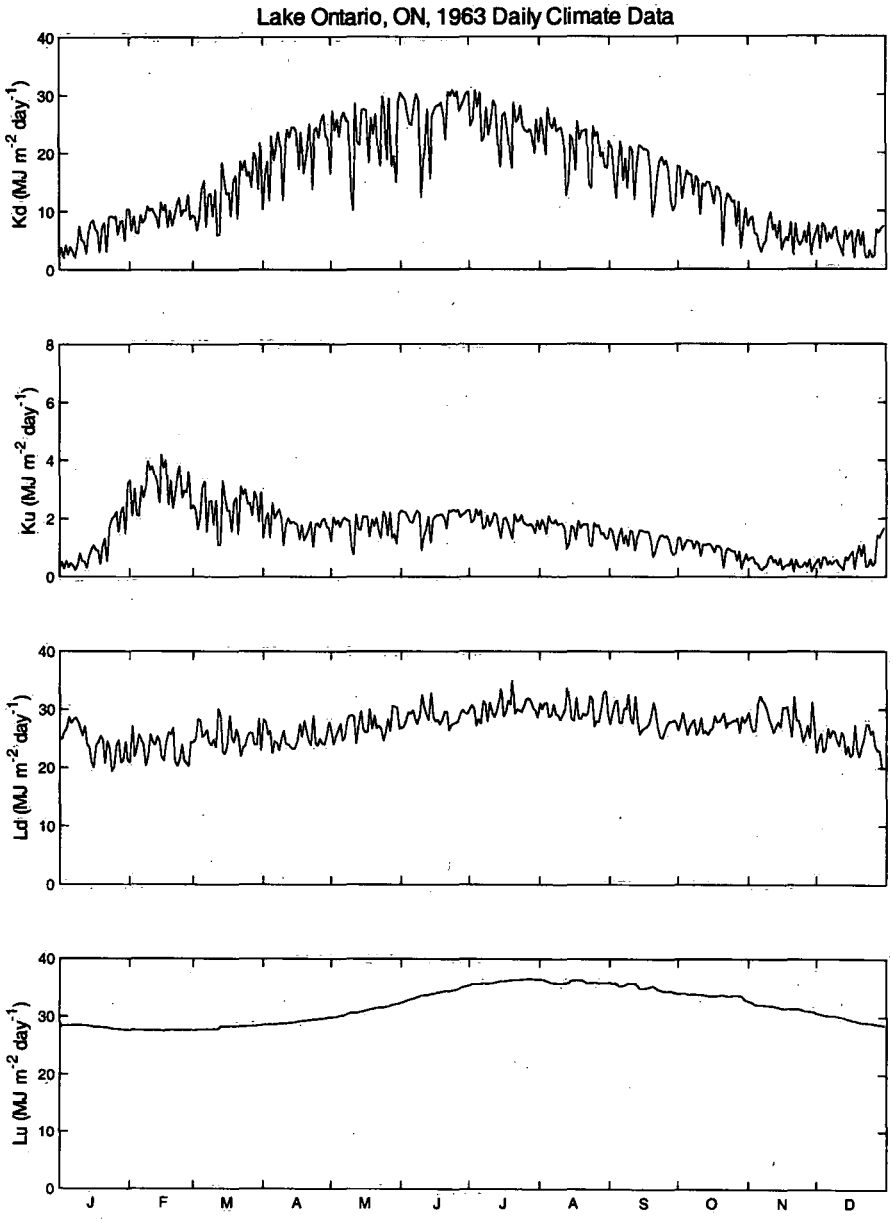
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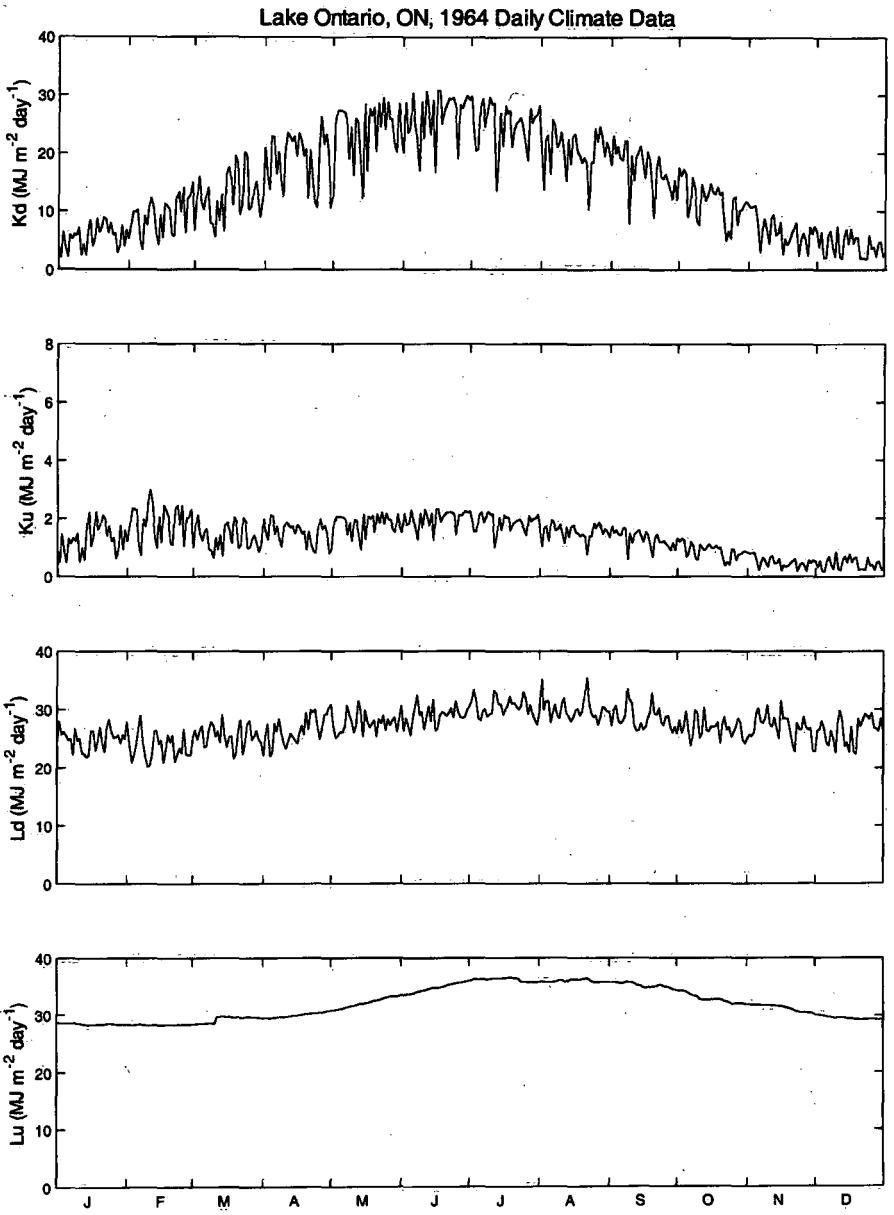
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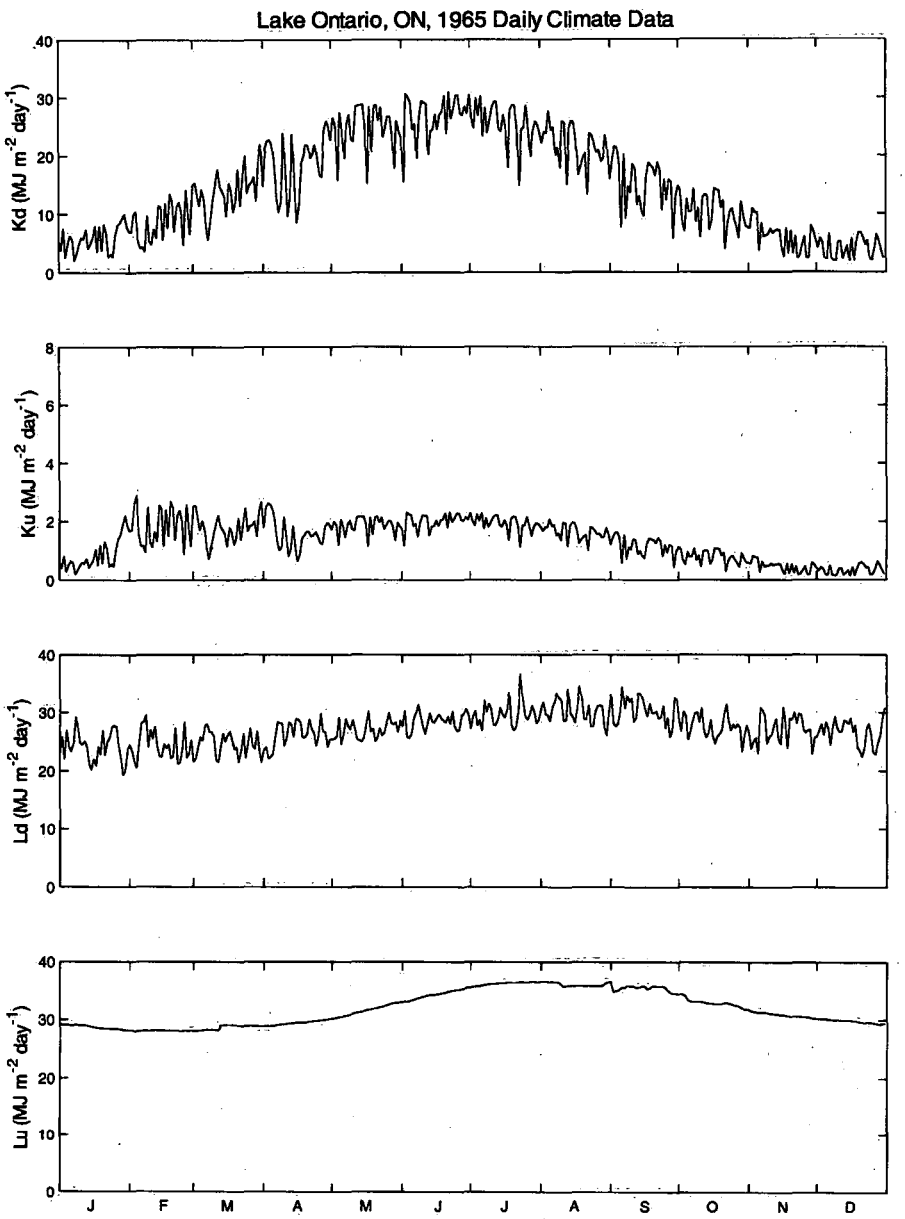
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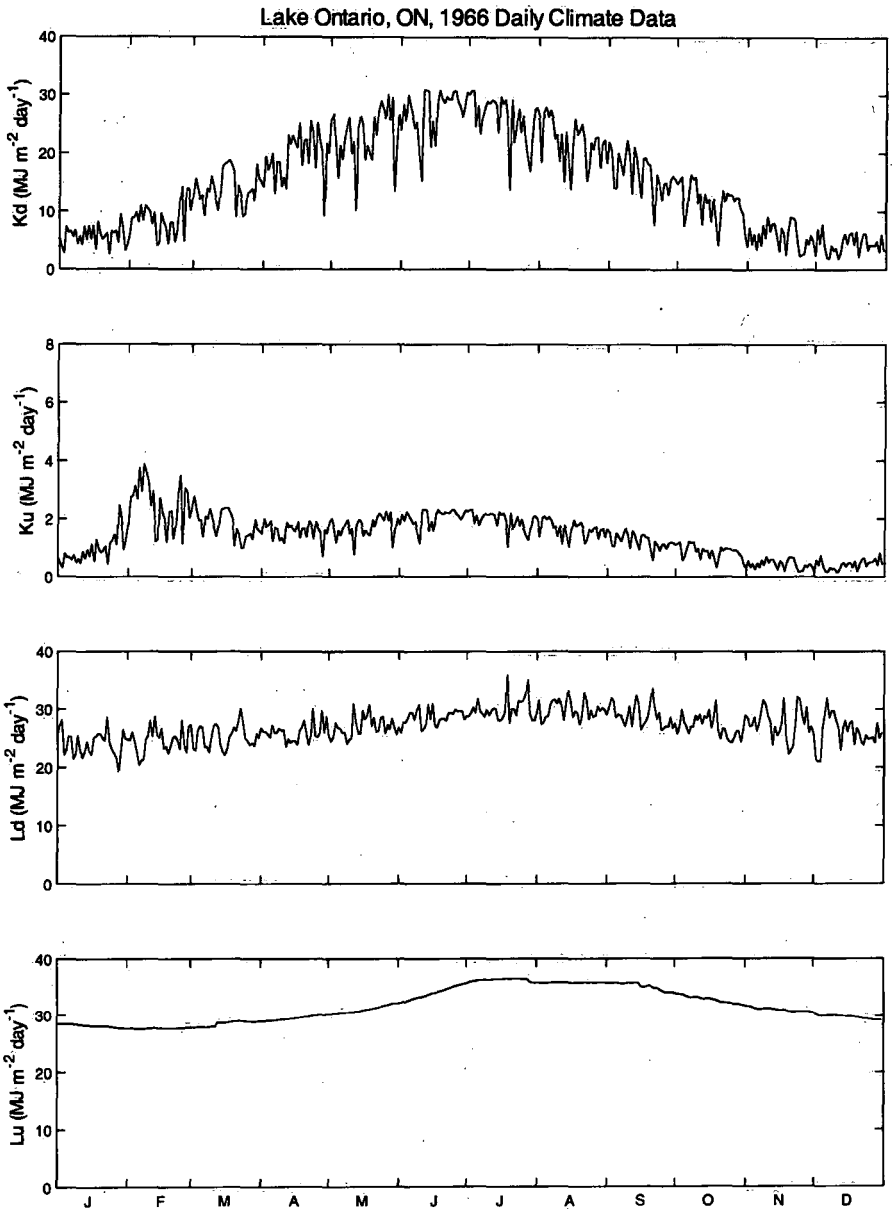
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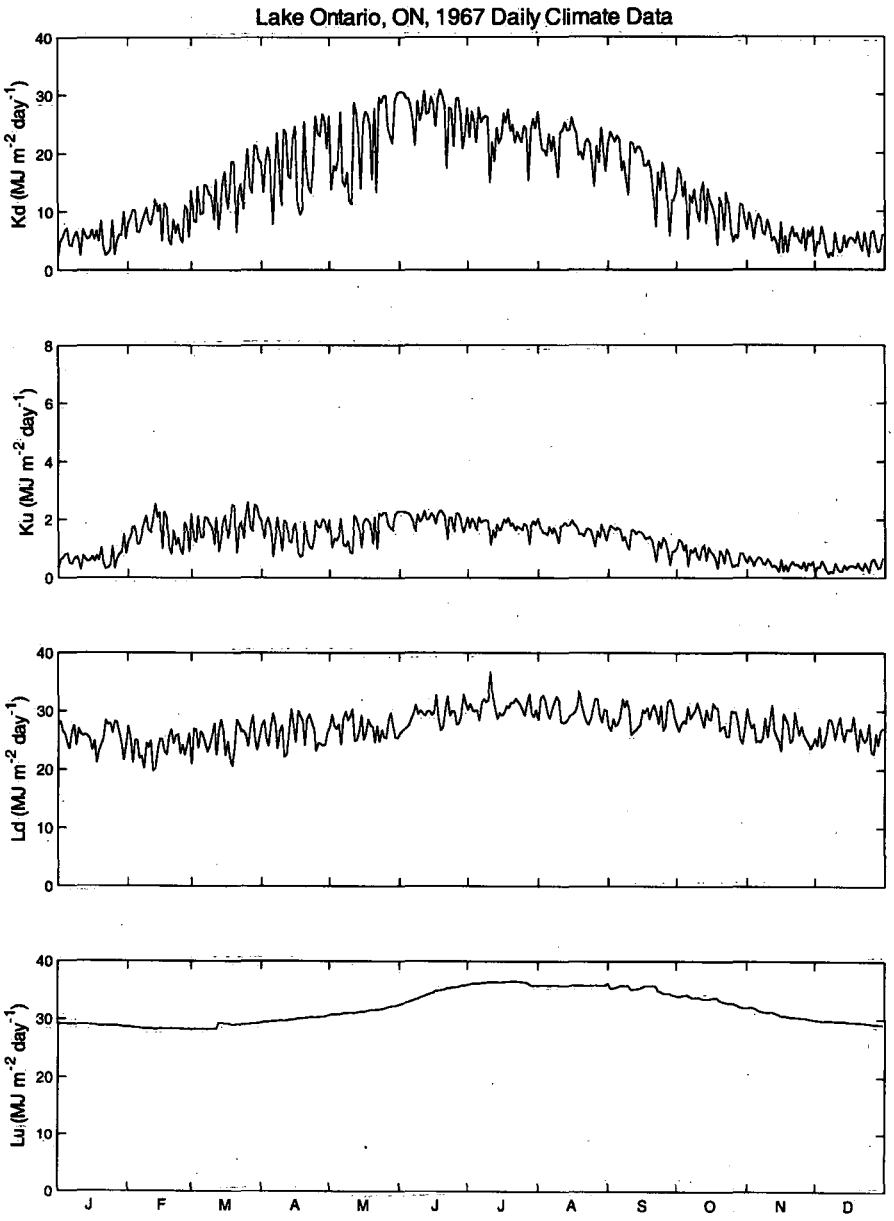
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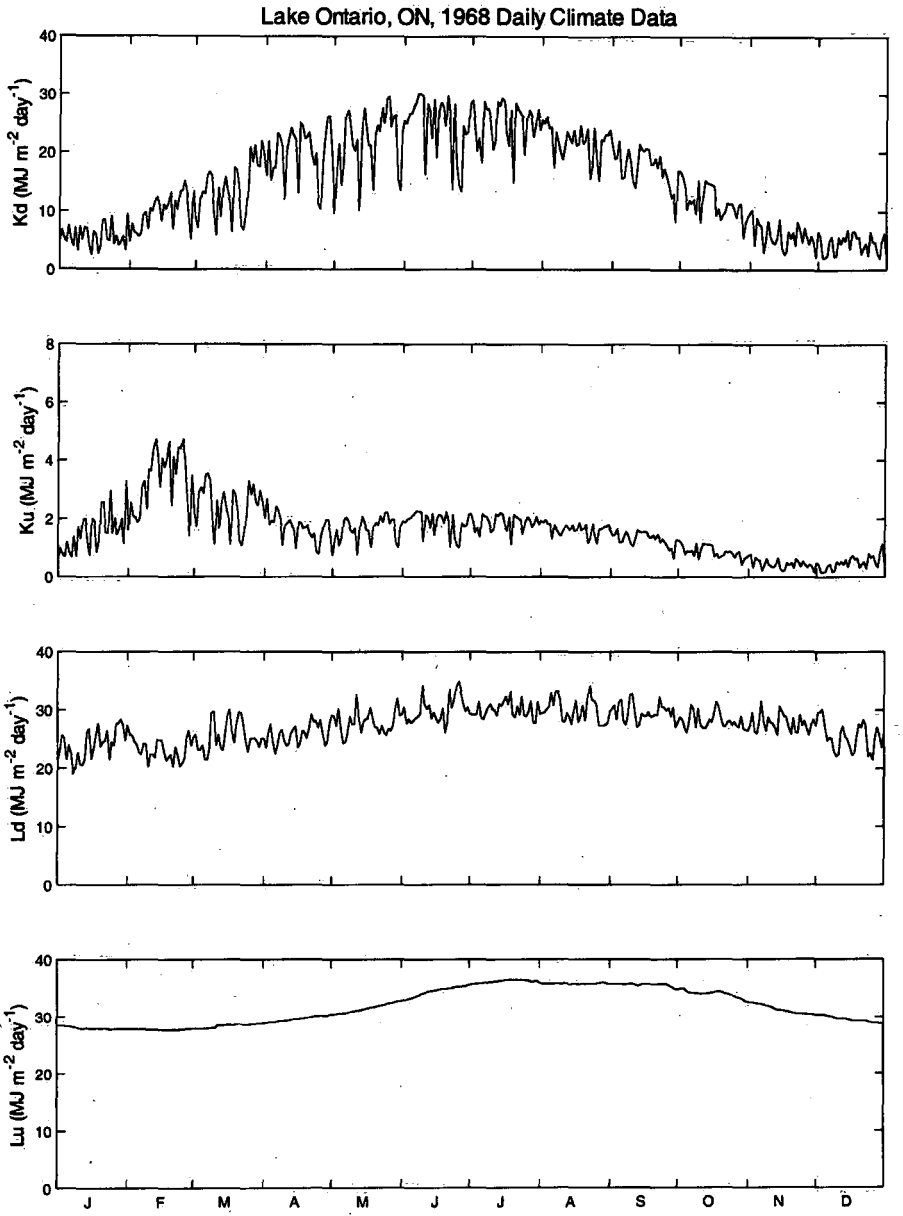
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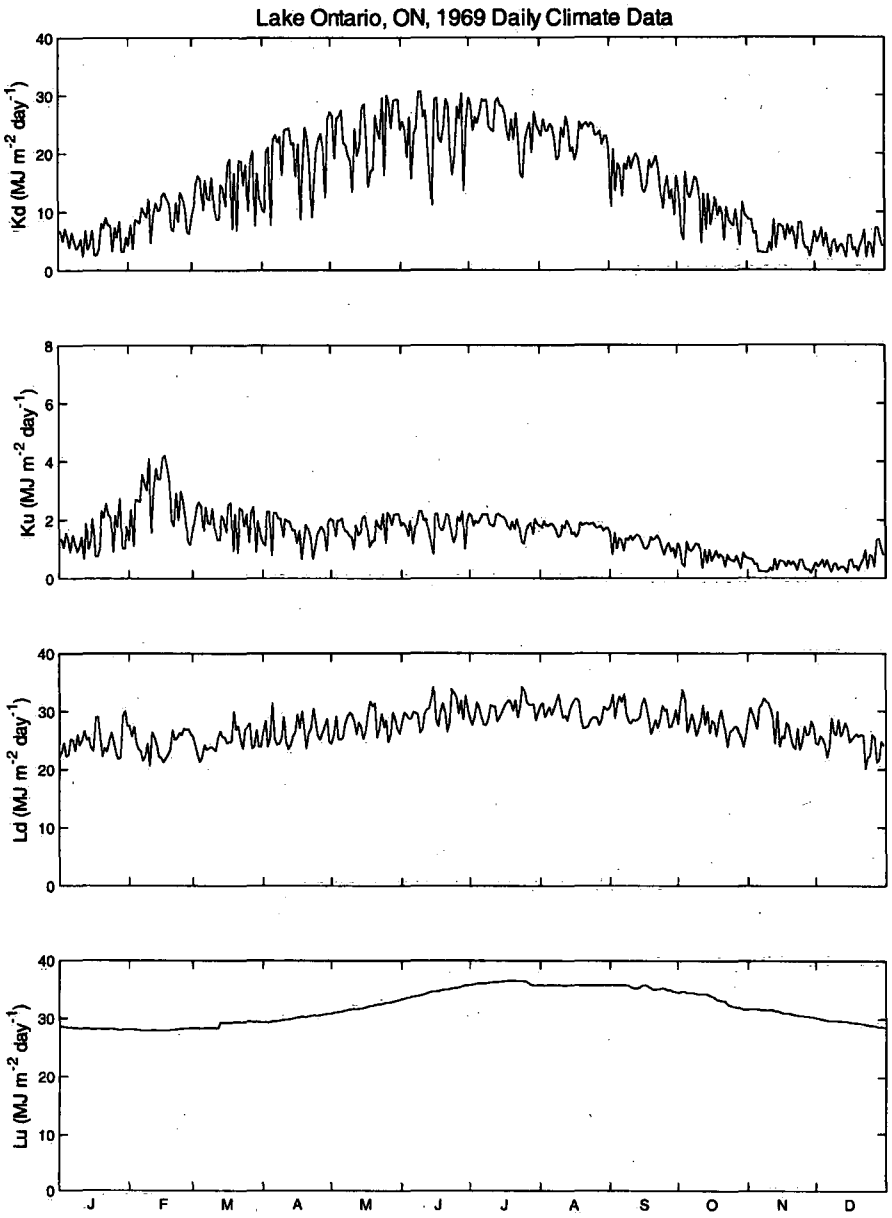
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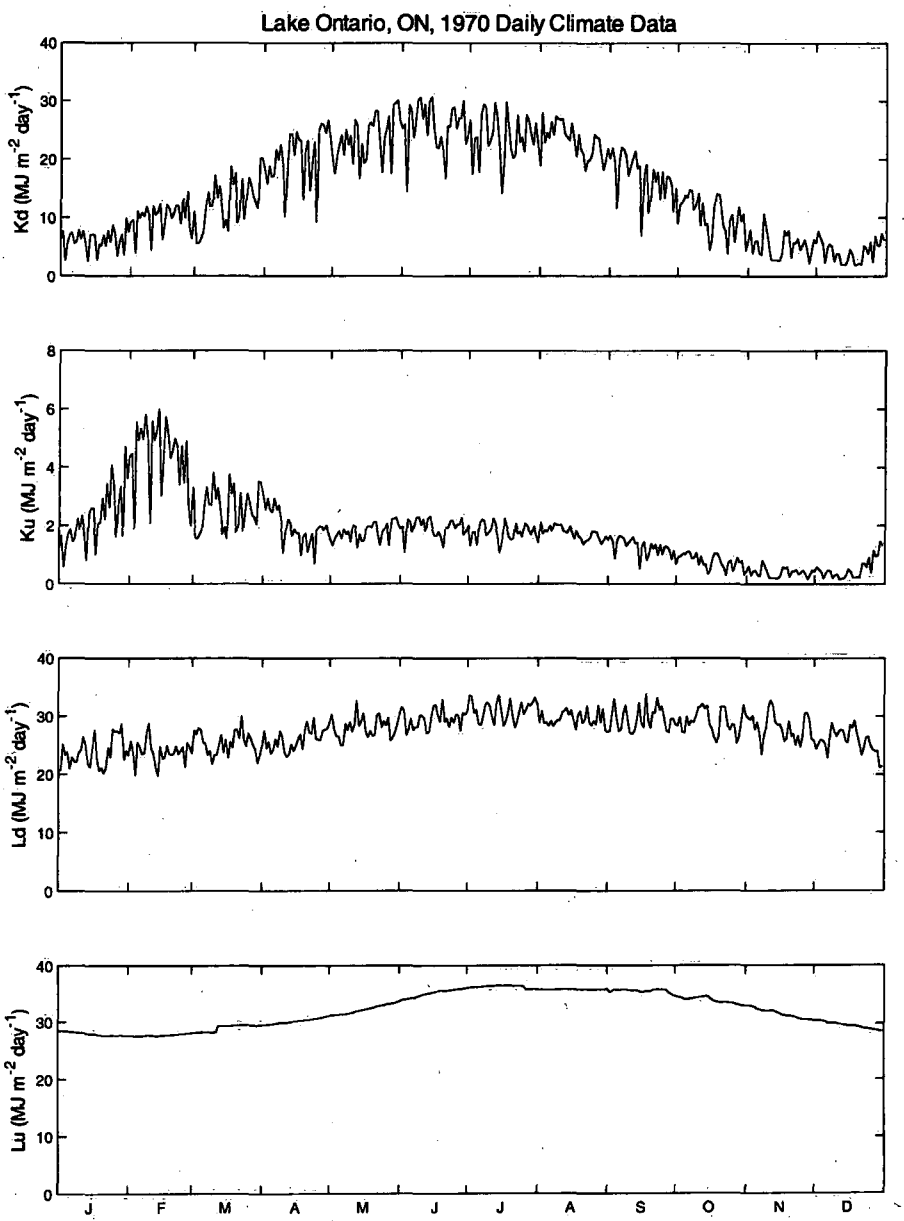
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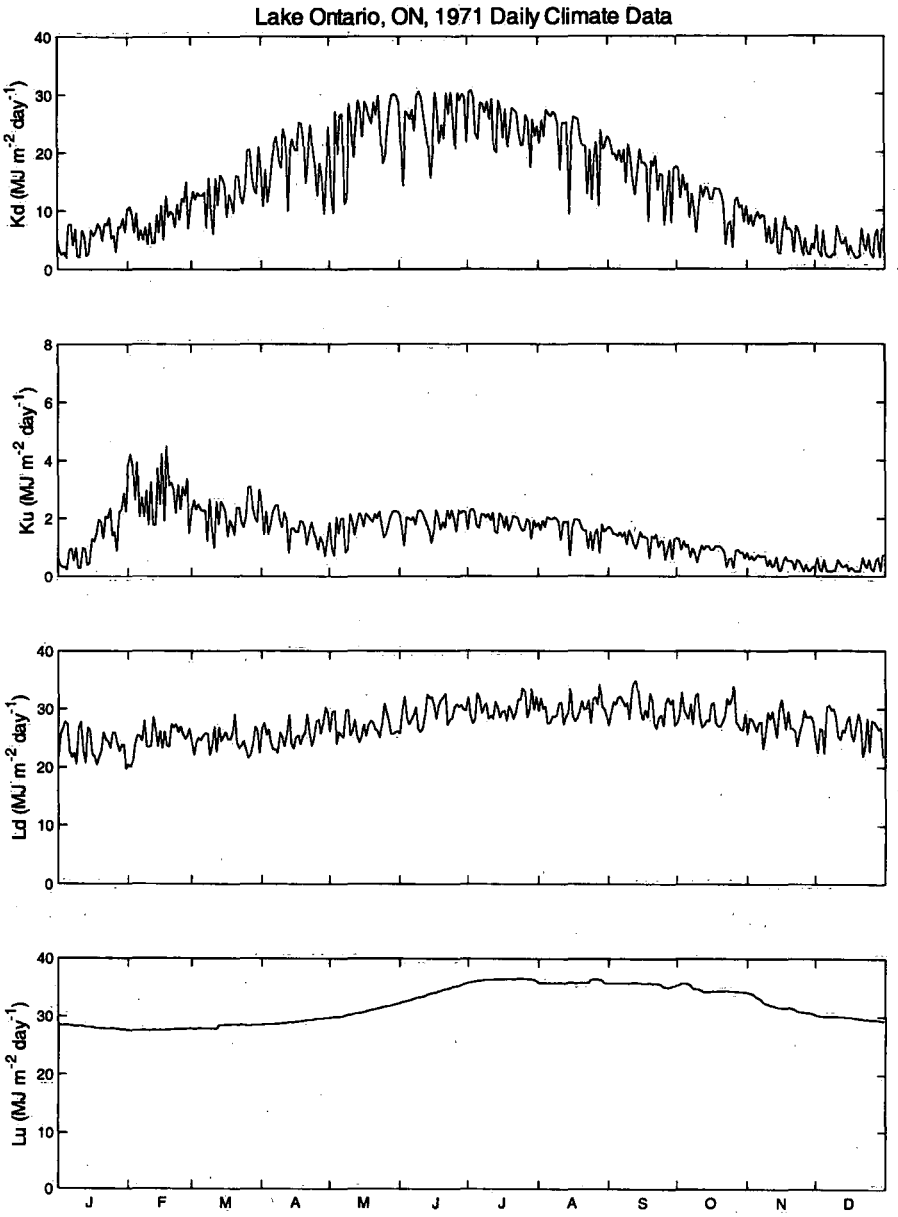
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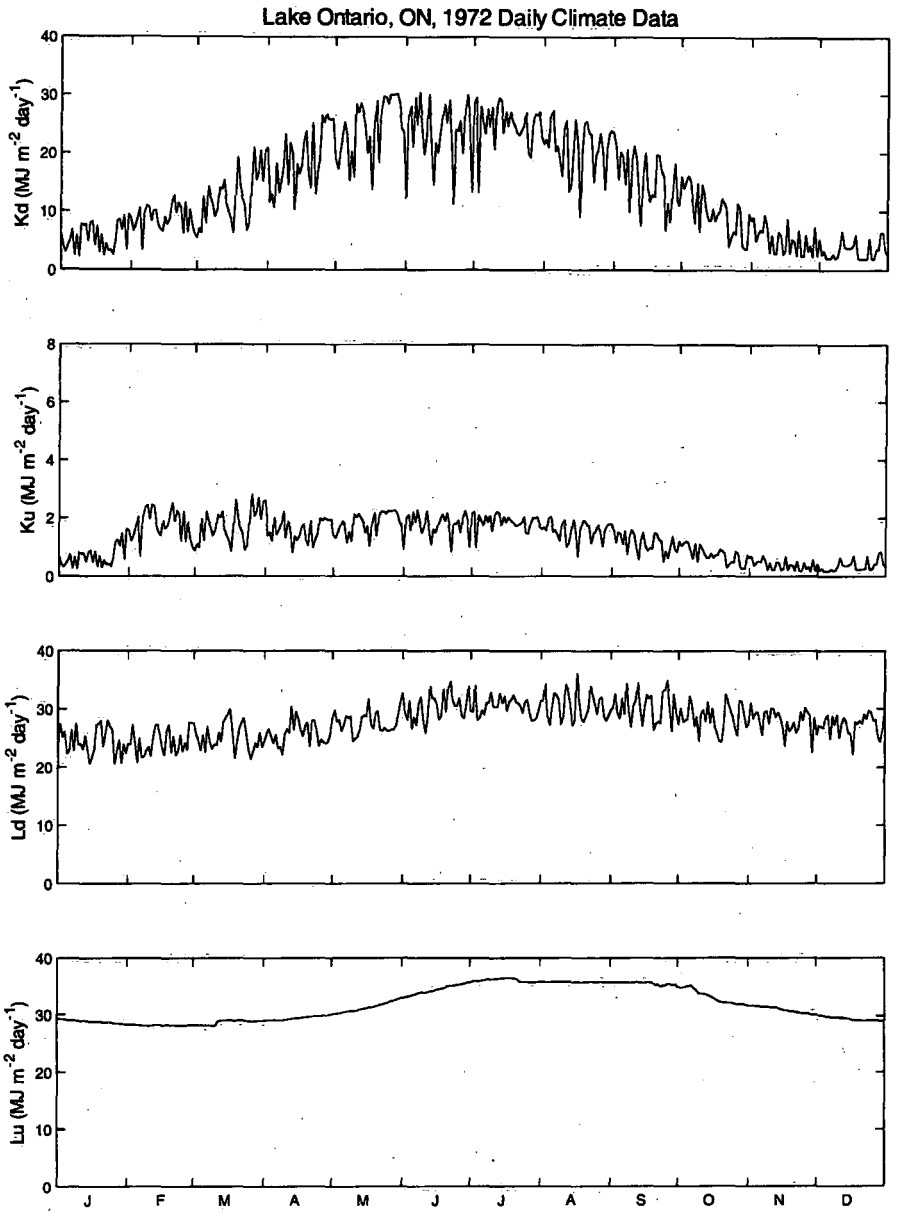
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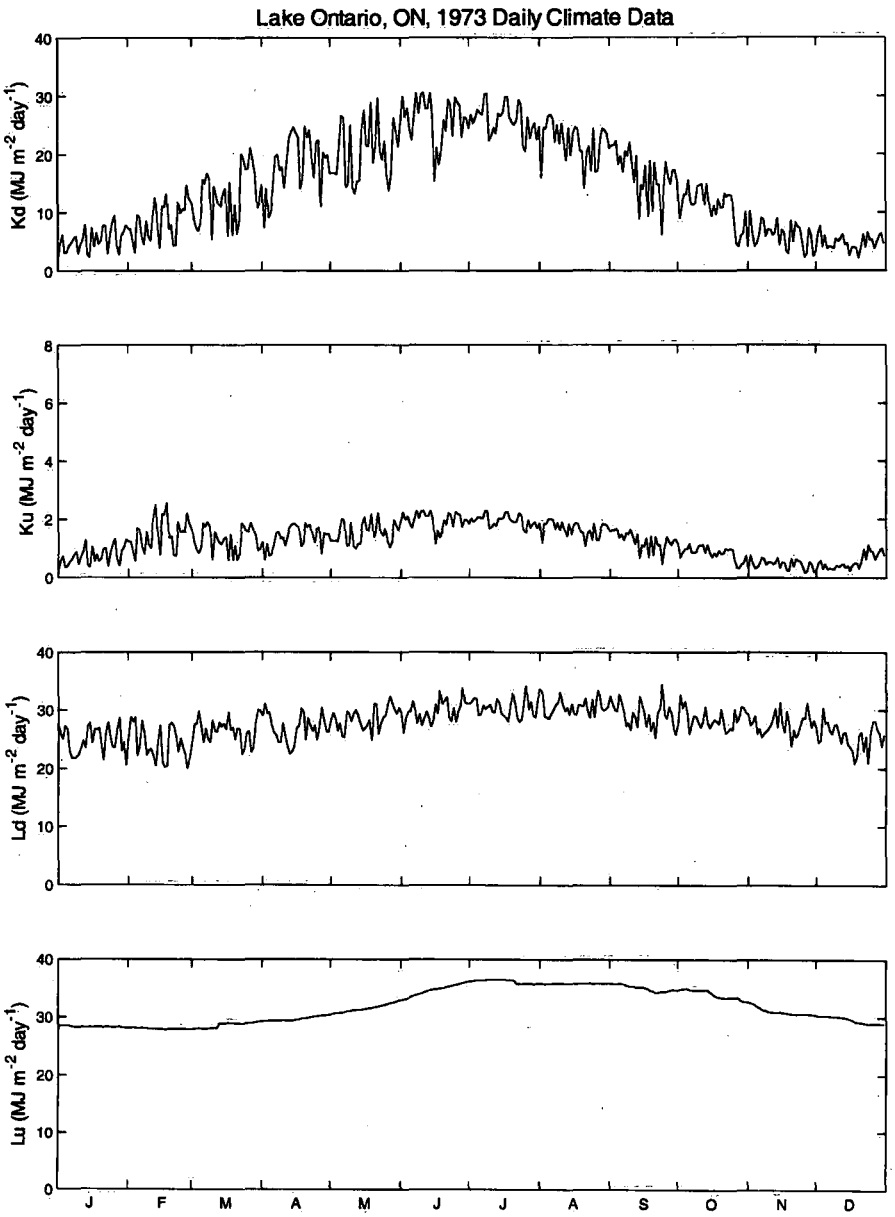
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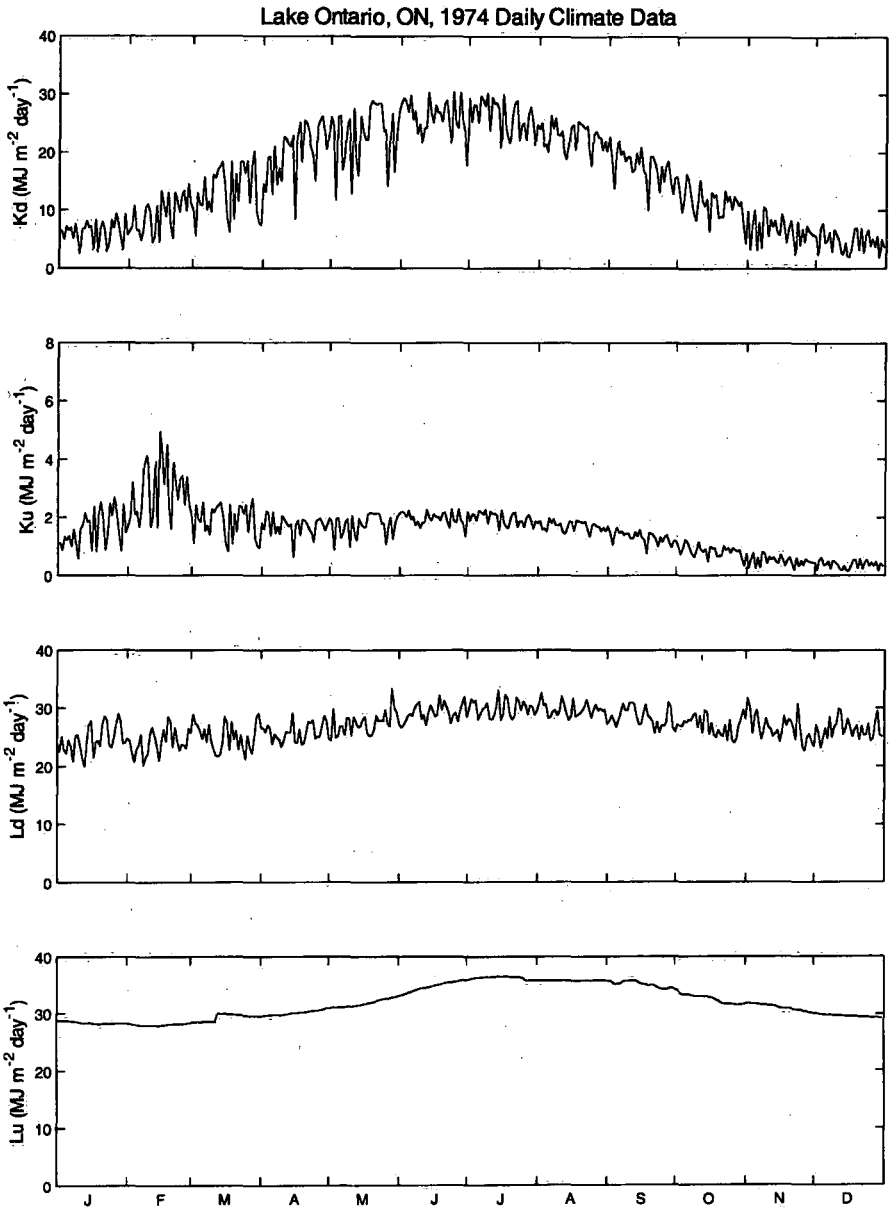
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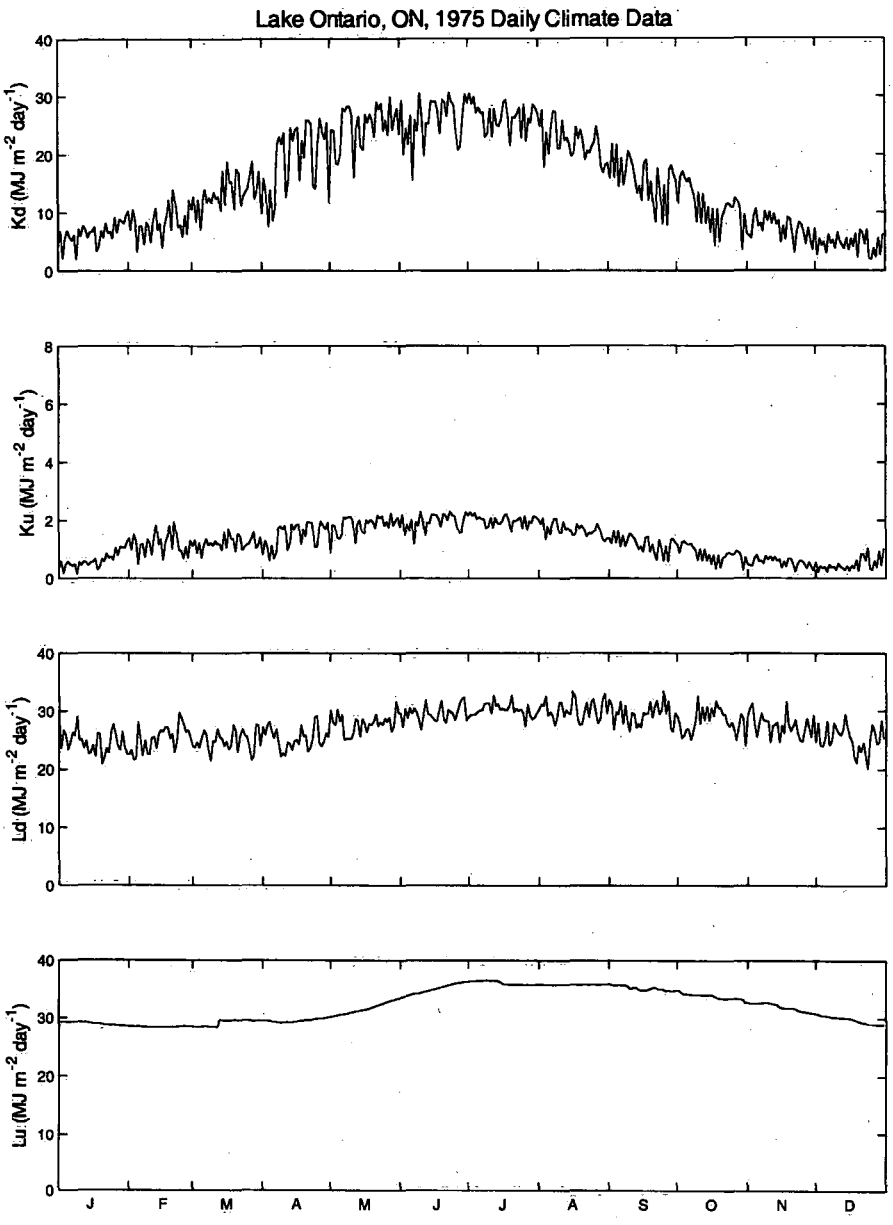
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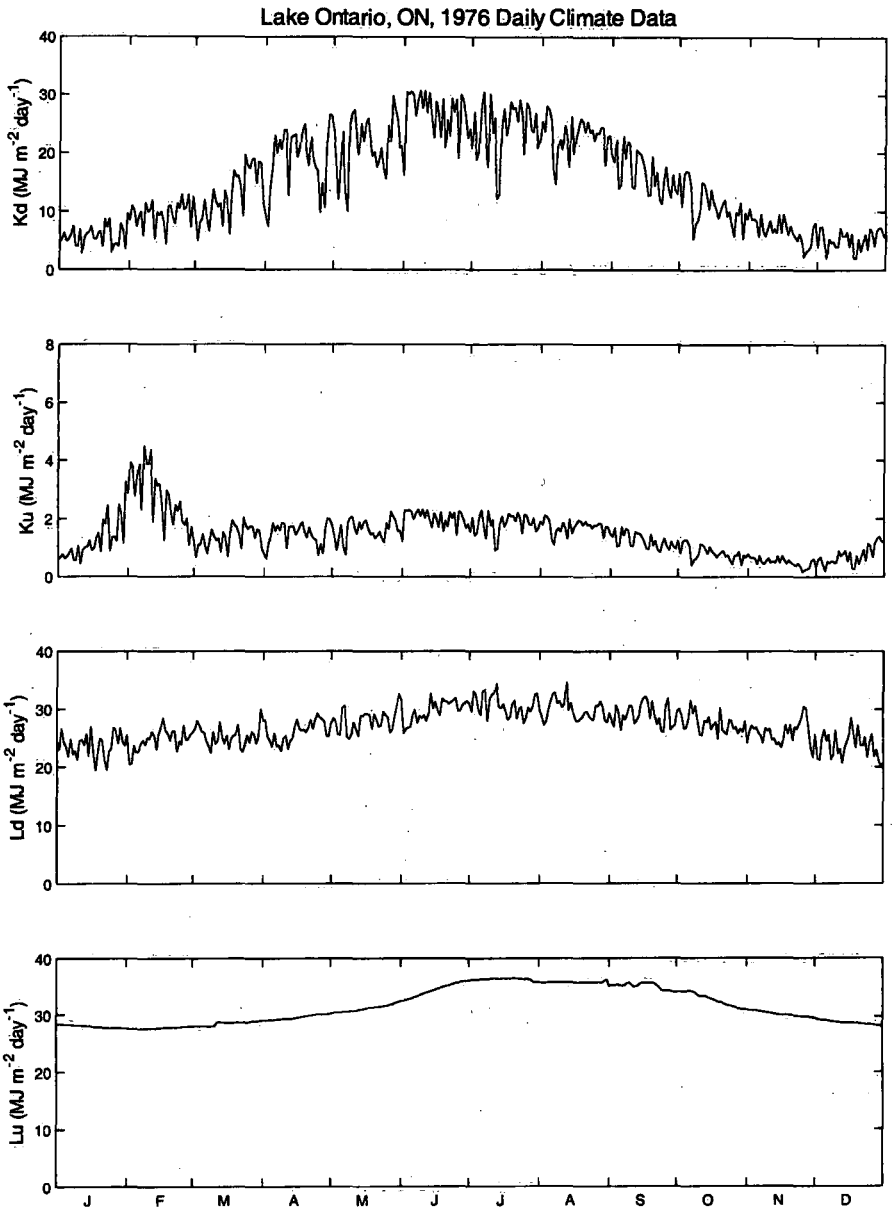
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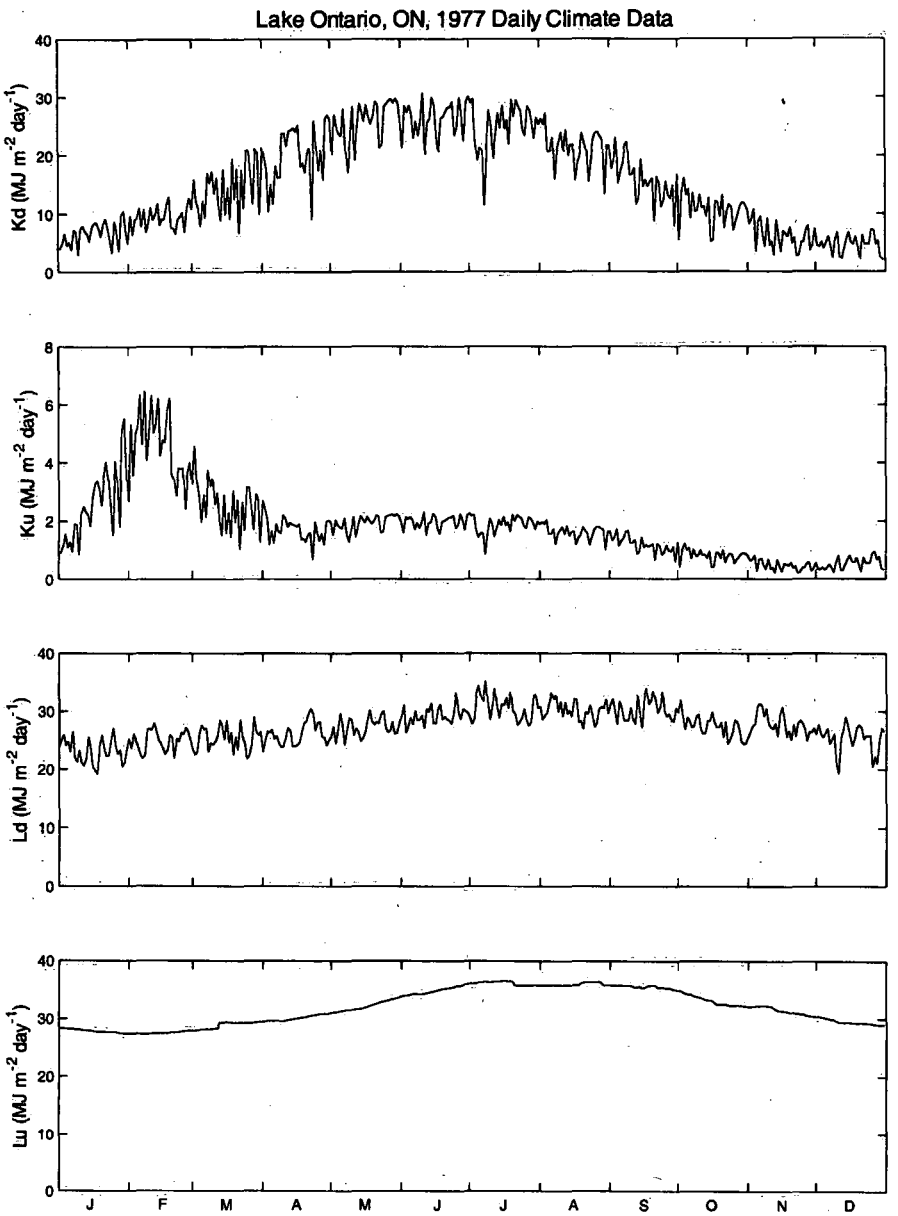
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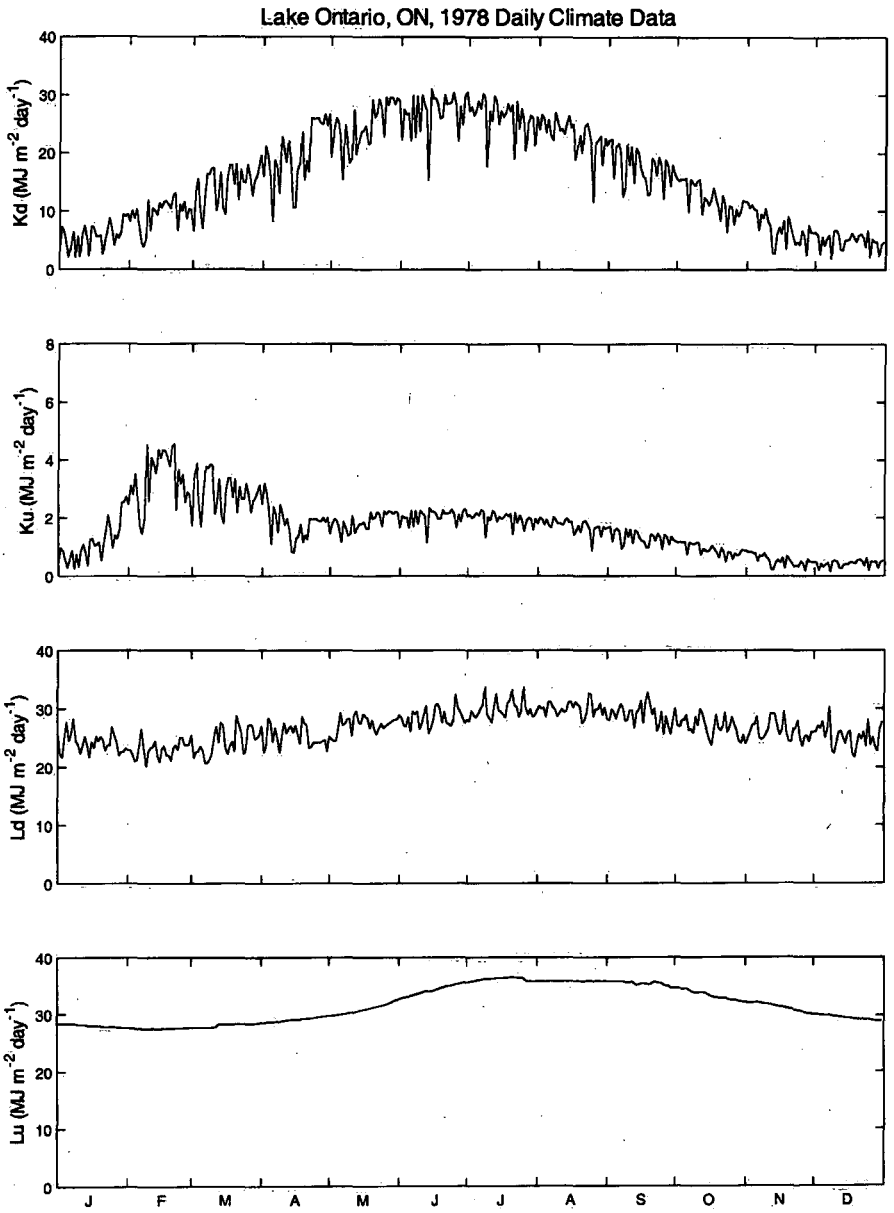
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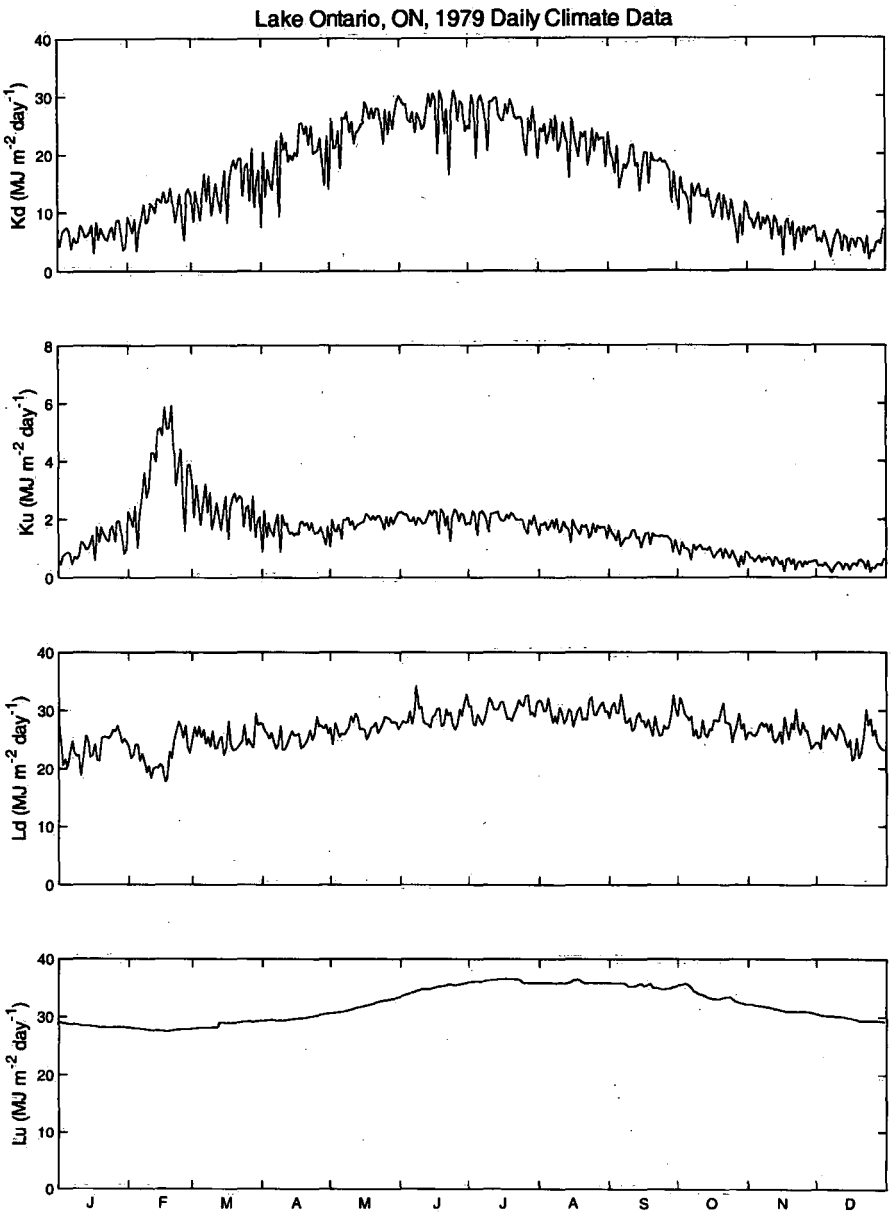
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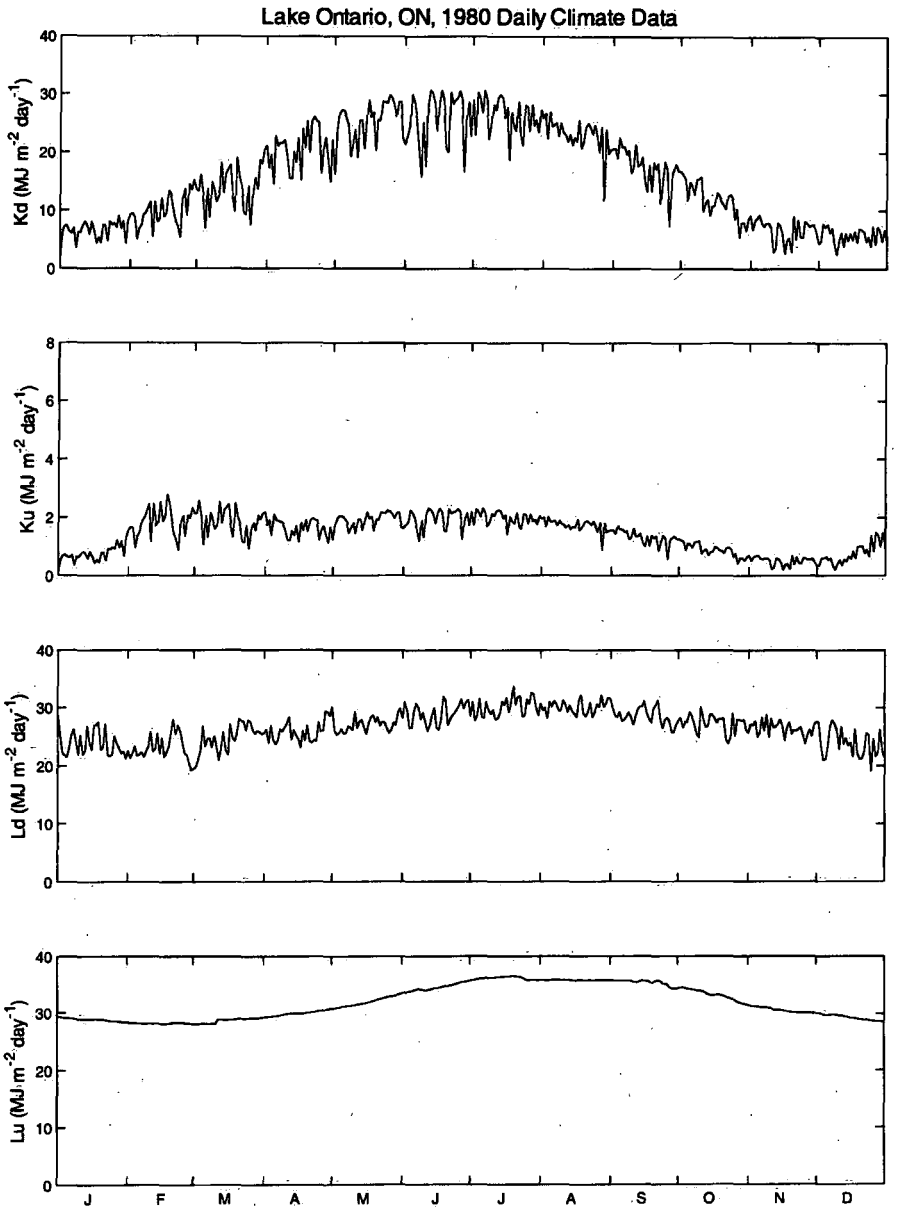
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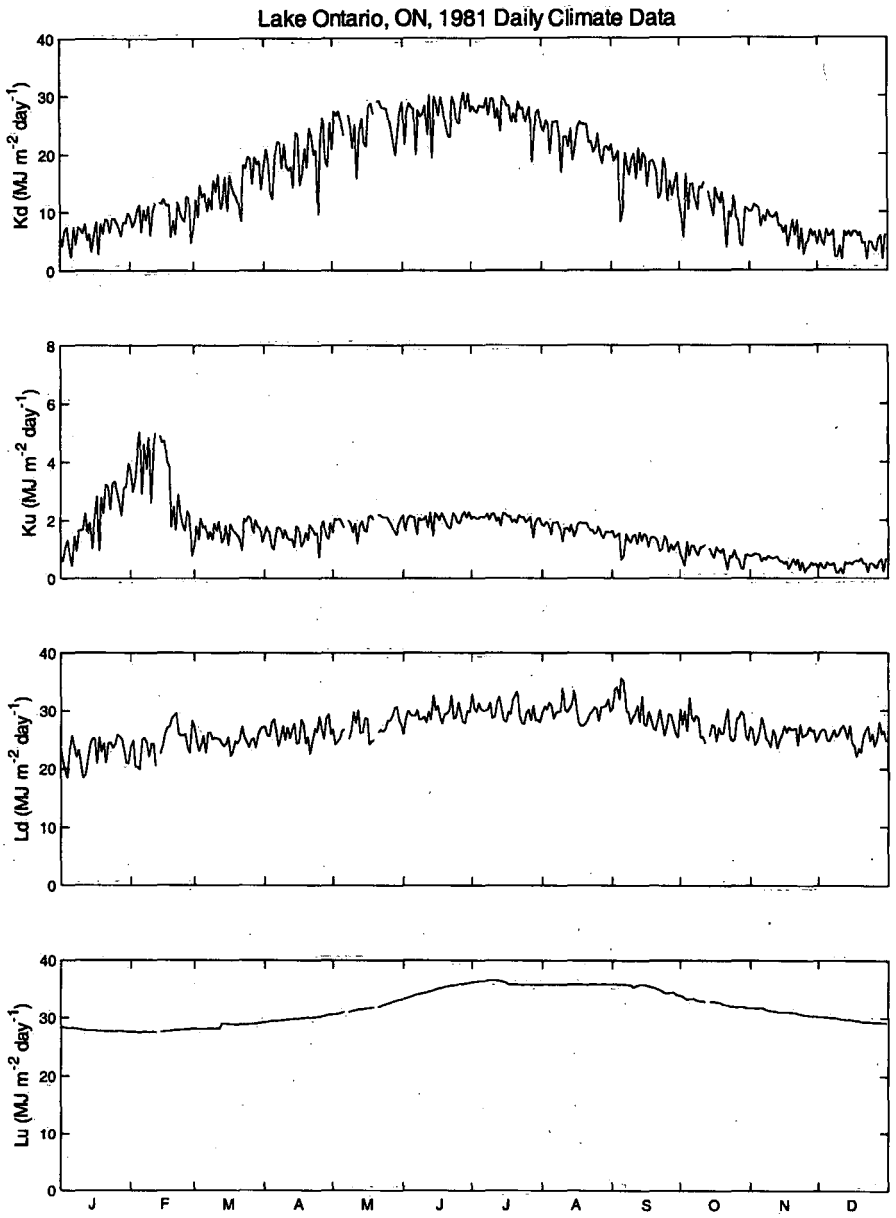
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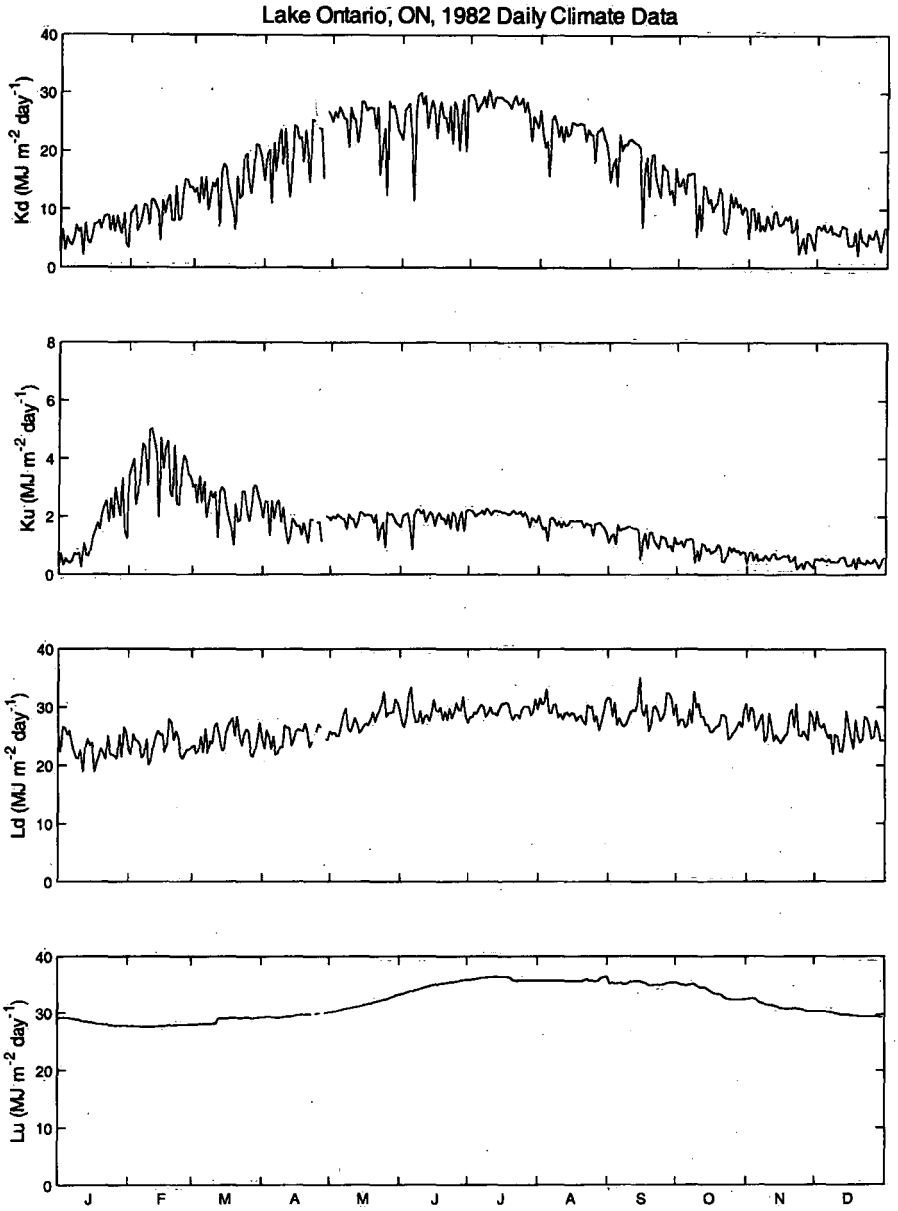
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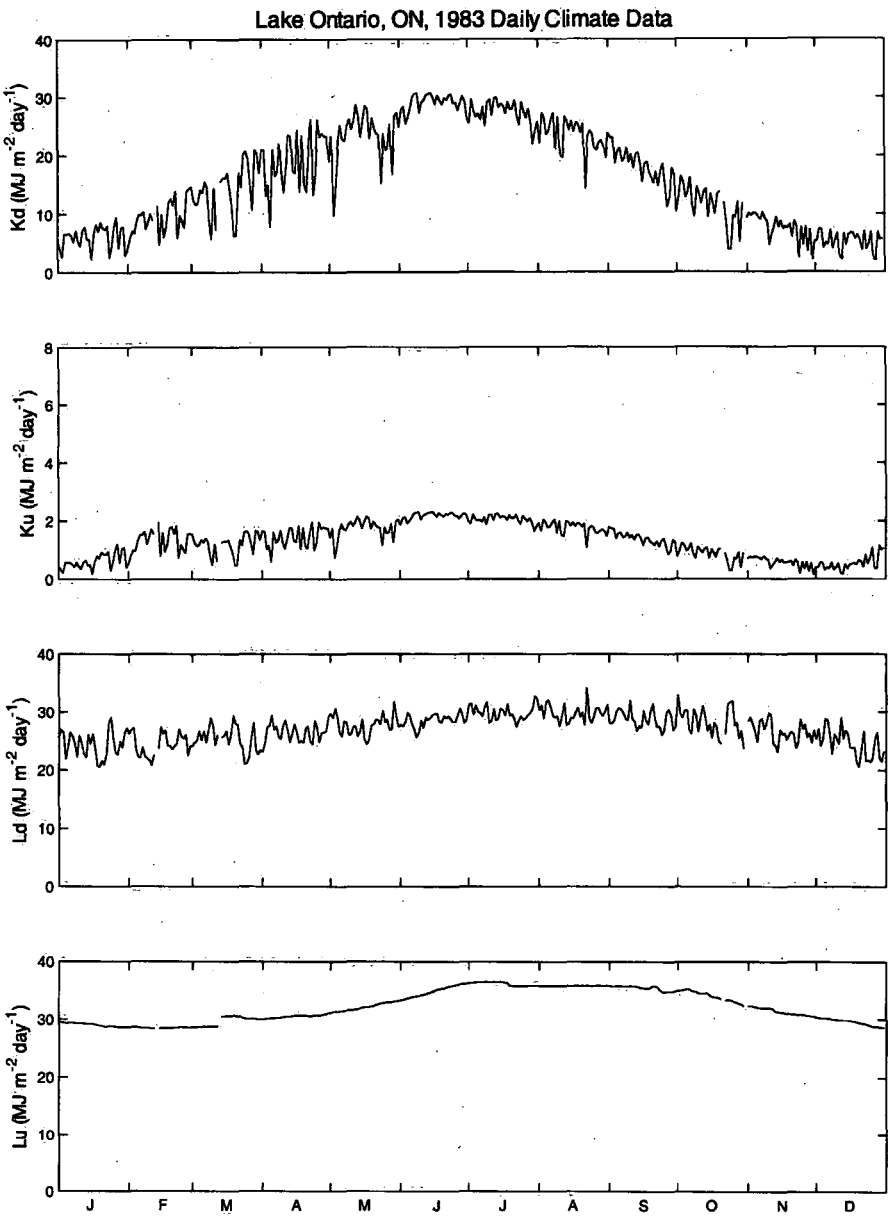
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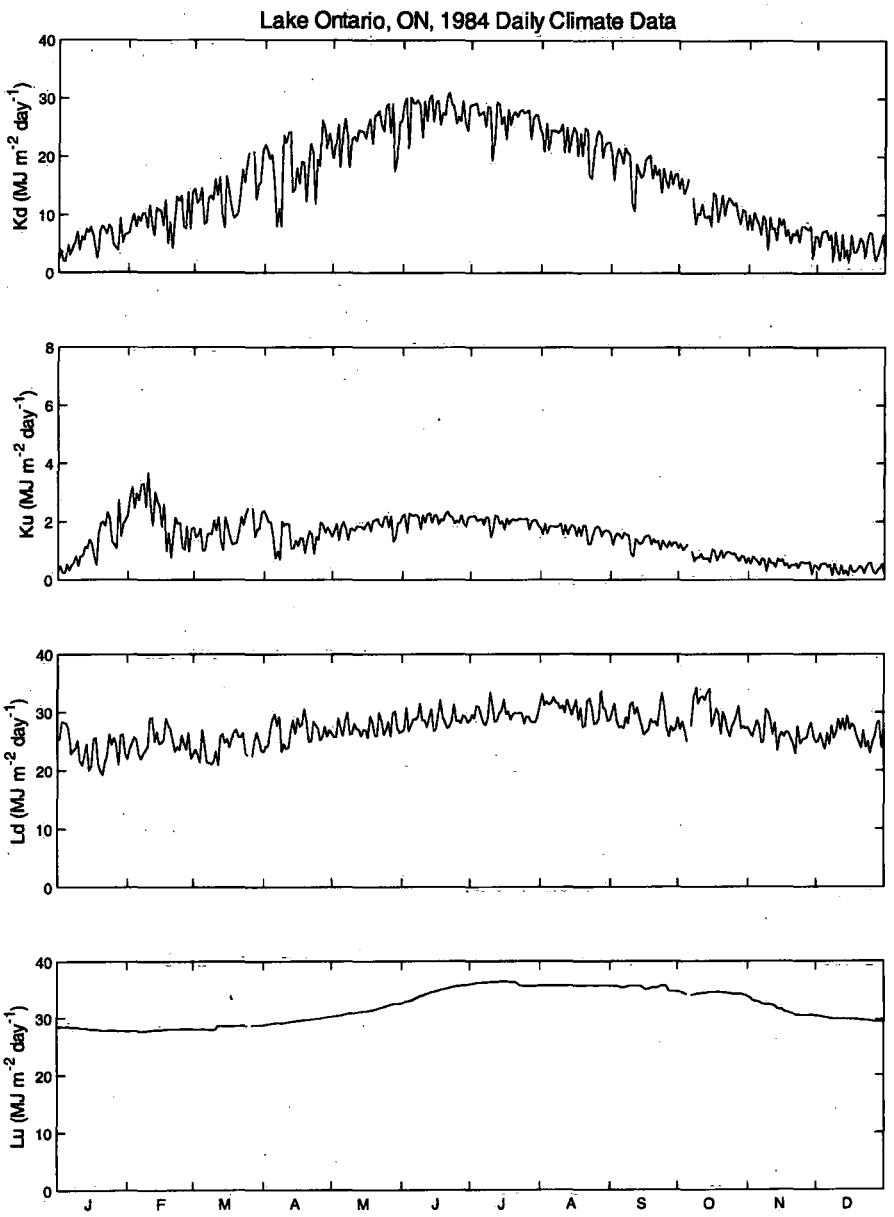
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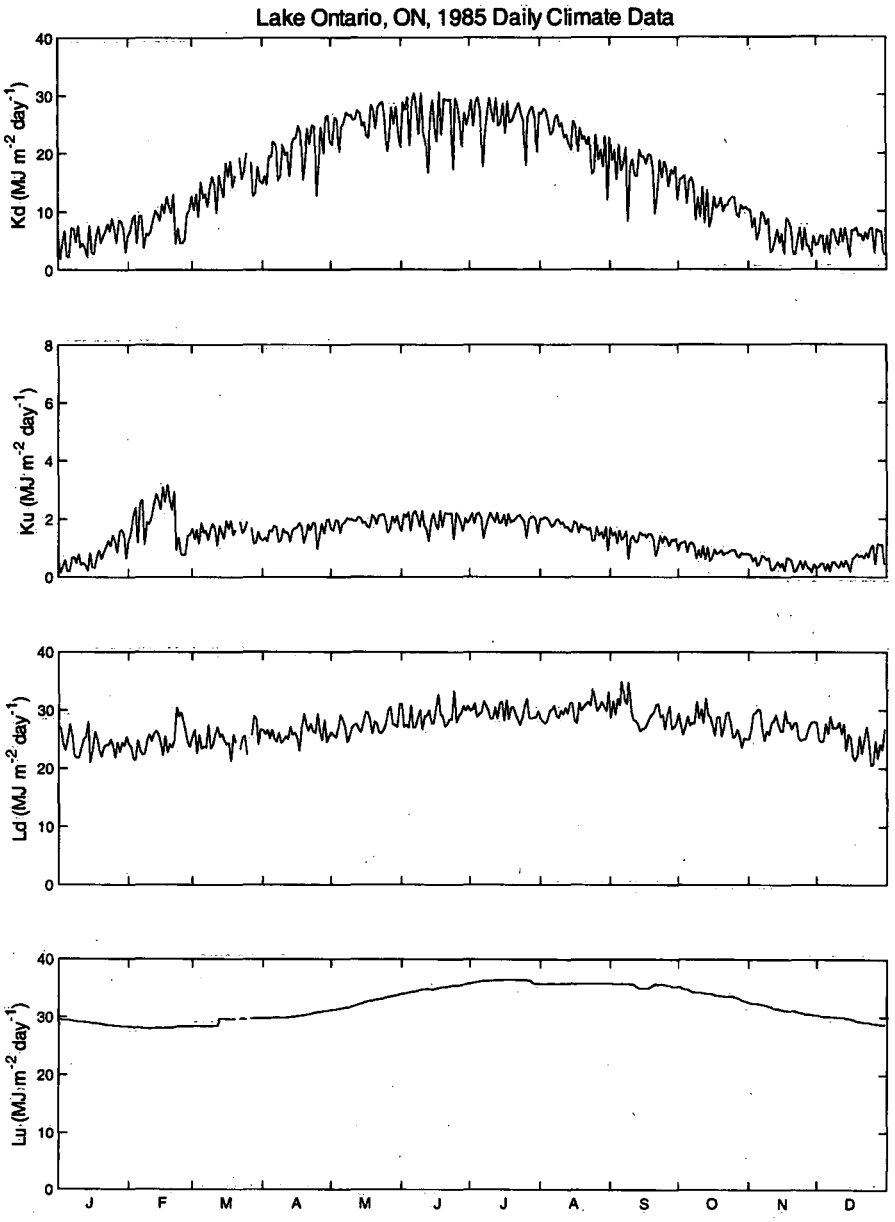
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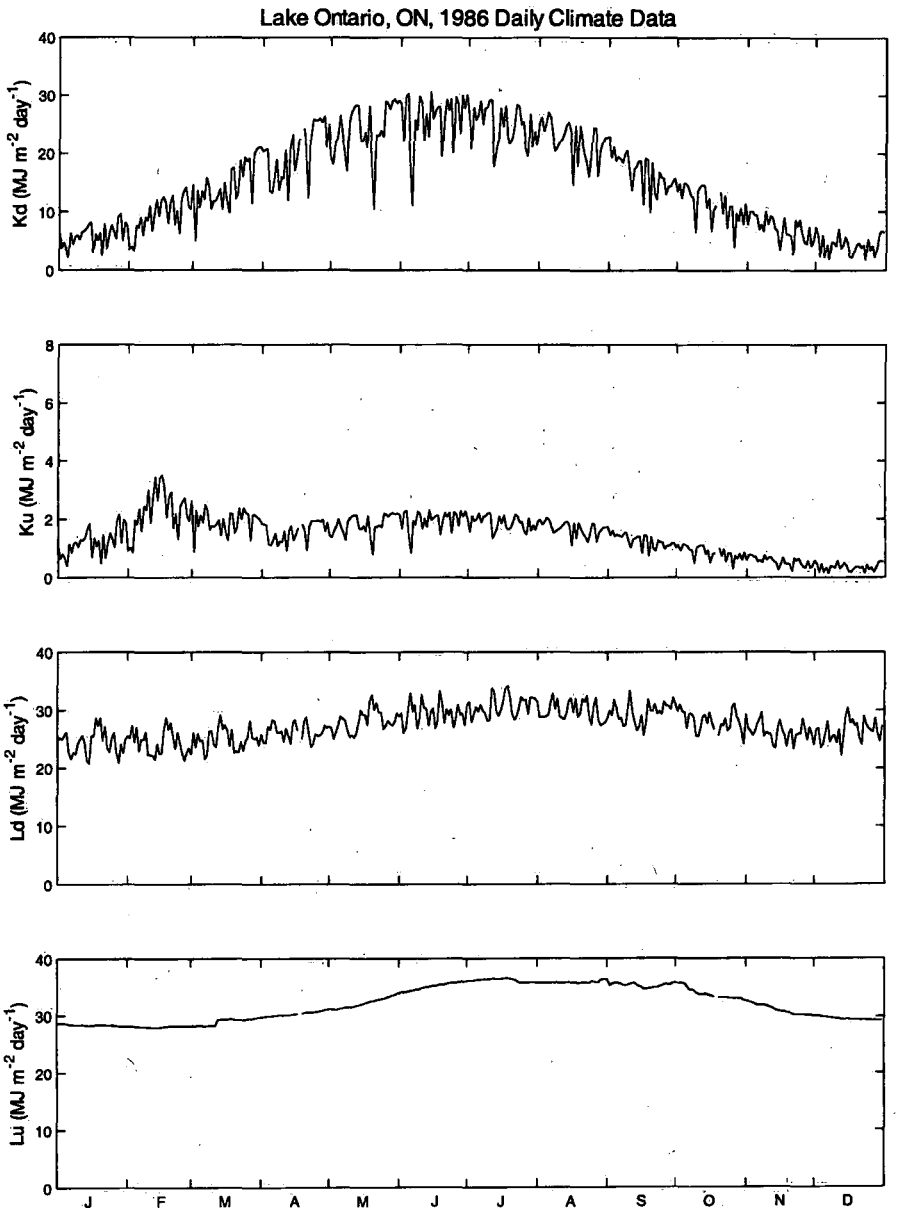
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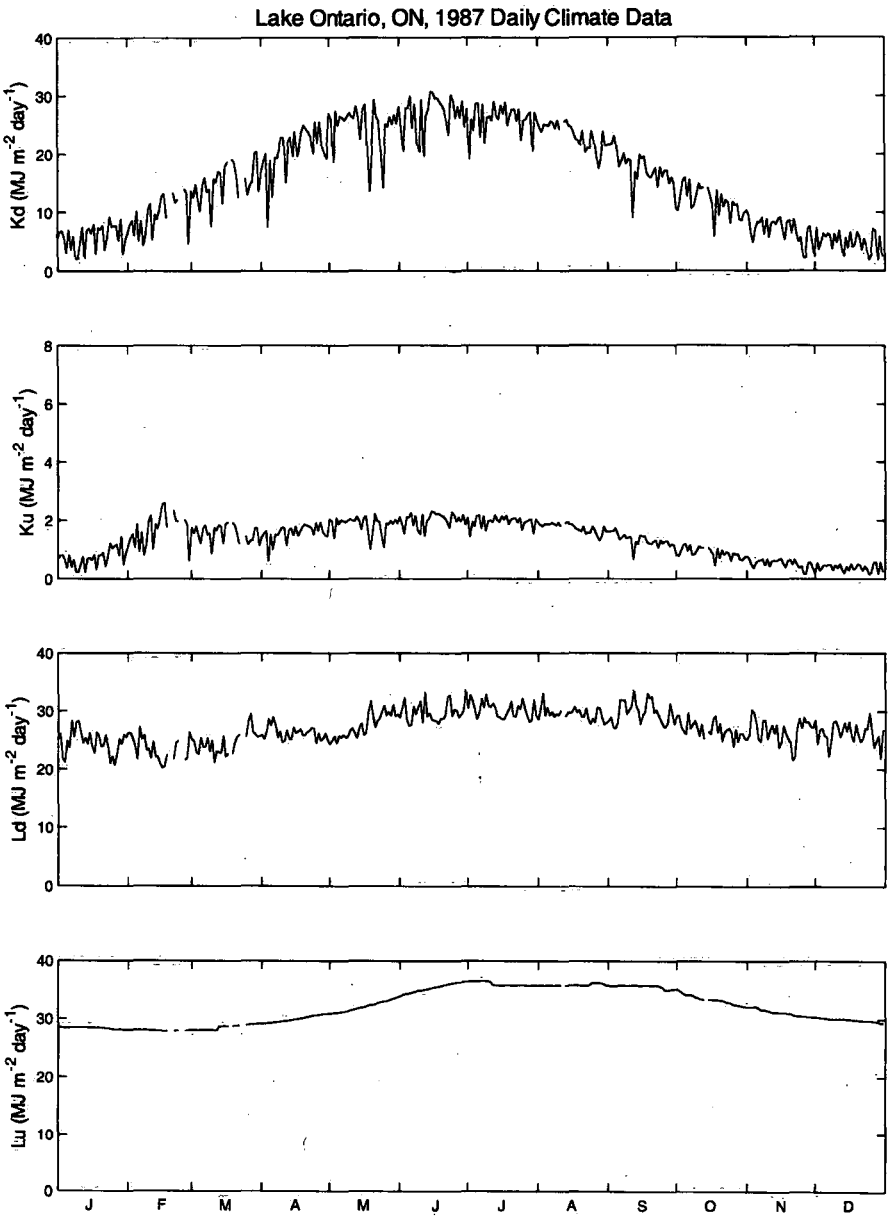
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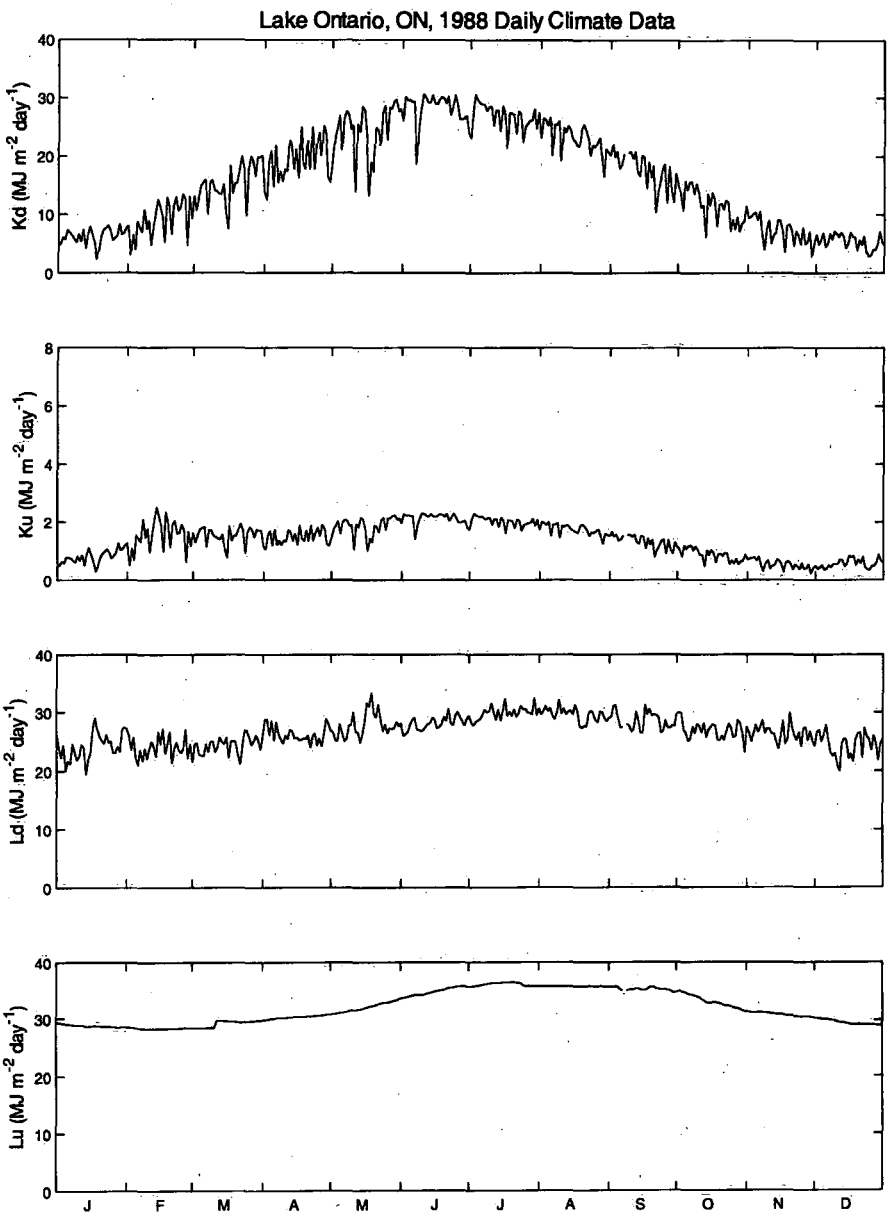
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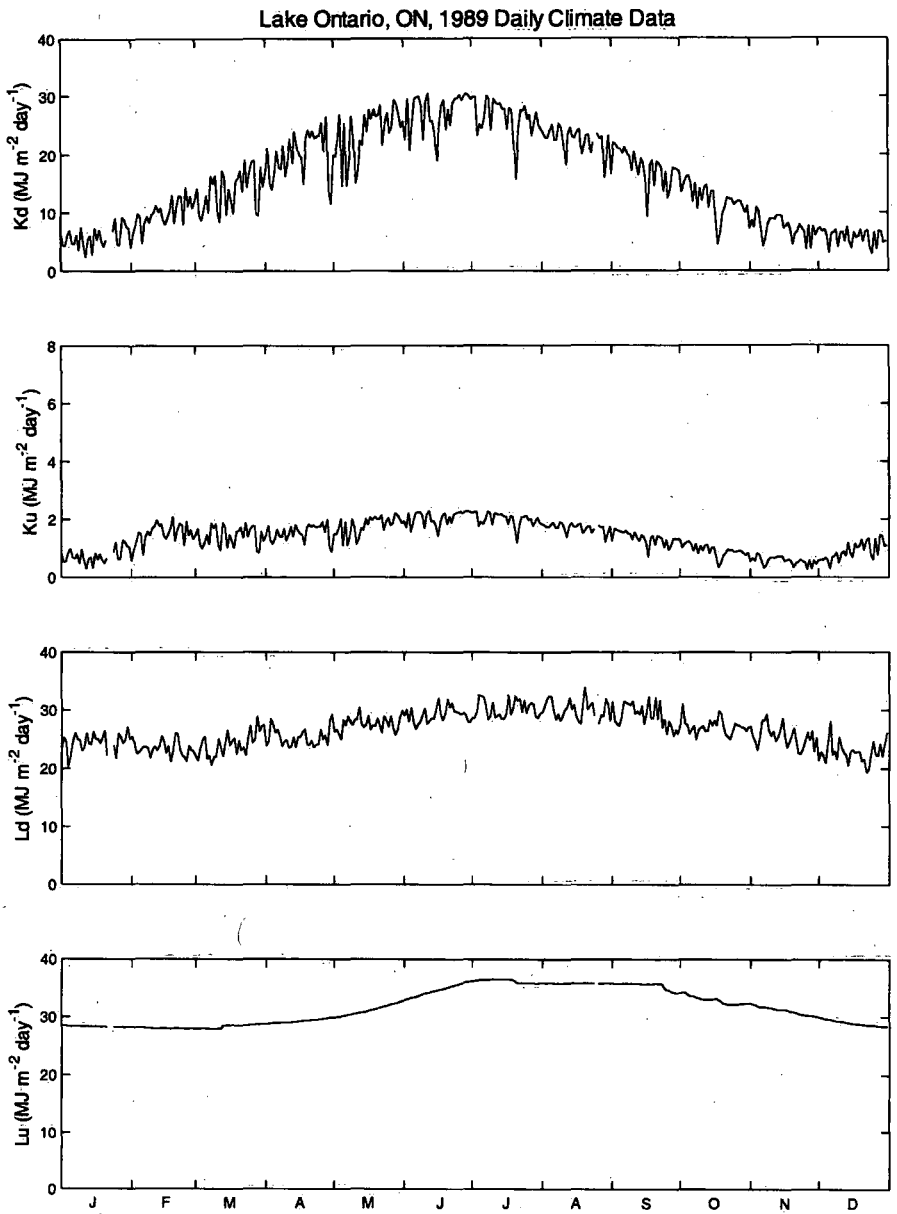
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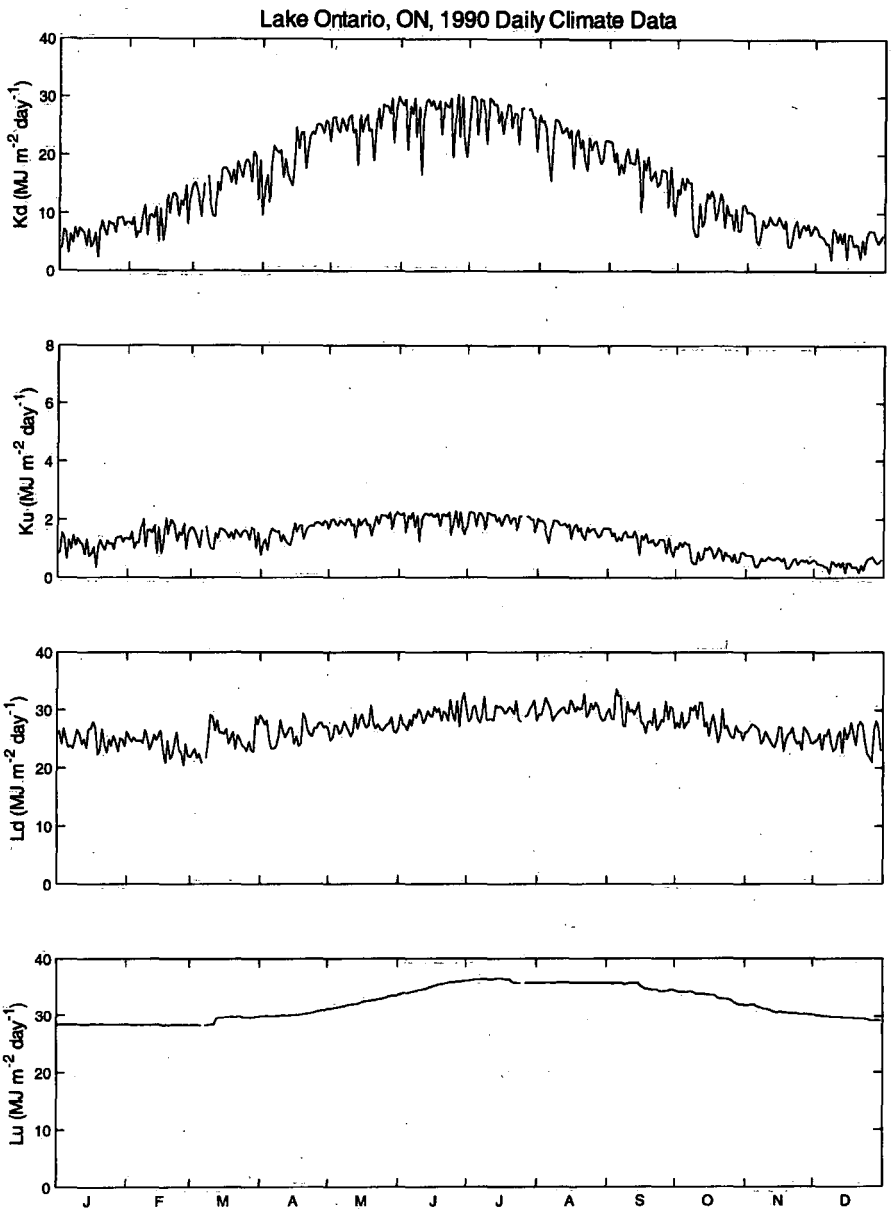
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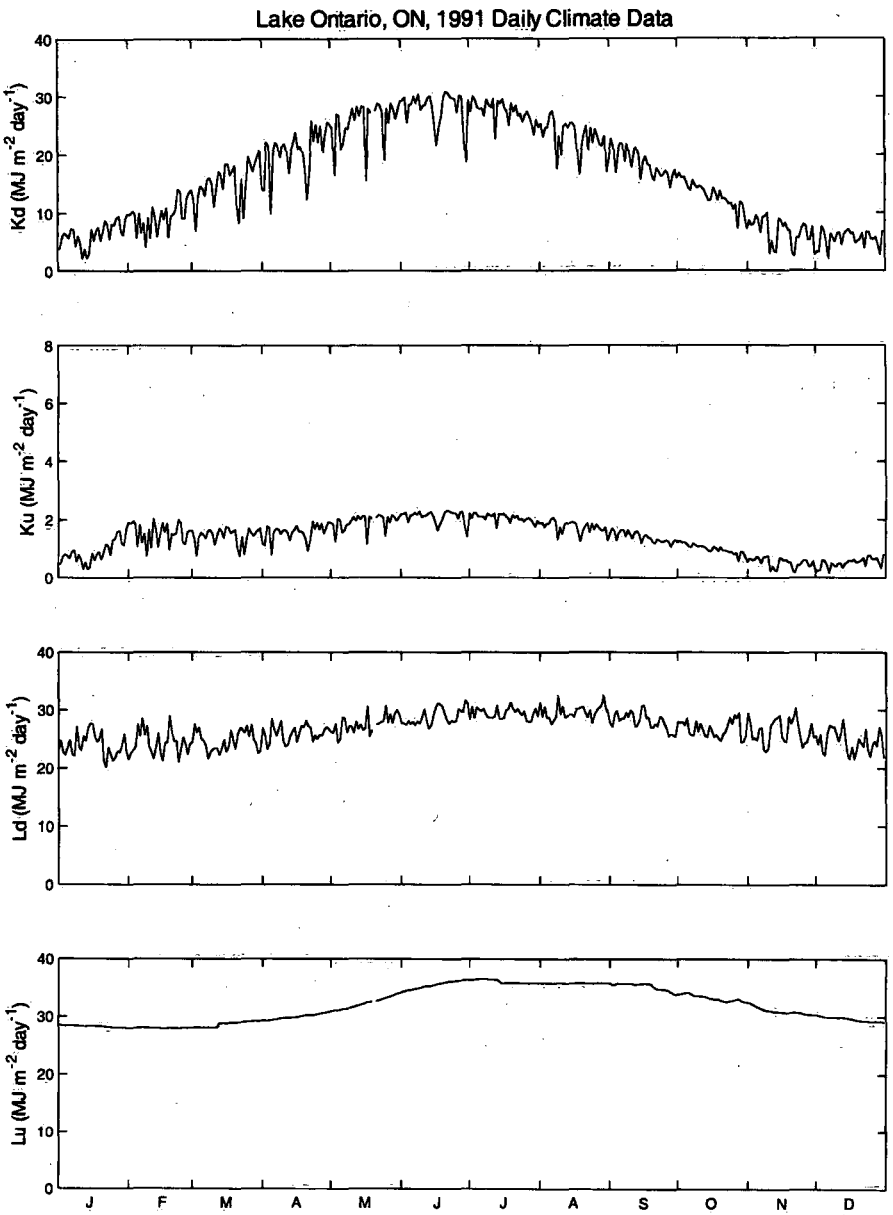
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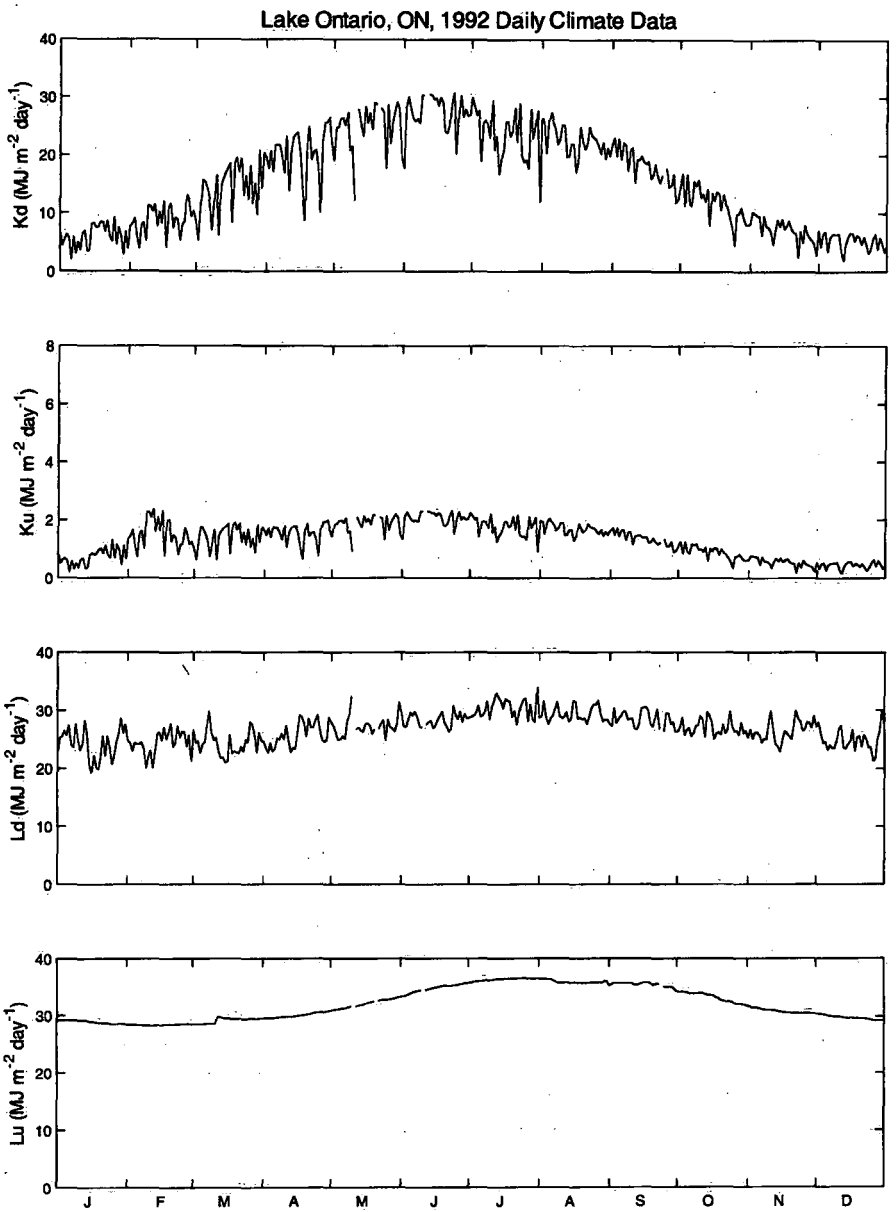
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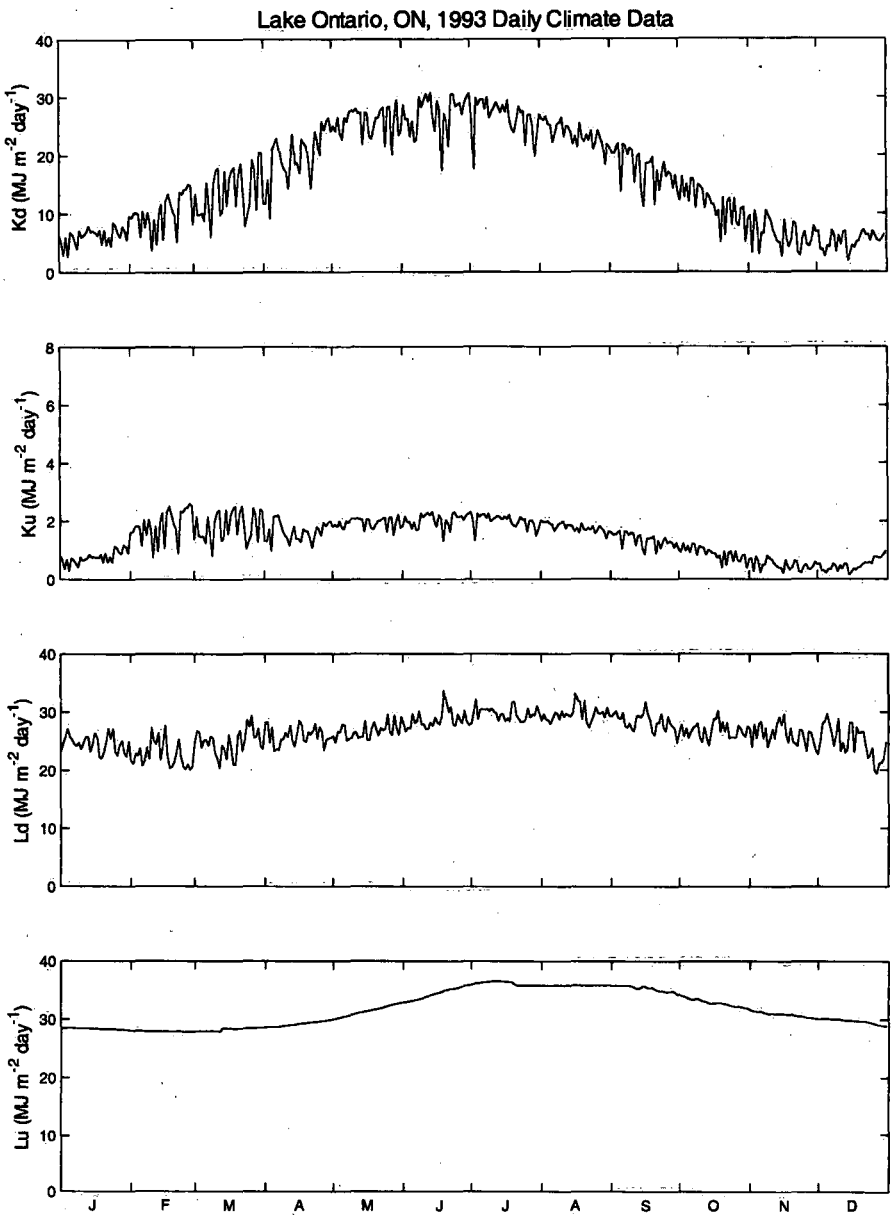
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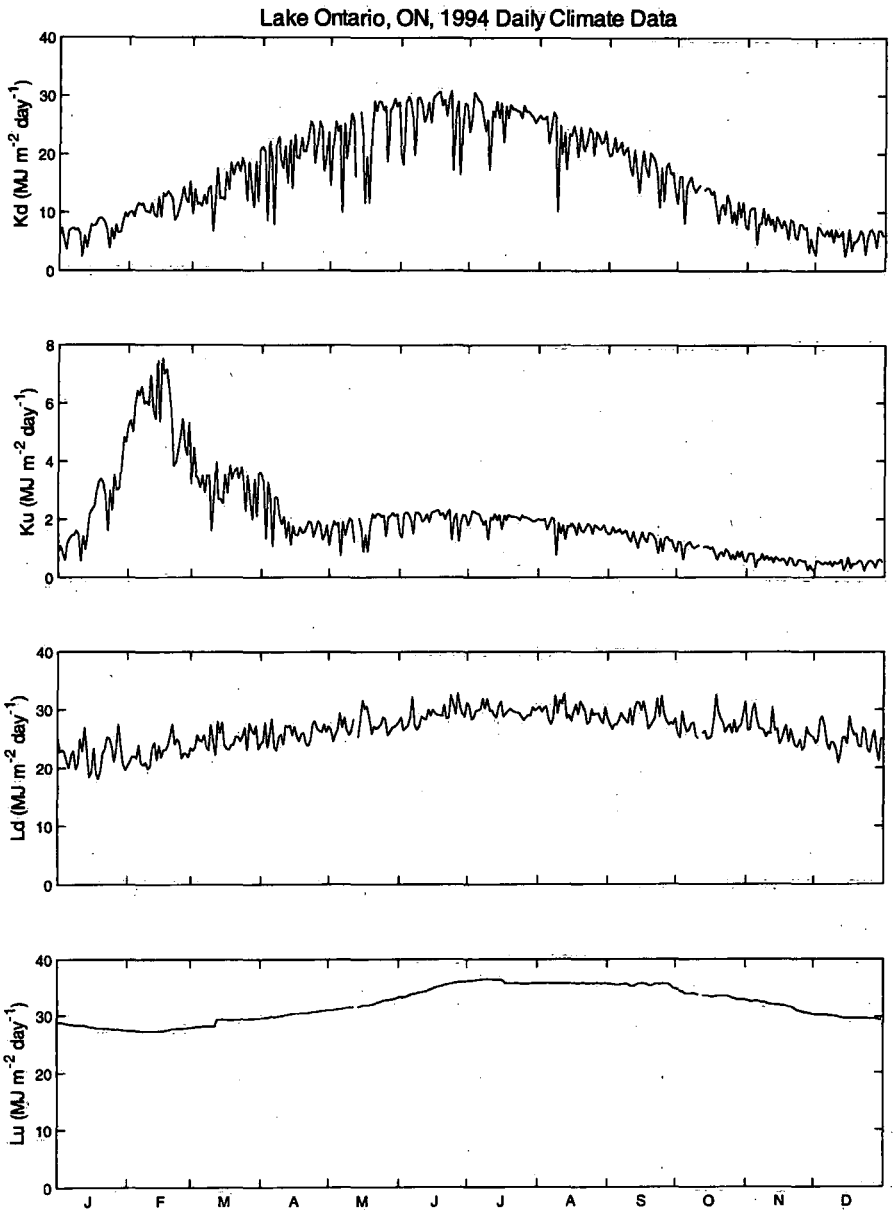
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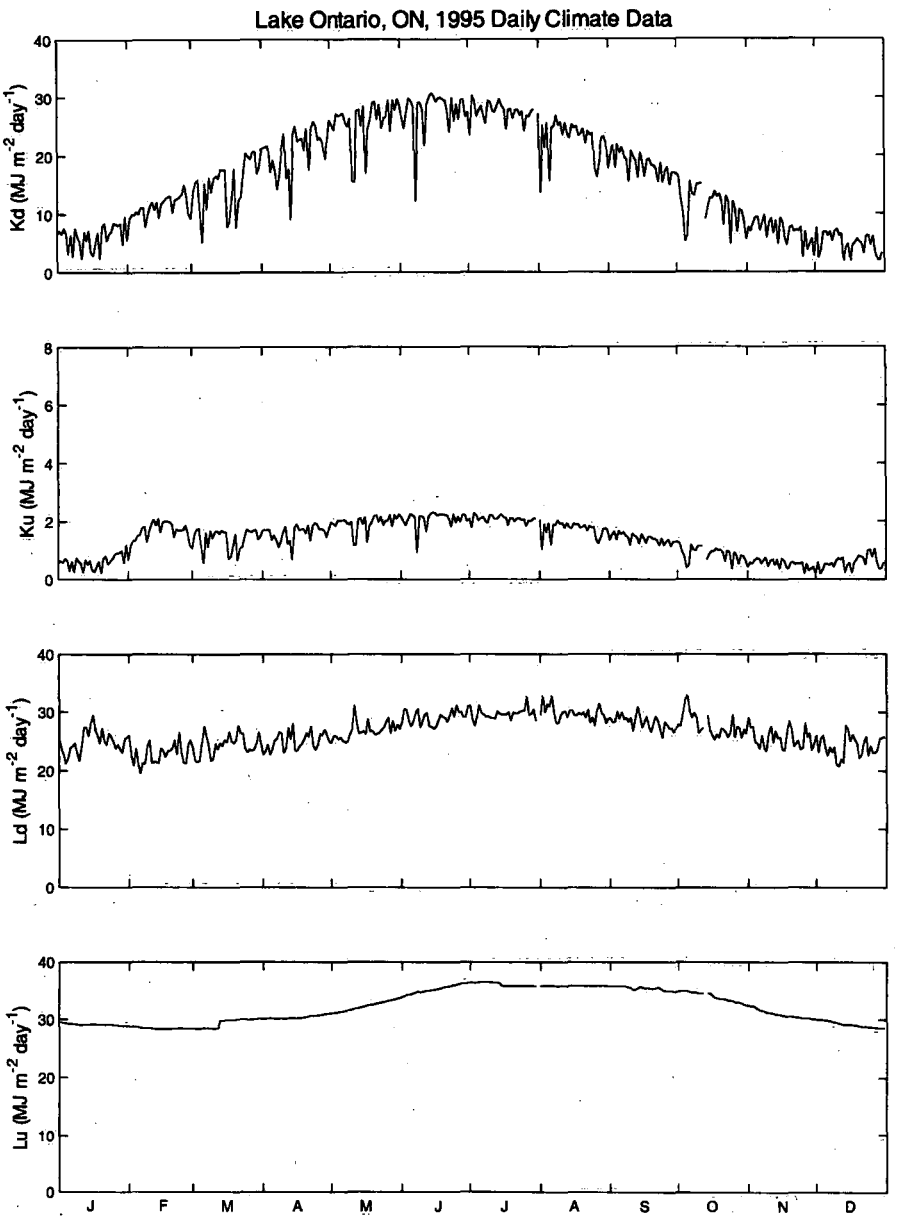
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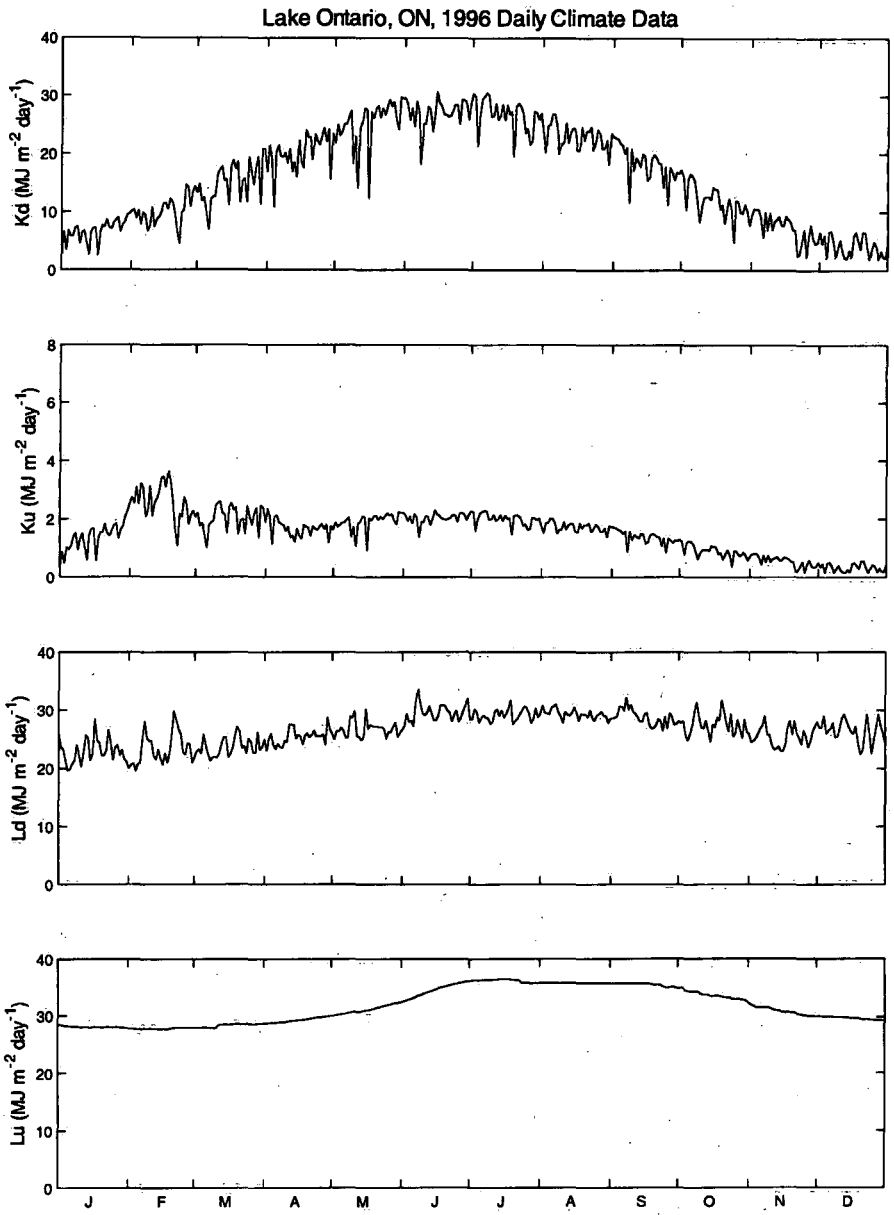
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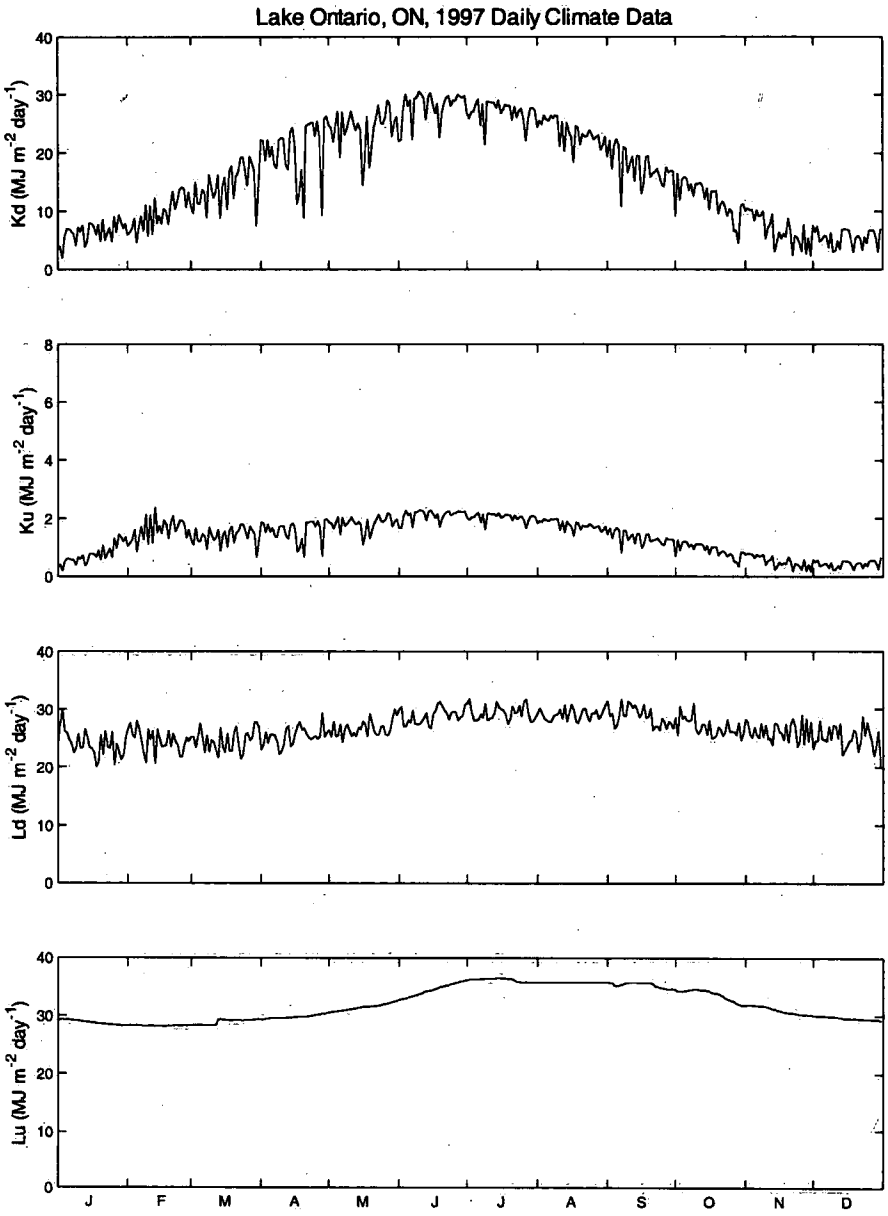
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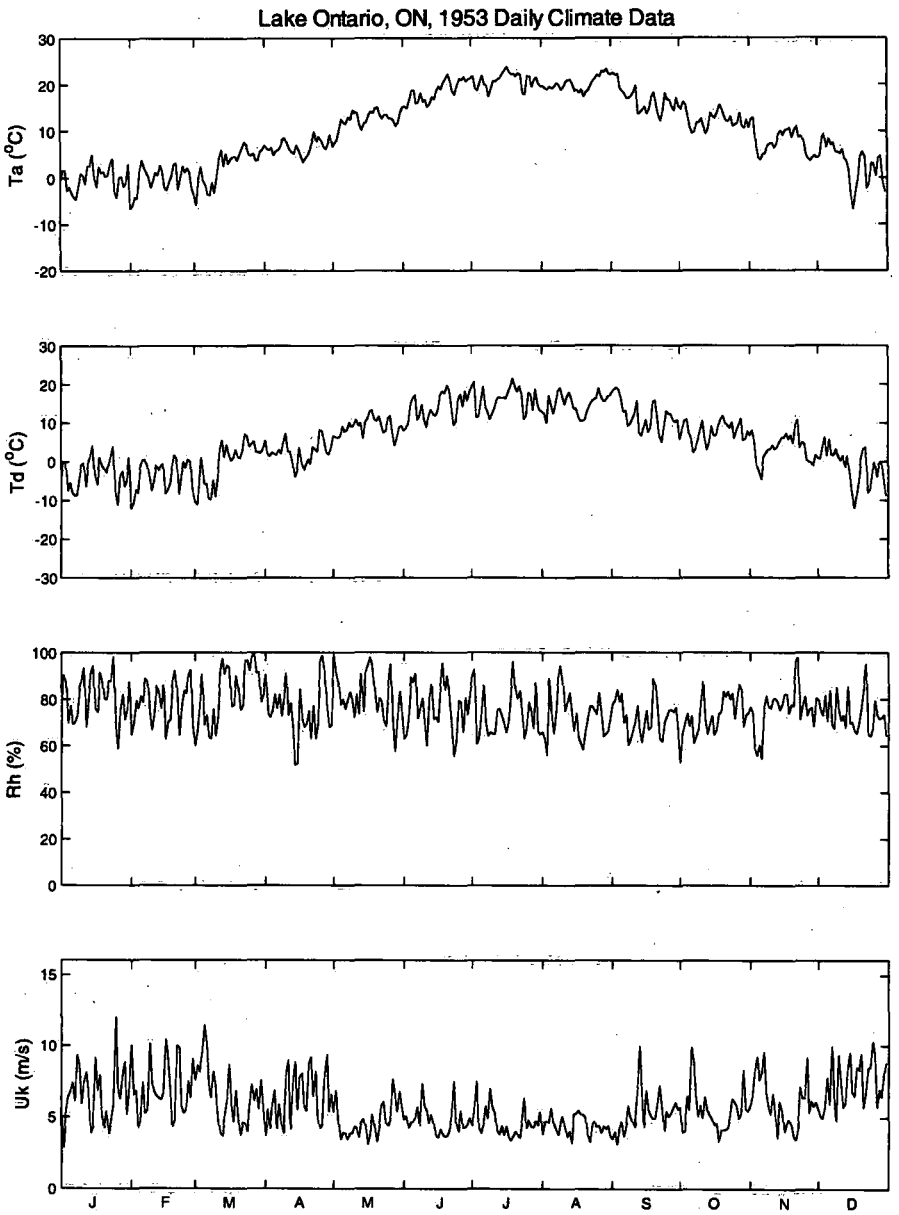
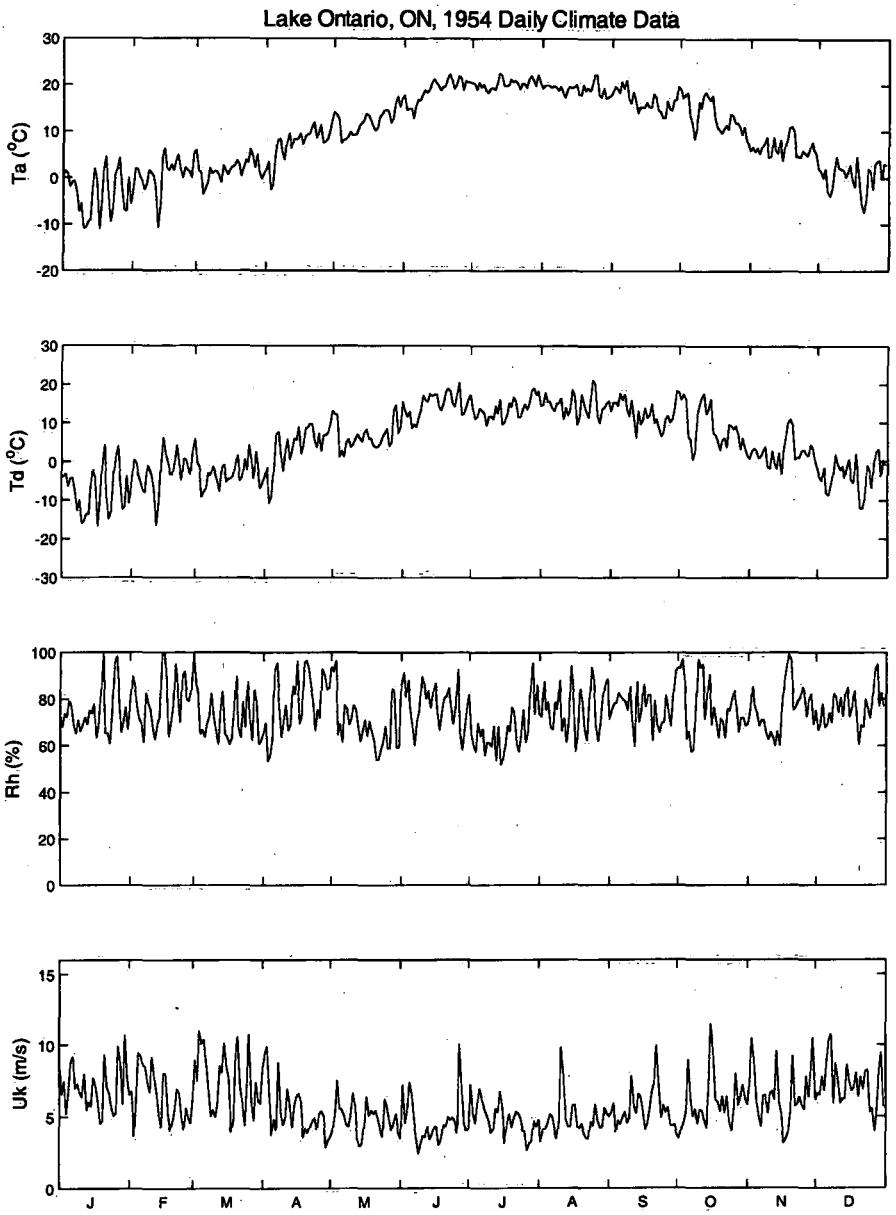
Appendix 5
Meteorological




Lake Ontario, ON, 1954 Daily Climate Data
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Td (°C)
Rh (%)
Uk (m/s)
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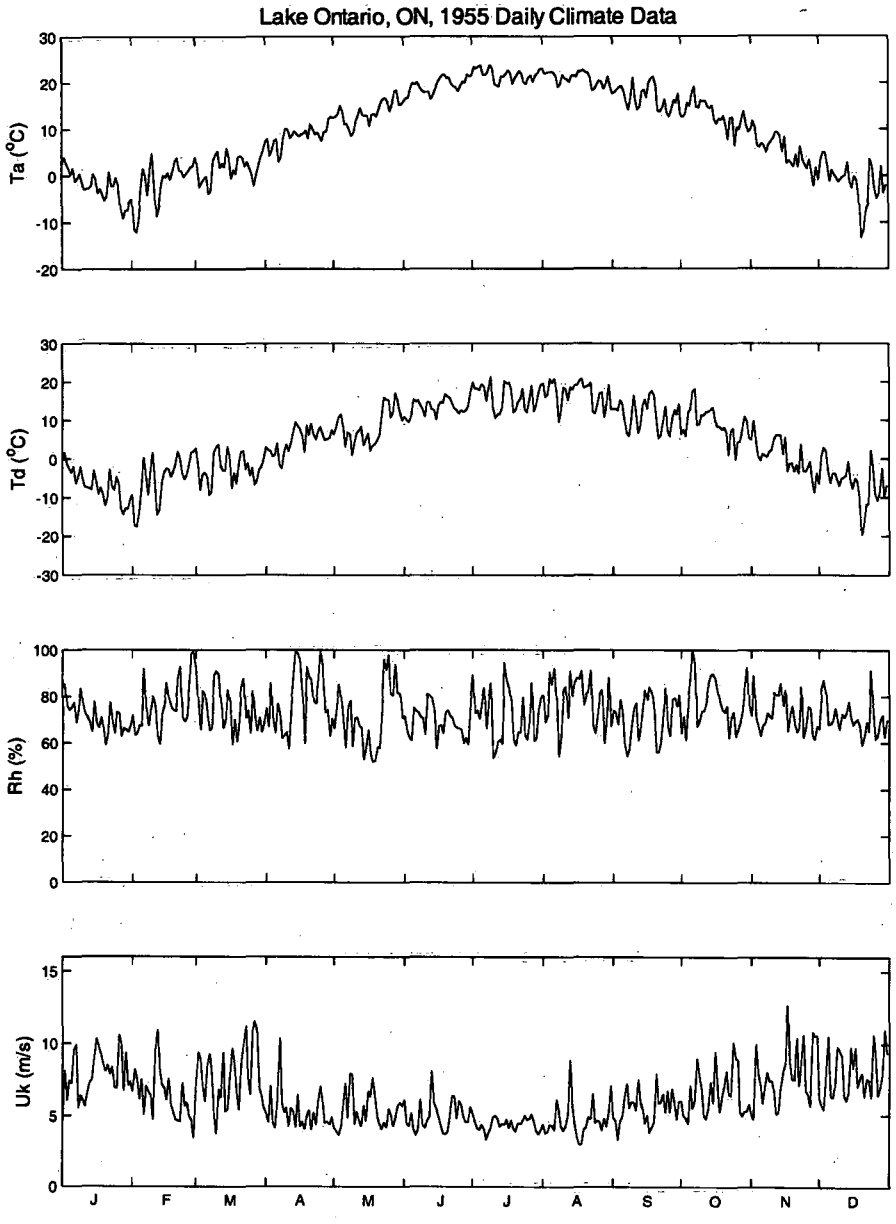
Lake Ontario, ON, 1955 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
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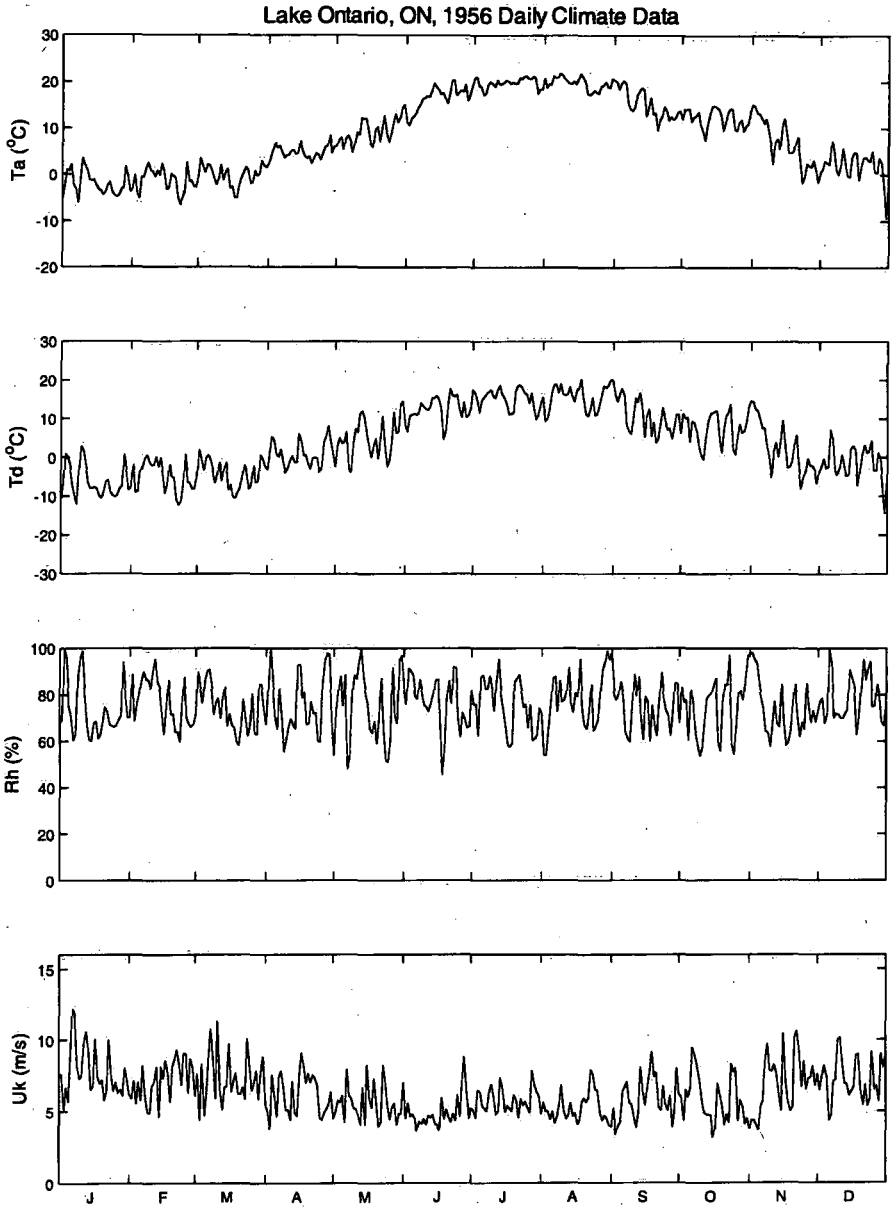
Lake Ontario, ON, 1956 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
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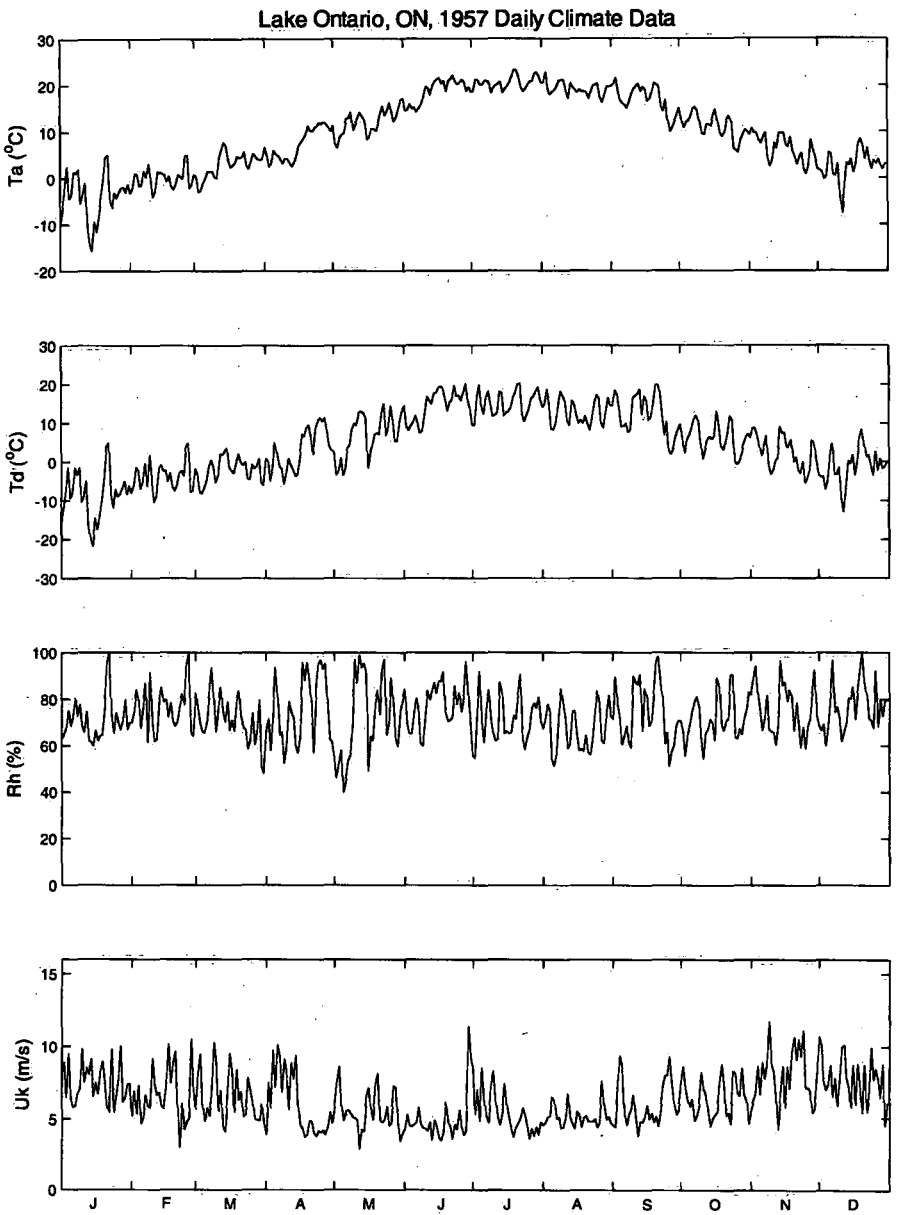
Lake Ontario, ON, 1957 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
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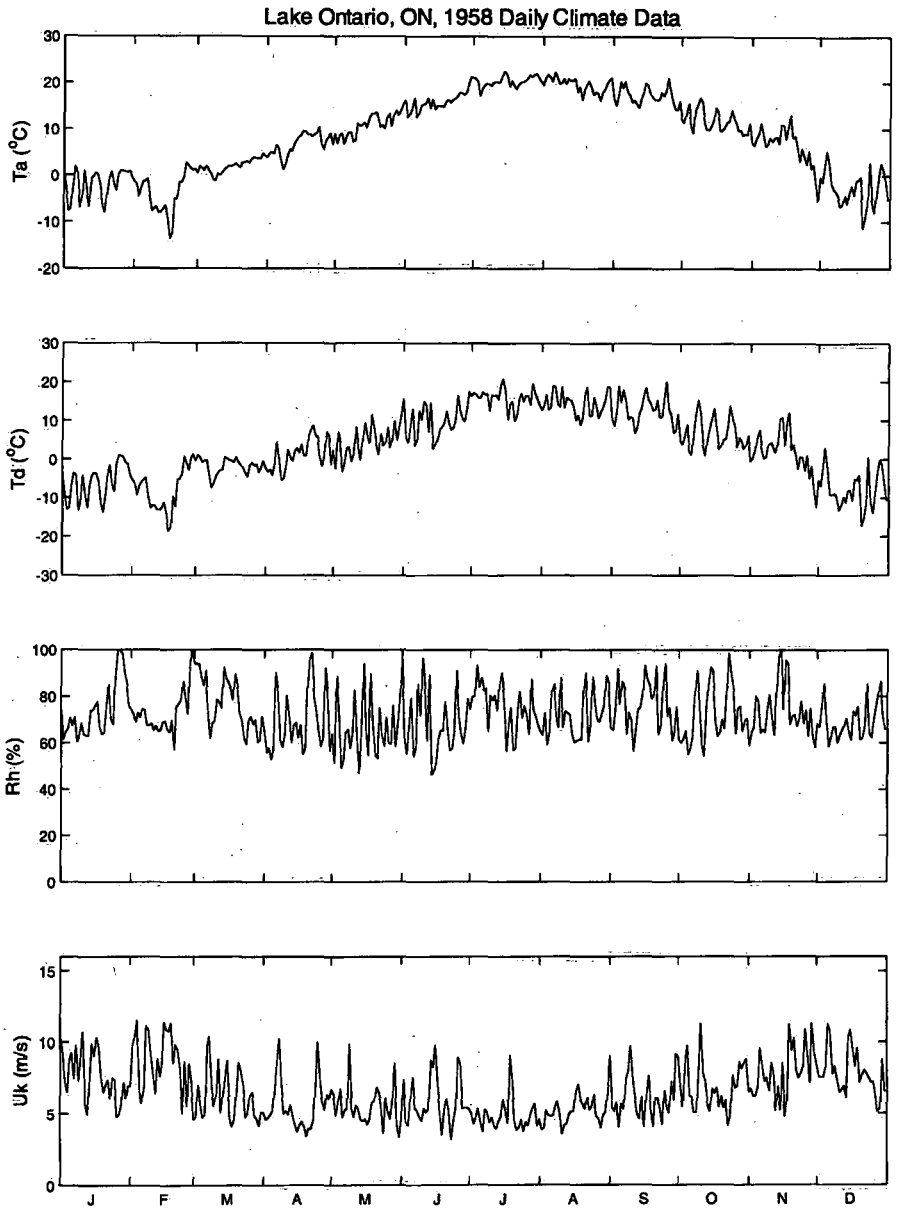
Lake Ontario, ON, 1958 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
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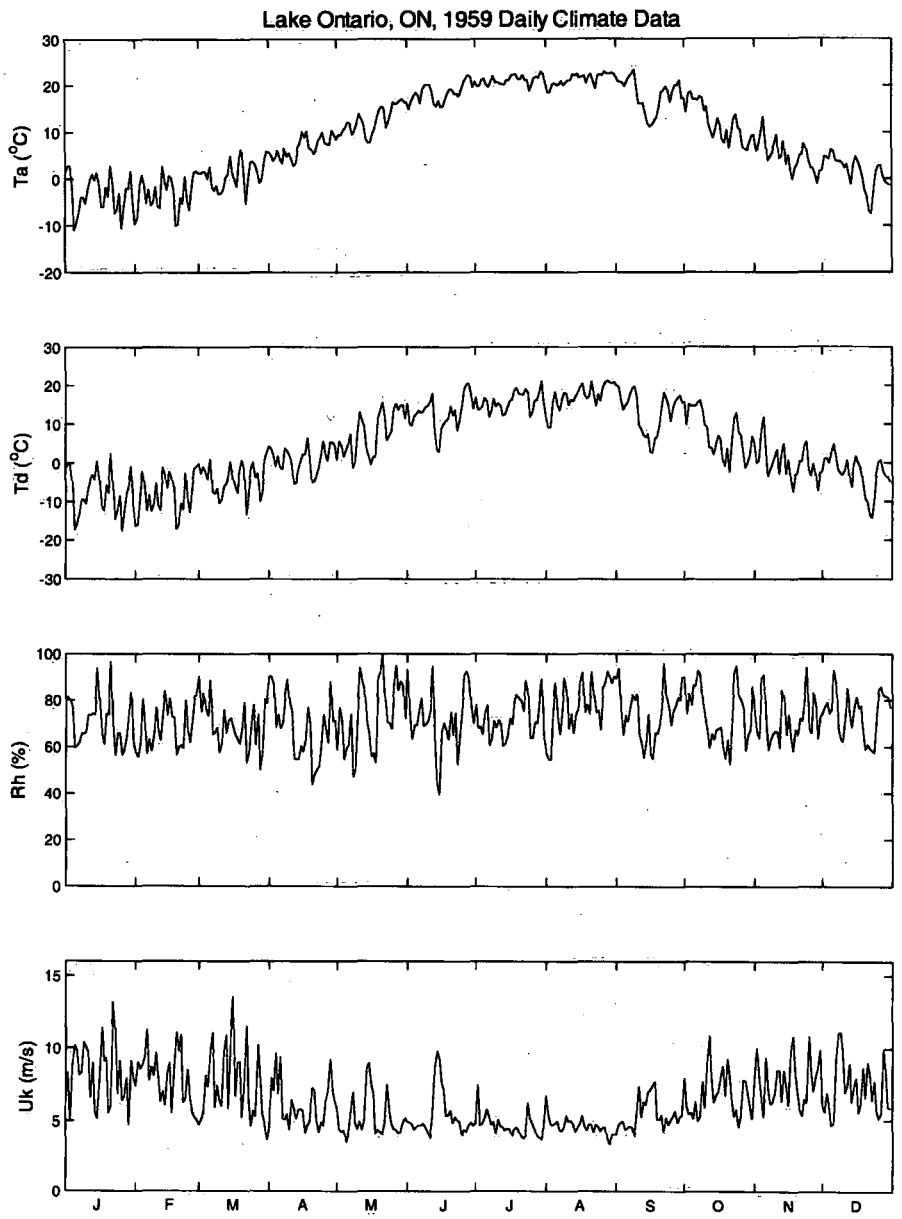
Lake Ontario, ON, 1959 Daily Climate Data
Ta (°C)
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Rh (%)
Uk (m/s)
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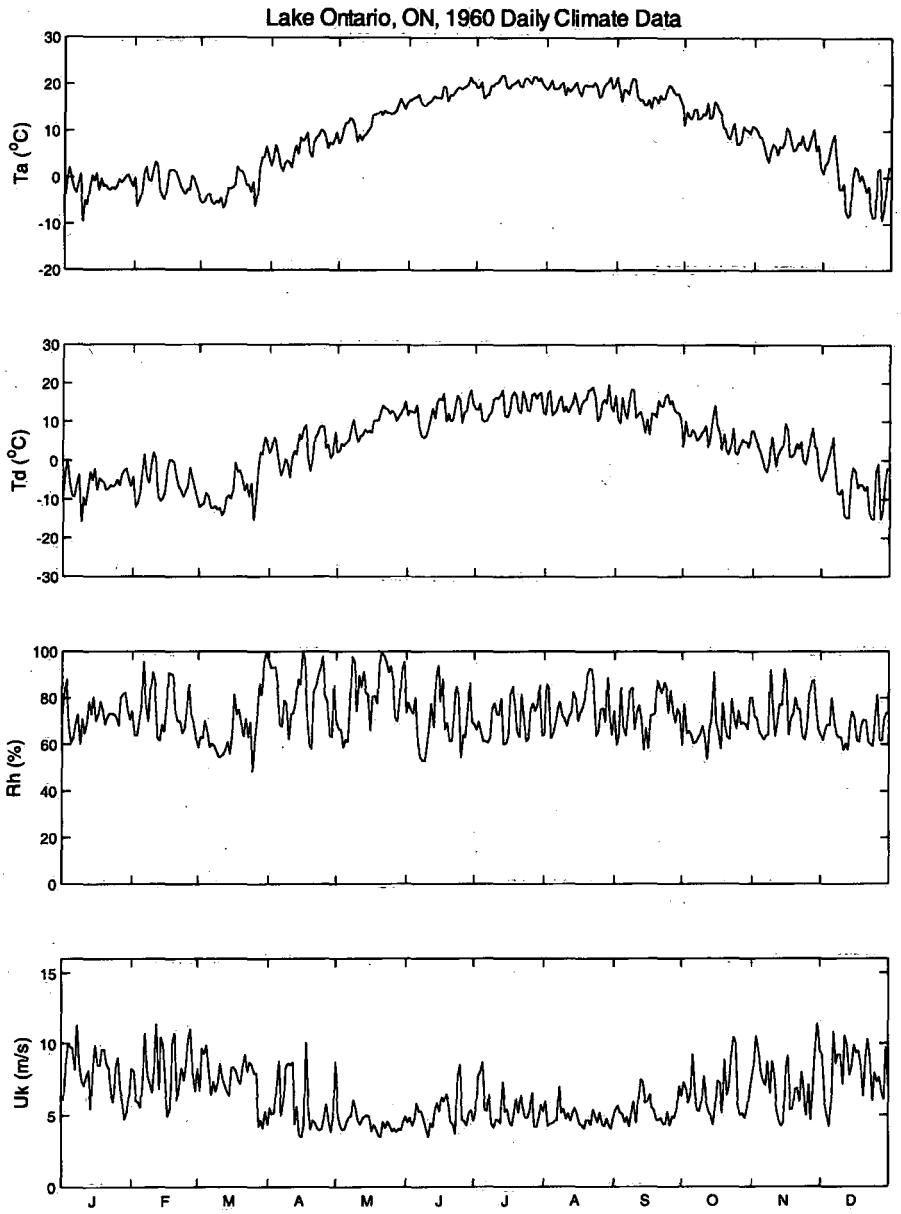
Lake Ontario, ON, 1960 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
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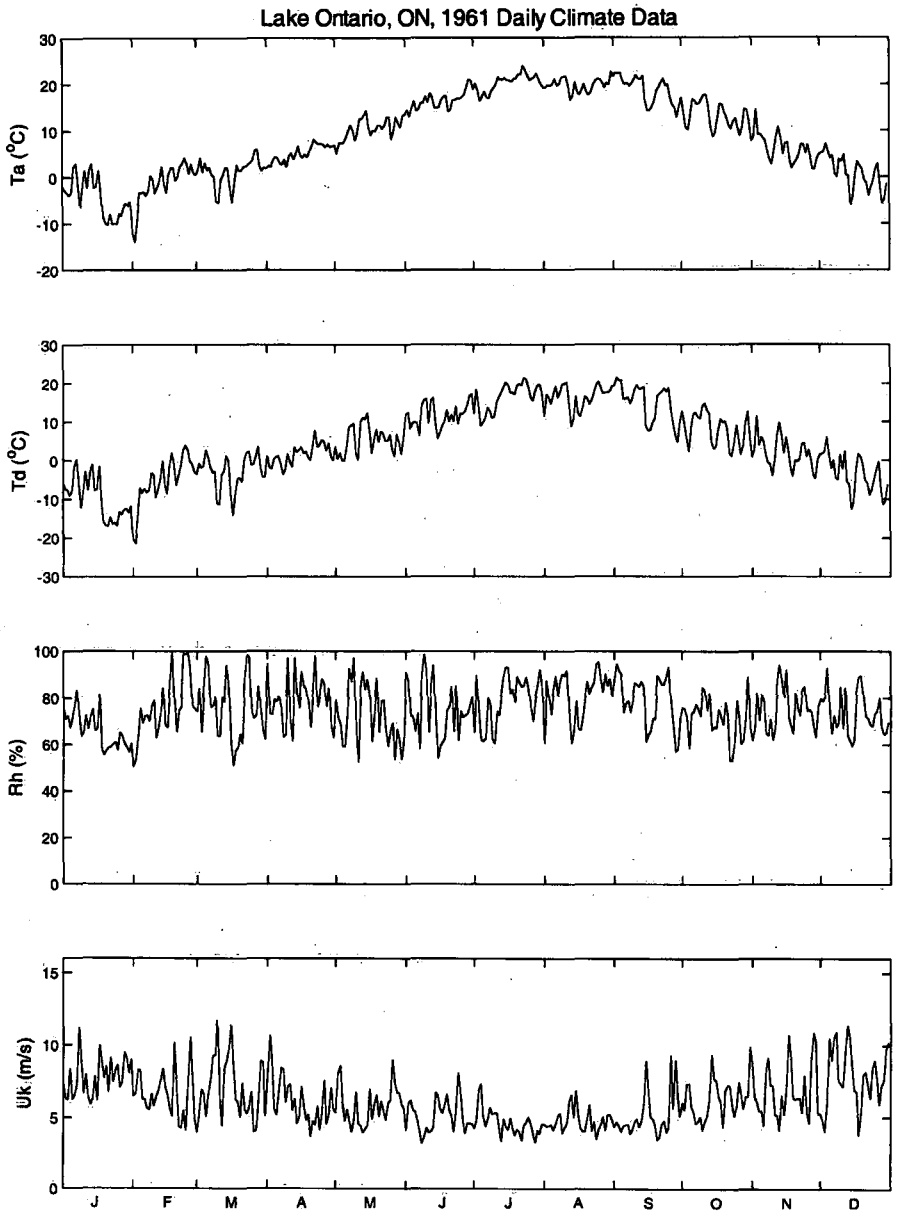
Lake Ontario, ON, 1961 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
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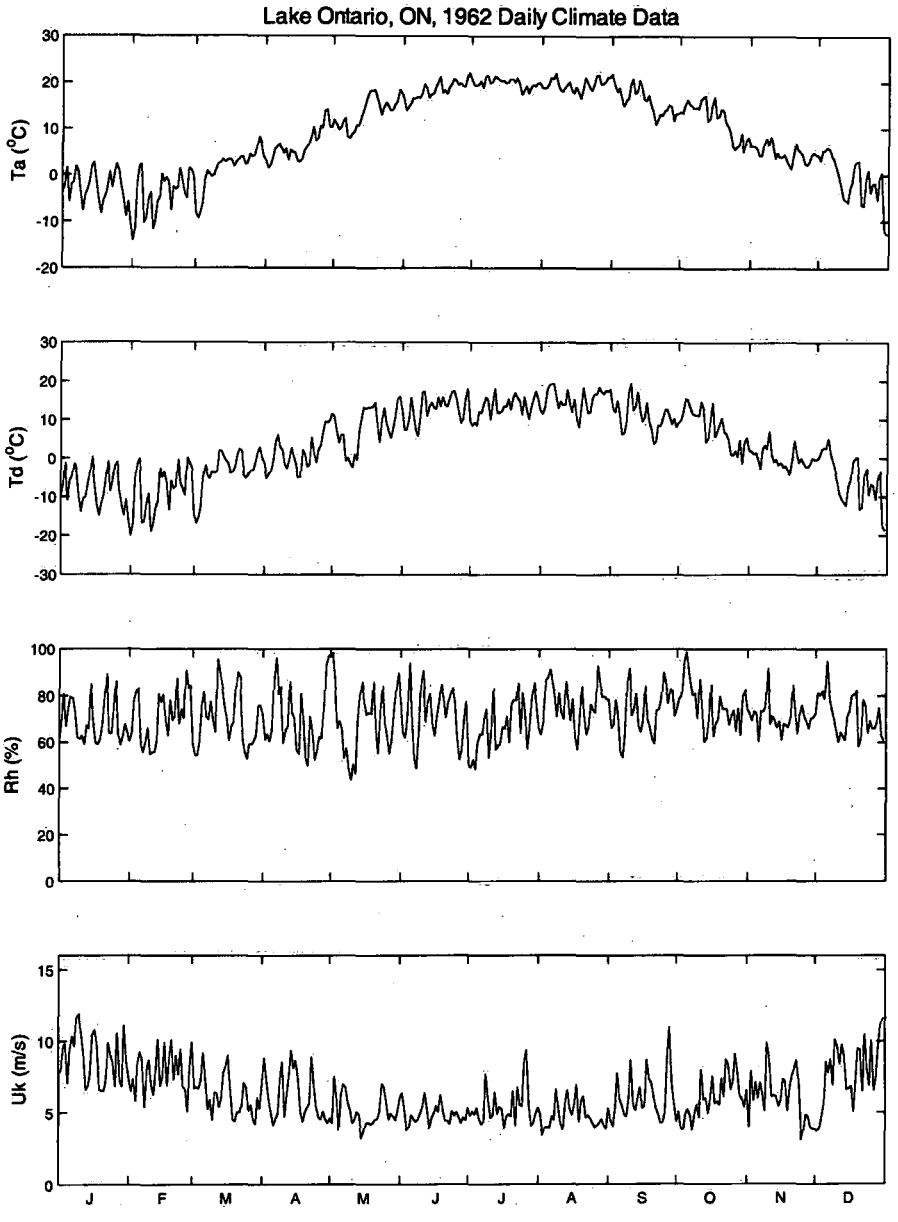
Lake Ontario, ON, 1962 Daily Climate Data
Ta (°C)
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Rh (%)
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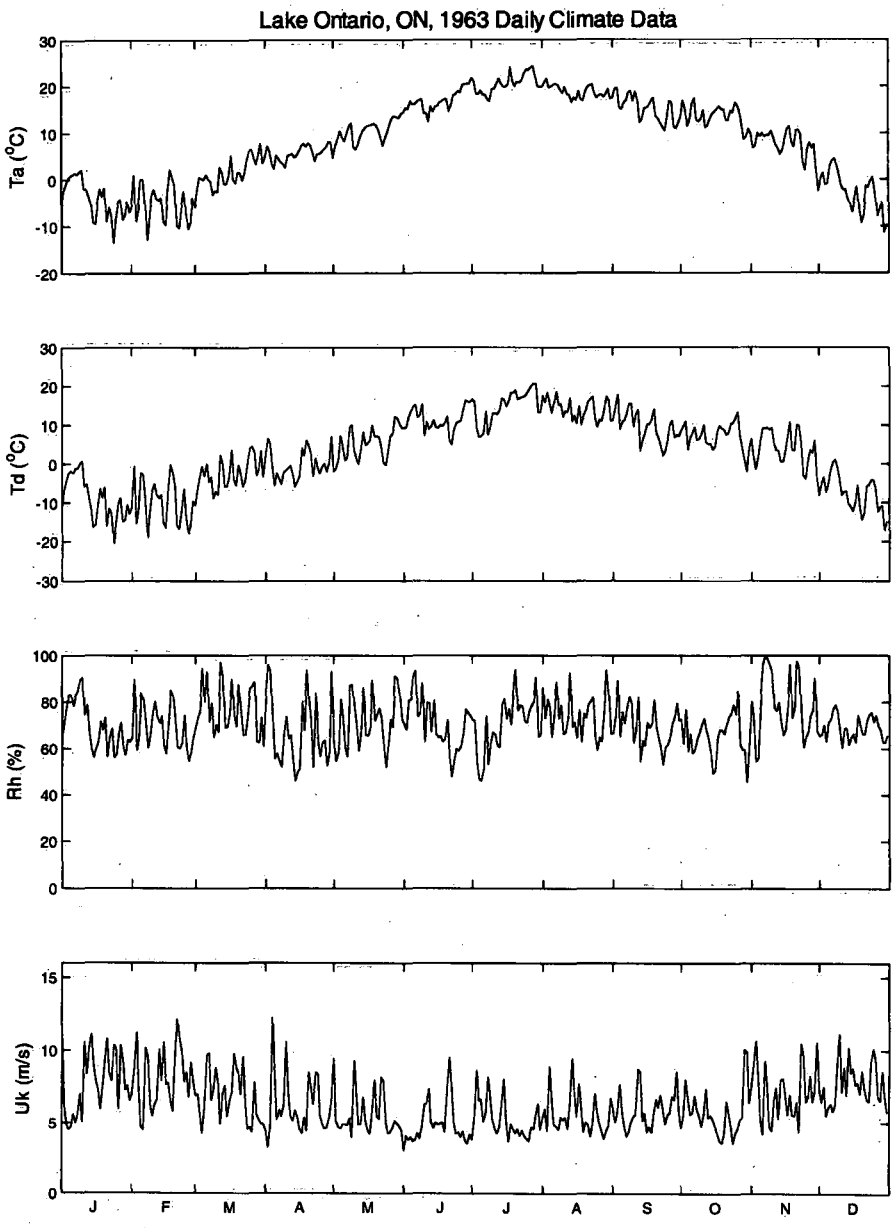
Lake Ontario, ON, 1963 Daily Climate Data
Ta (°C)
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Rh (%)
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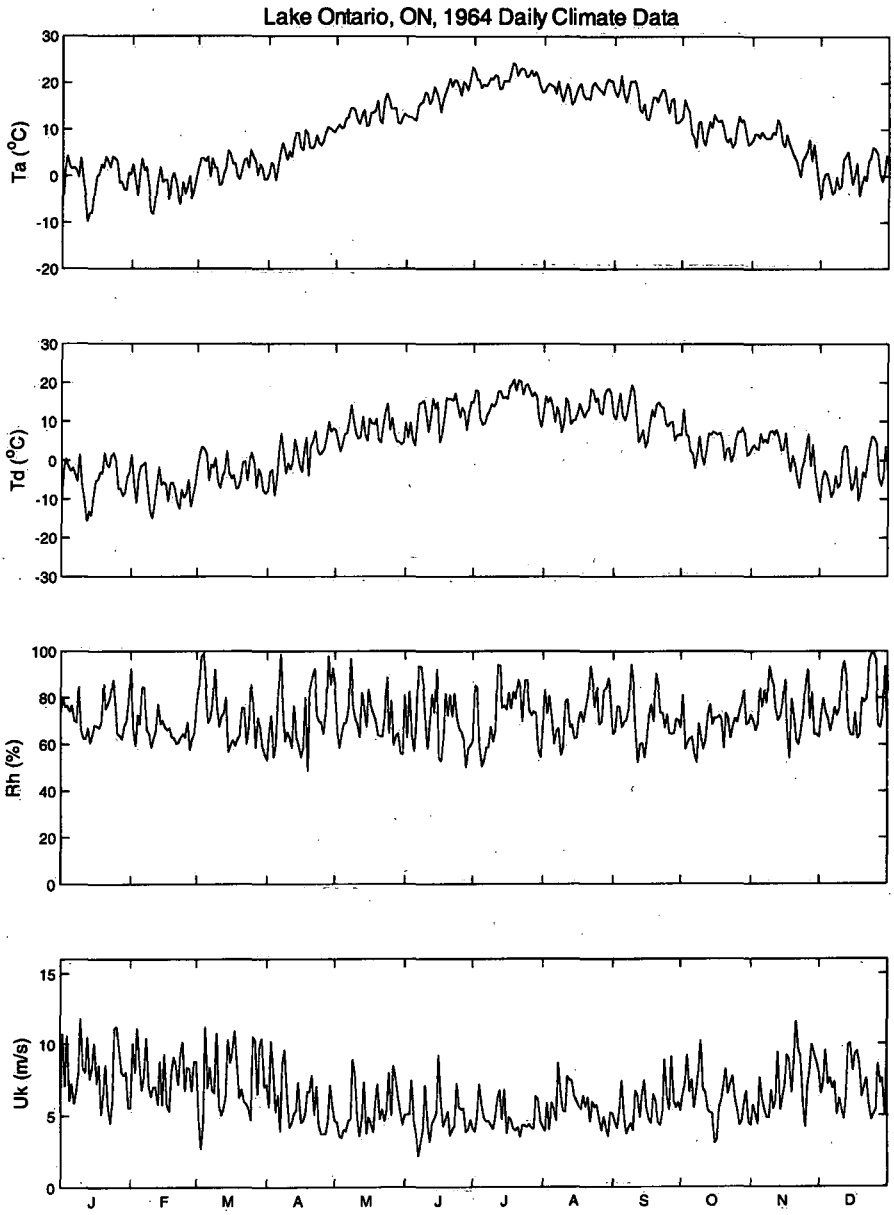
Lake Ontario, ON, 1964 Daily Climate Data
Ta (°C)
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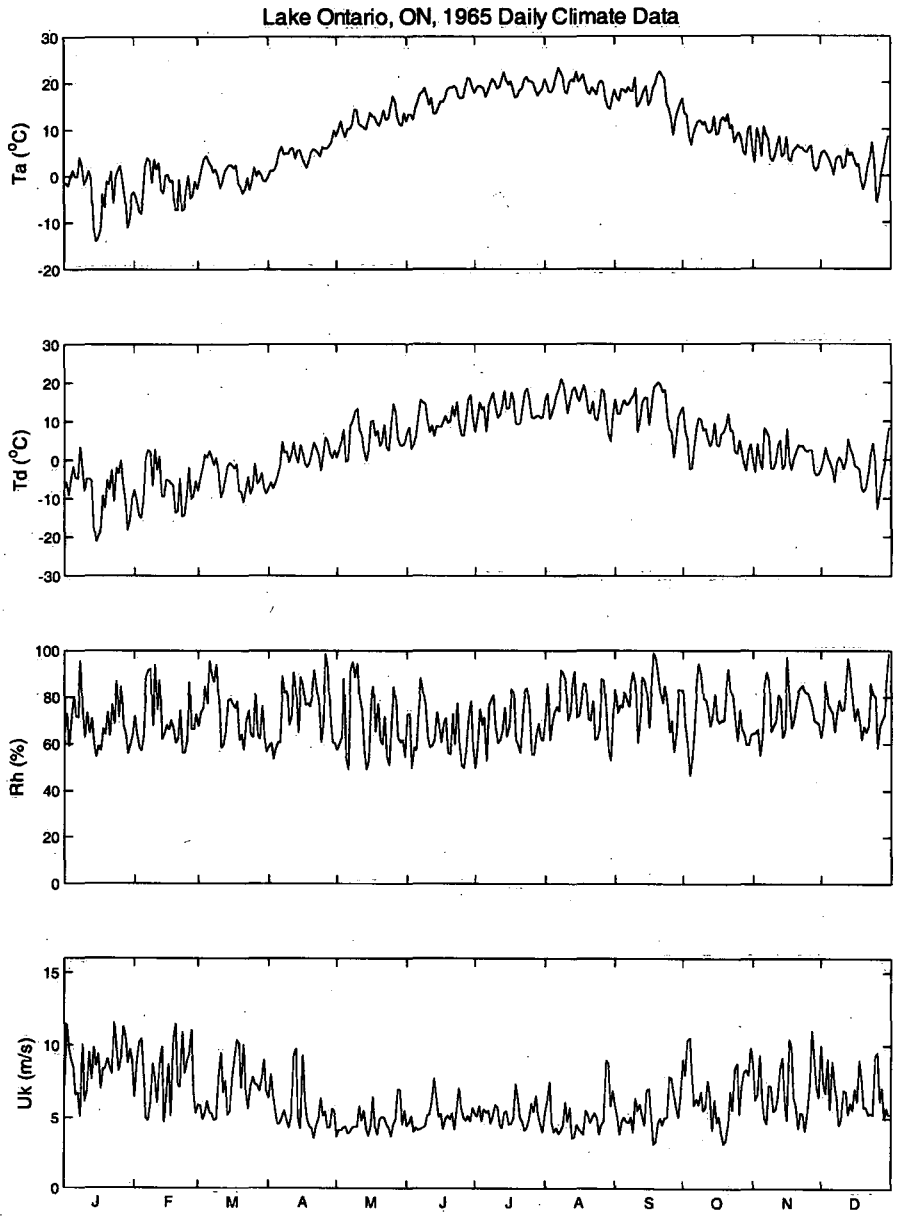
Lake Ontario, ON, 1965 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
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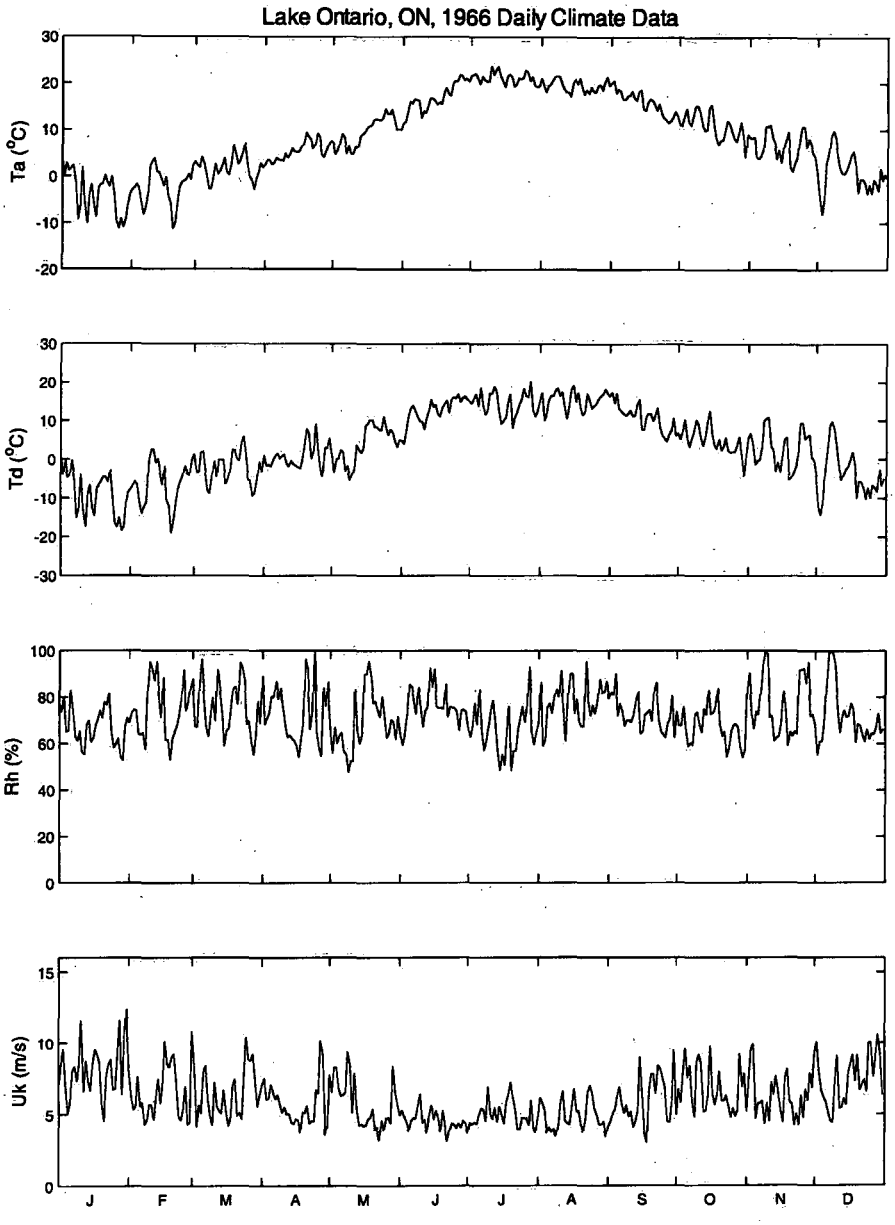
Lake Ontario, ON, 1966 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
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M
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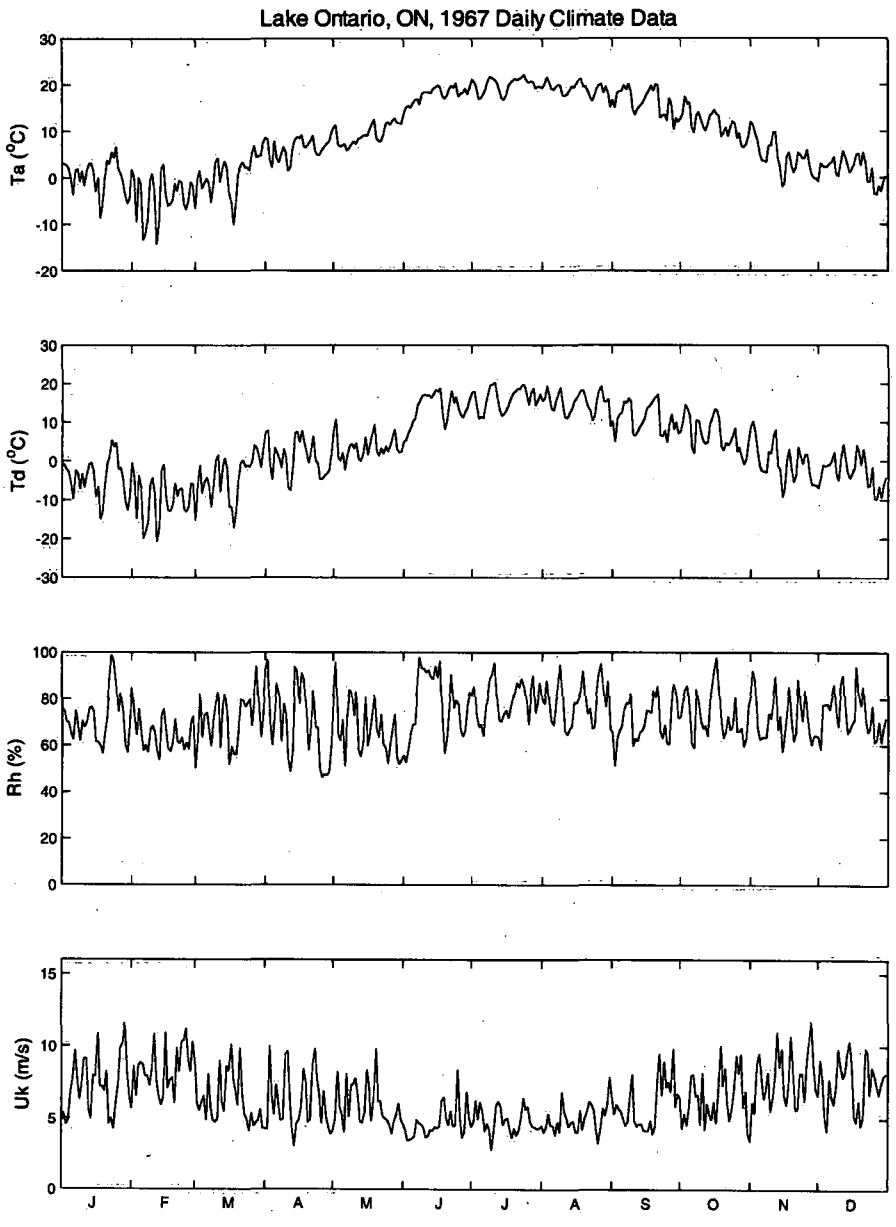
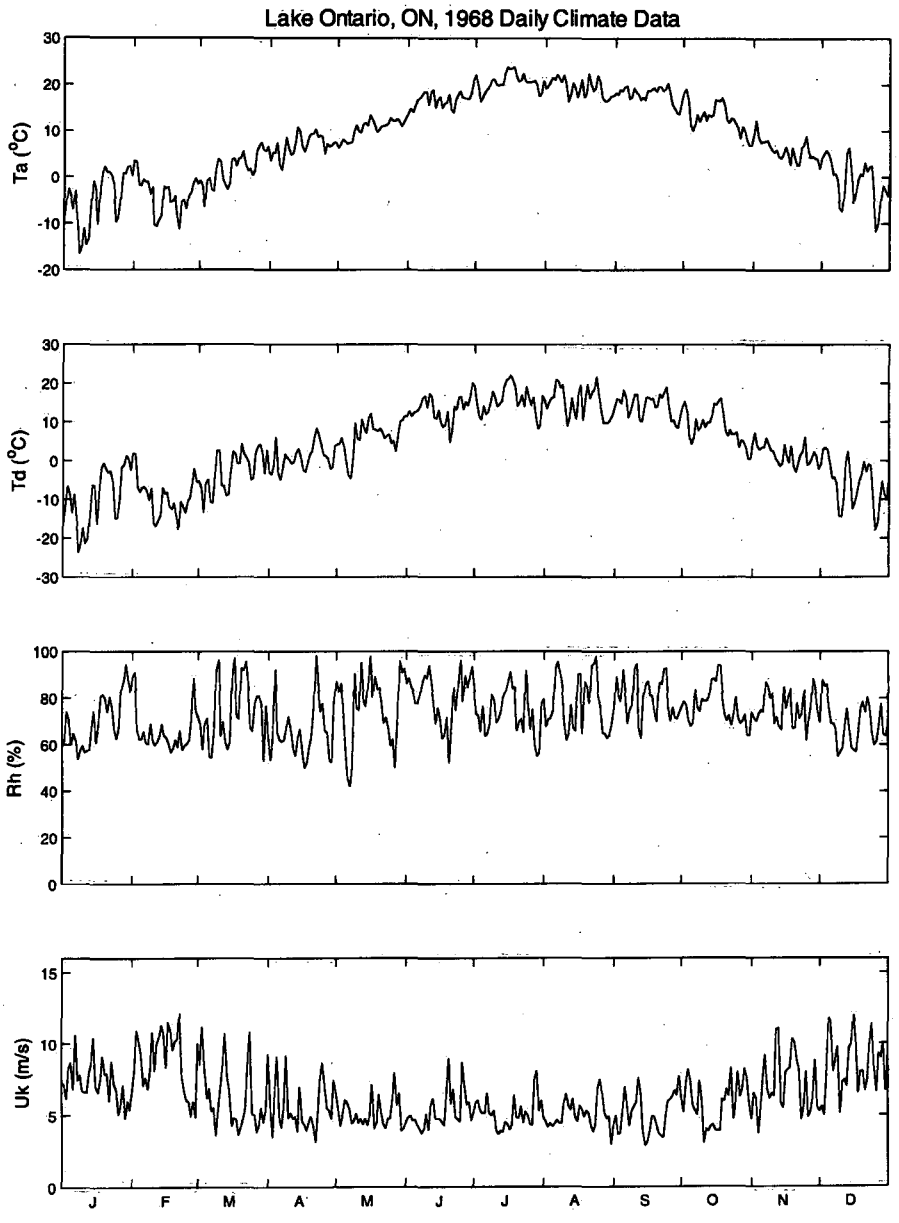

Lake Ontario, ON, 1967 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J F M A M J J A S O N D


Lake Ontario, ON, 1968 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
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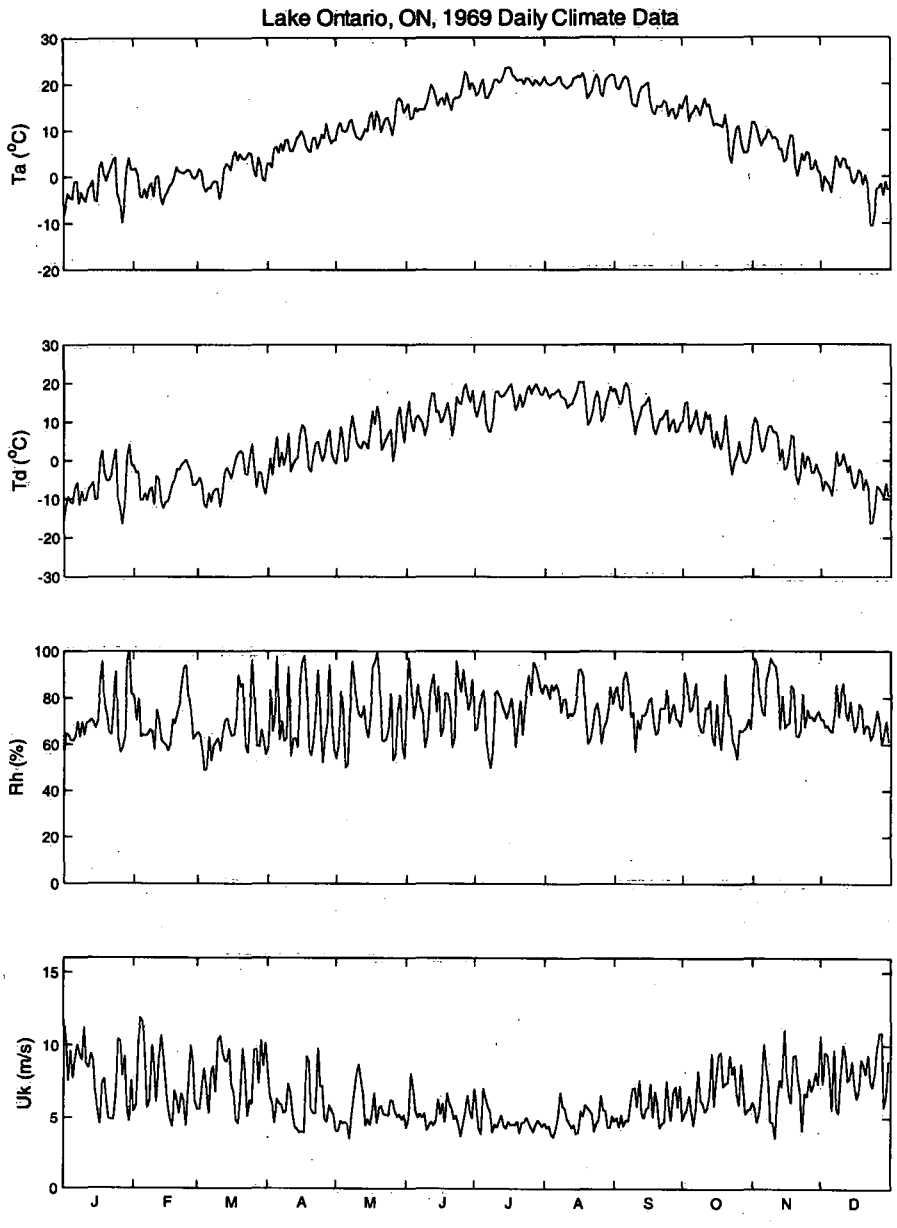
Lake Ontario, ON, 1969 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
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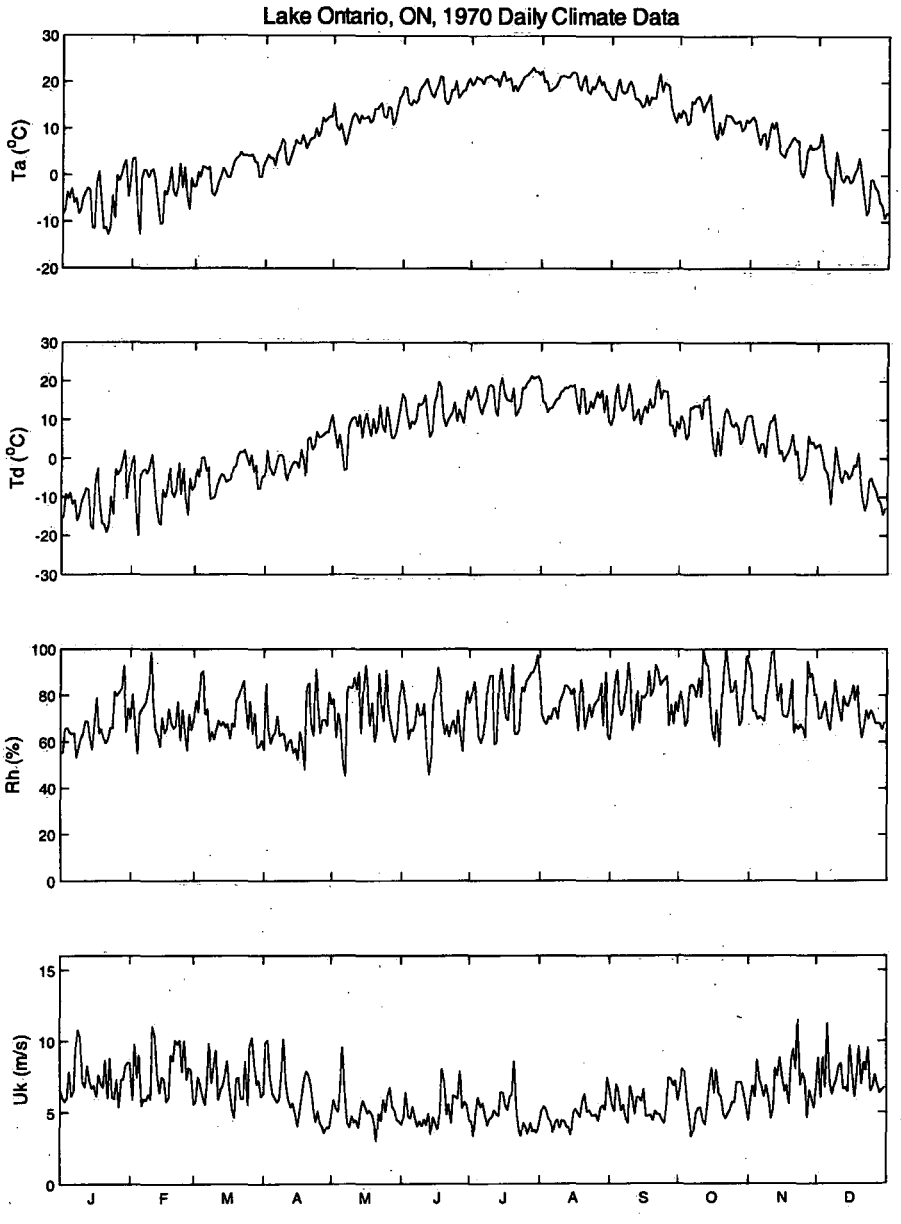
N
D


Lake Ontario, ON, 1970 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
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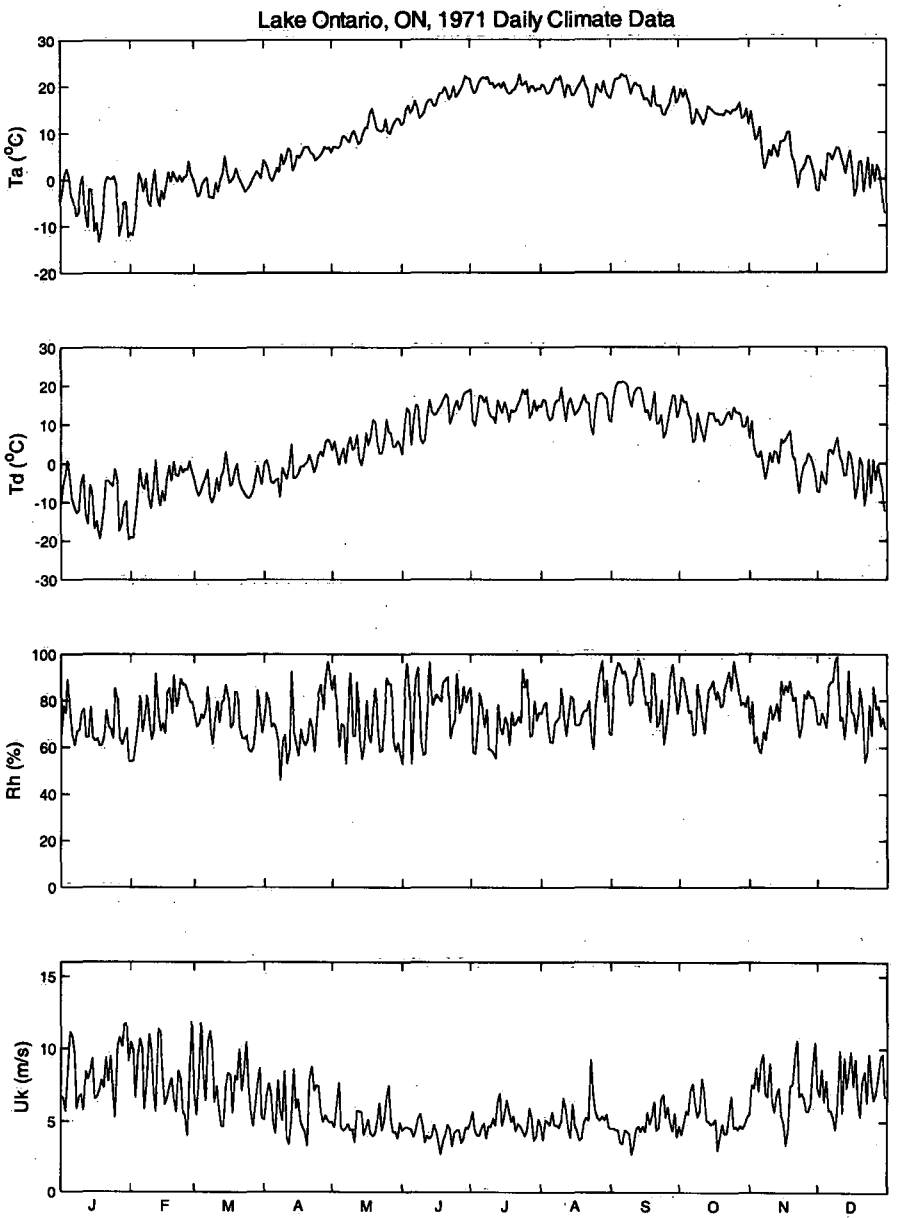
Lake Ontario, ON, 1971 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
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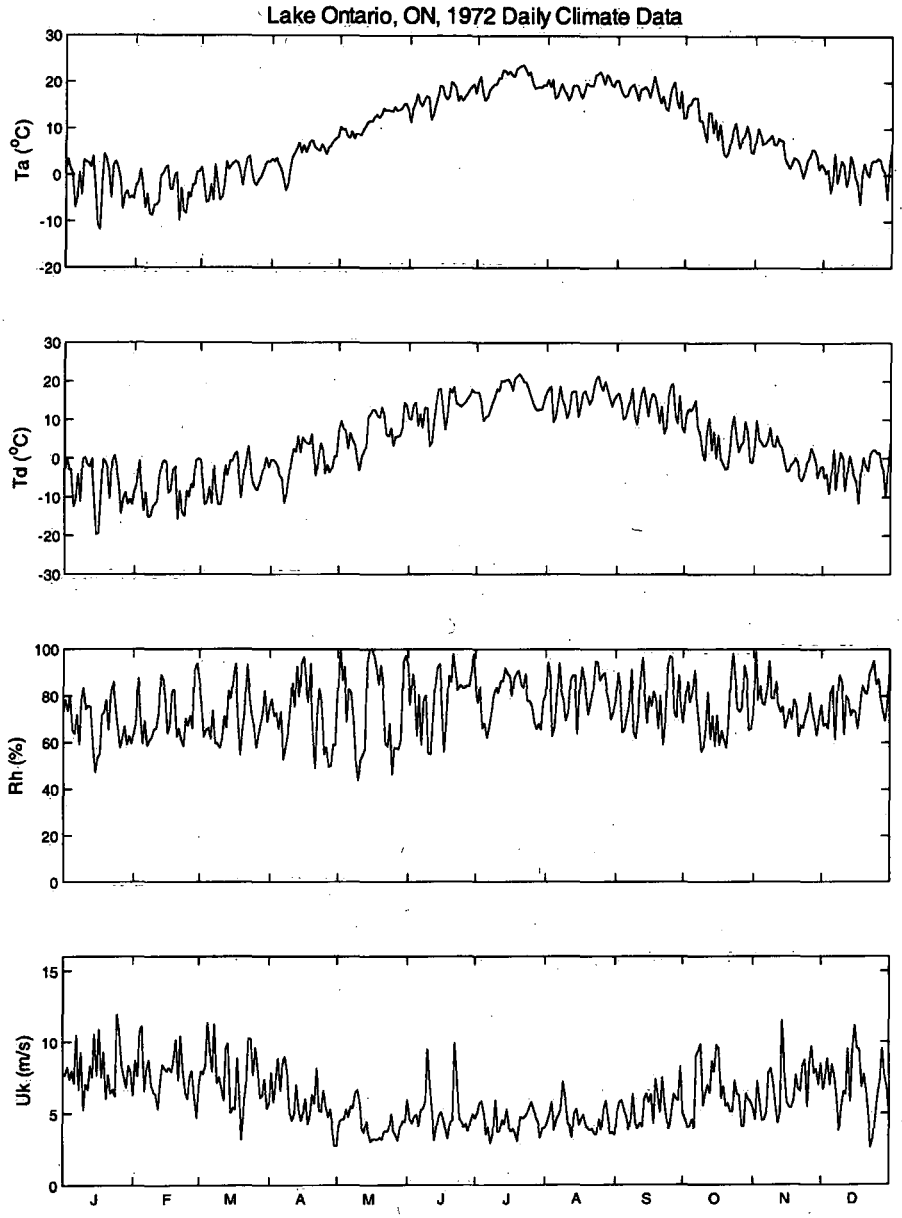
D


Lake Ontario, ON, 1972 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
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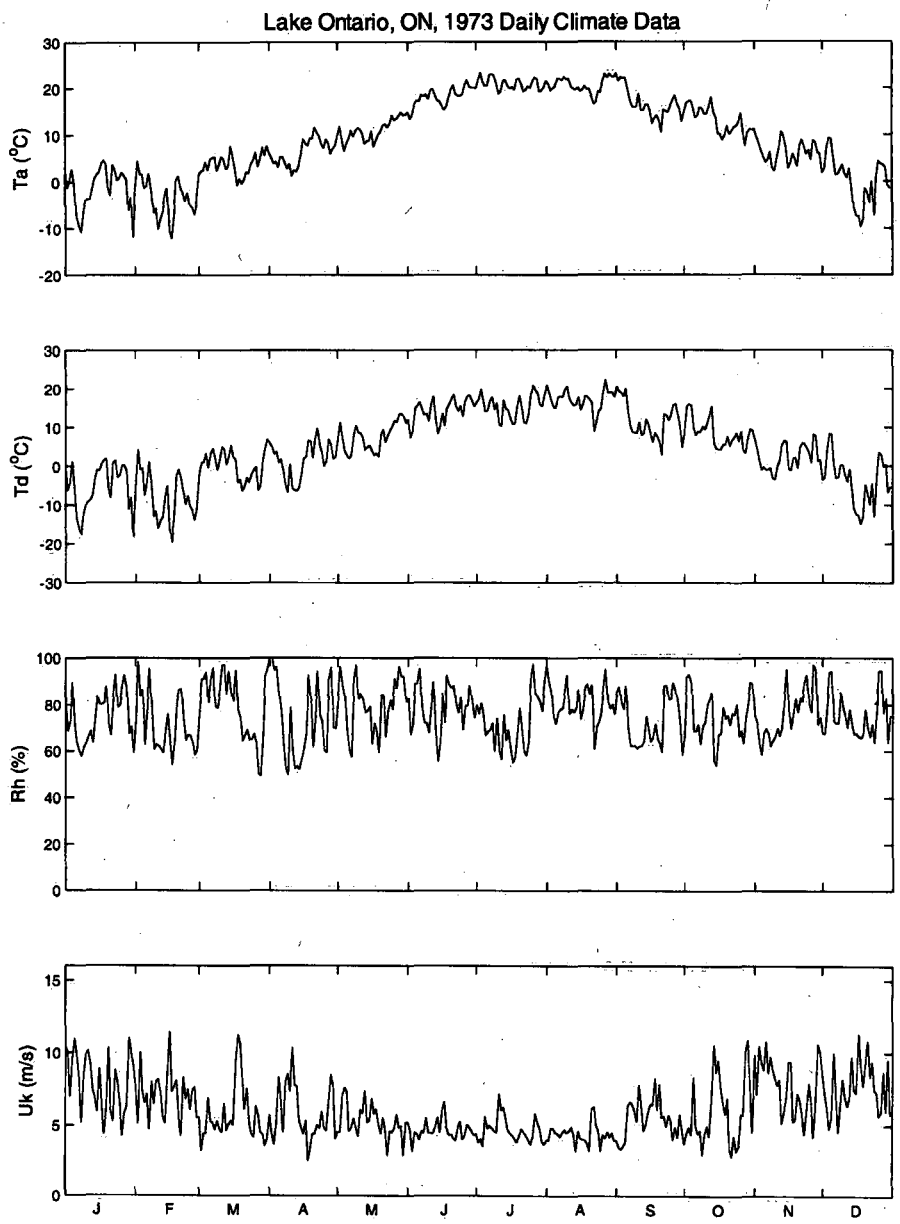
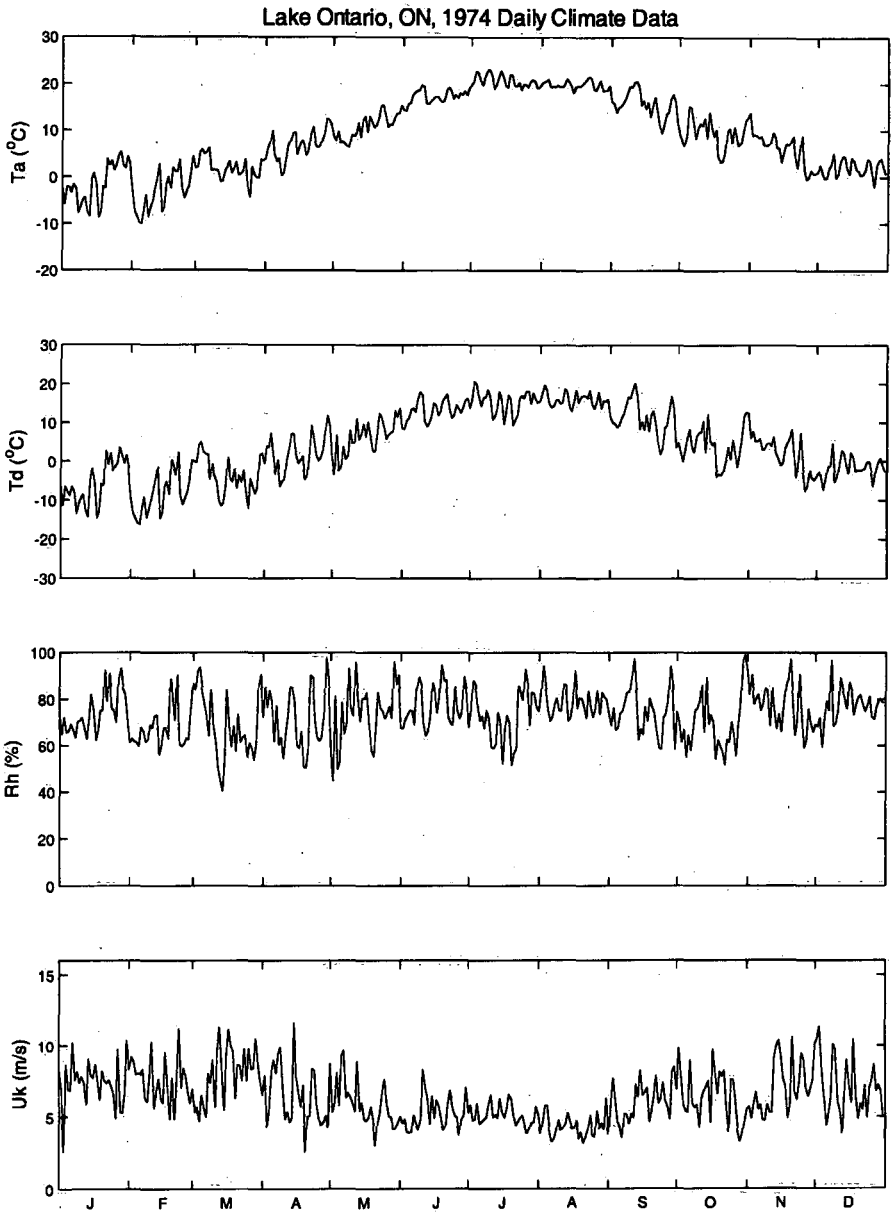

Lake Ontario, ON, 1973 Daily Climate Data
Ta (°C)
30
20
10
0
-10
-20
Td (°C)
30
20
10
0
-10
-20
-30
Rh (%)
100
80
60
40
20
0
Uk (m/s)
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D


Lake Ontario, ON, 1974 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
F
M
A
M
J
J
A
S
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N
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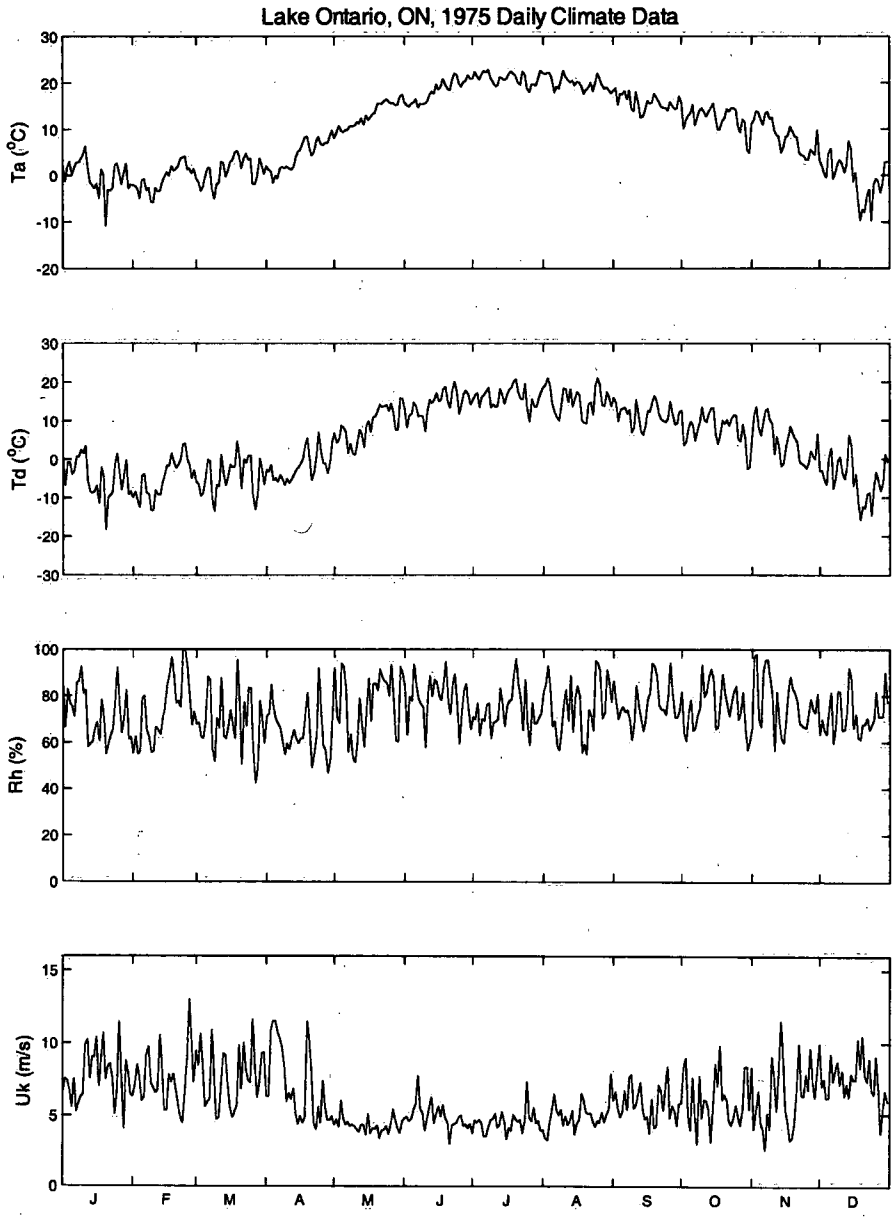
Lake Ontario, ON, 1975 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
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M
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A
S
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N
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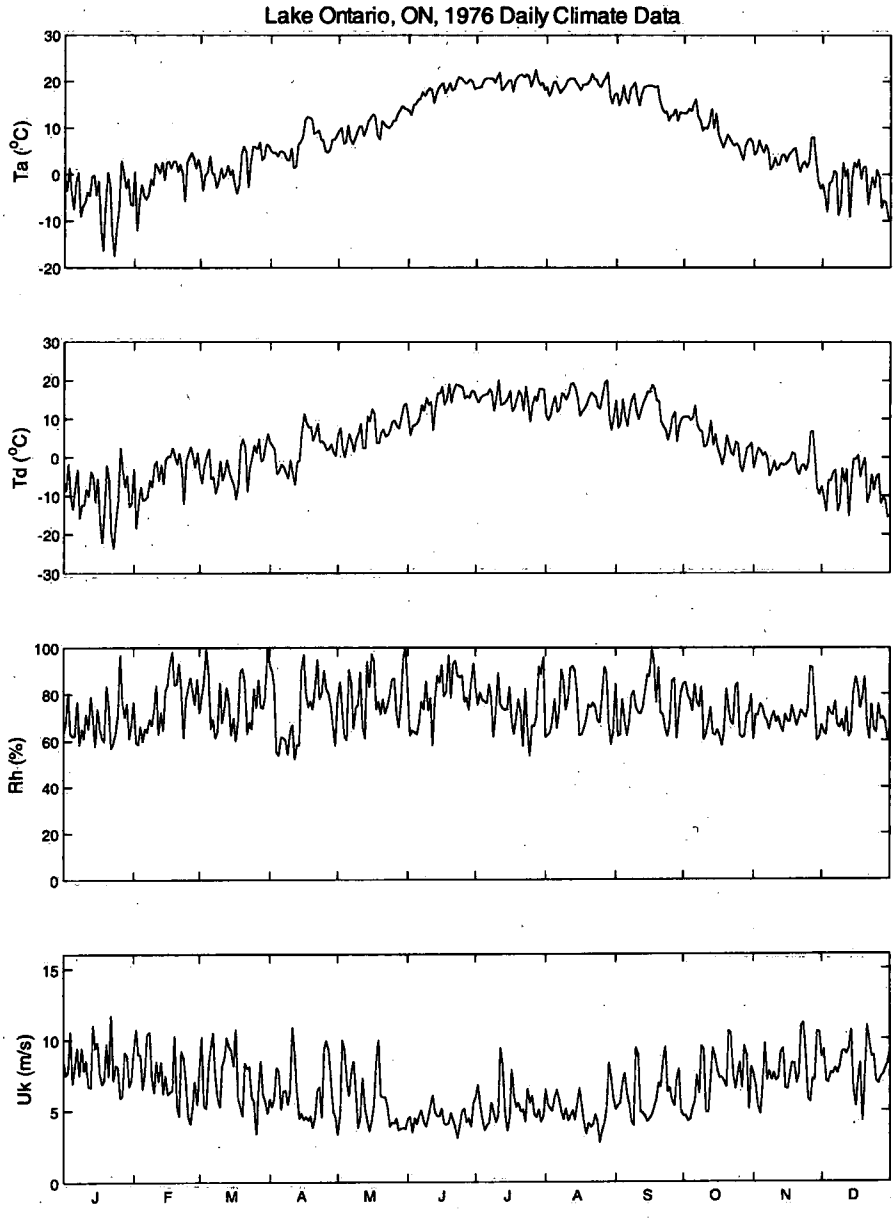
Lake Ontario, ON, 1976 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
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J
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S
O
N
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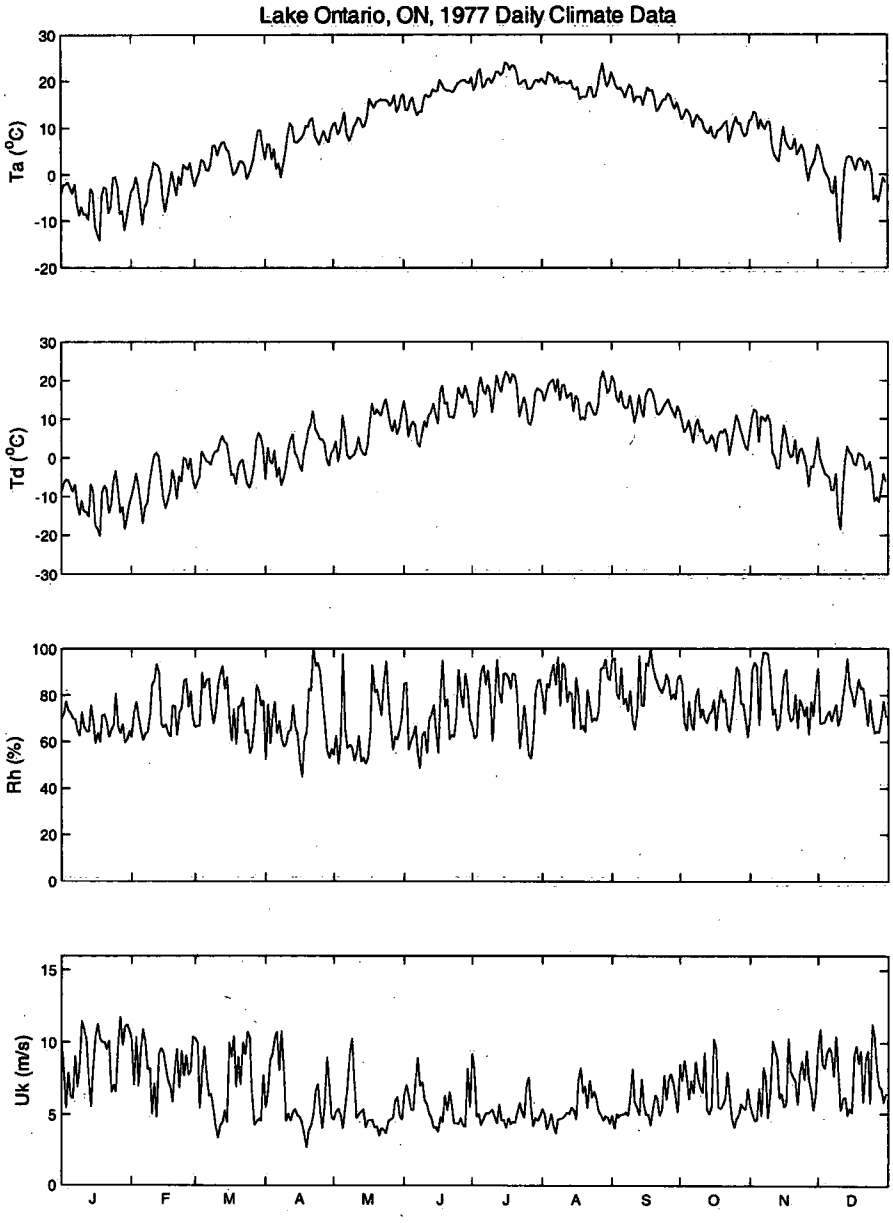
Lake Ontario, ON, 1977 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
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A
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N
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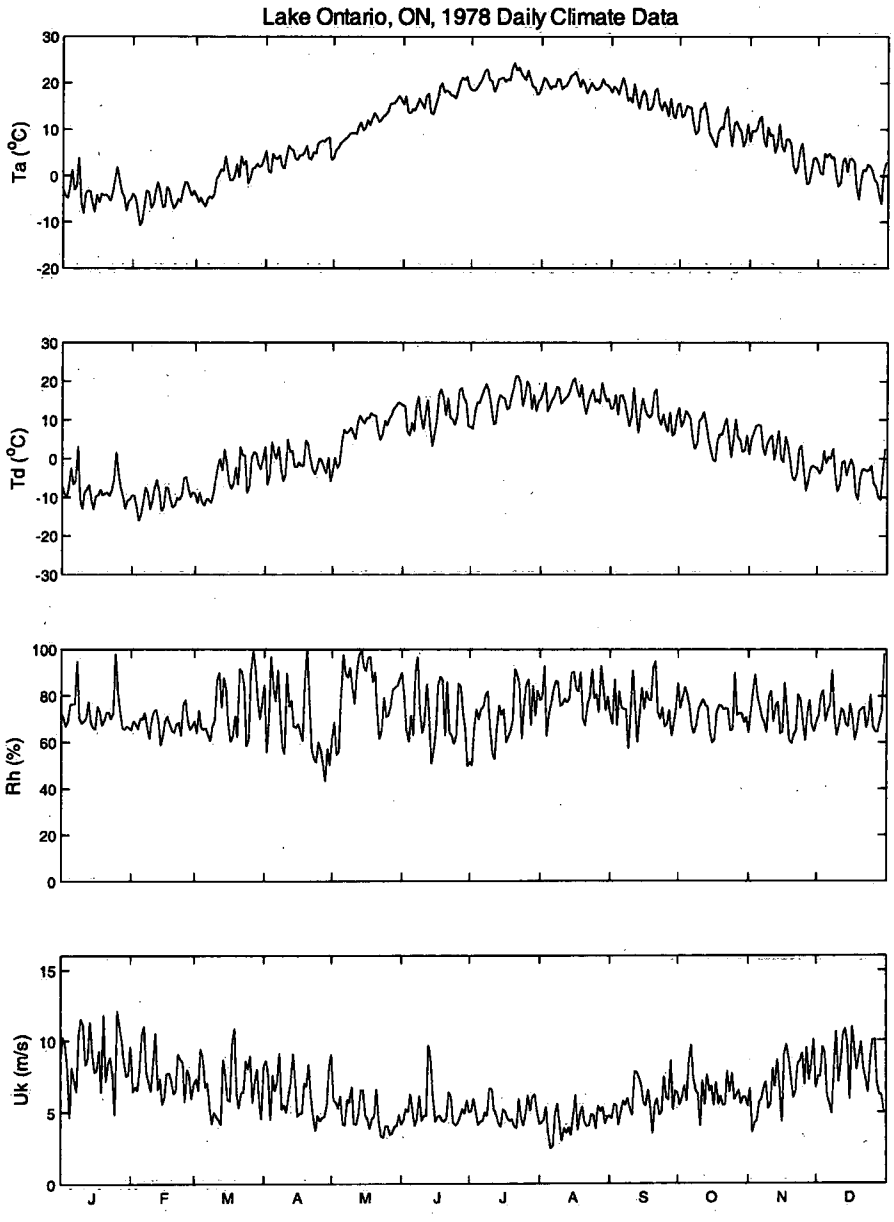
Lake Ontario, ON, 1978 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
F
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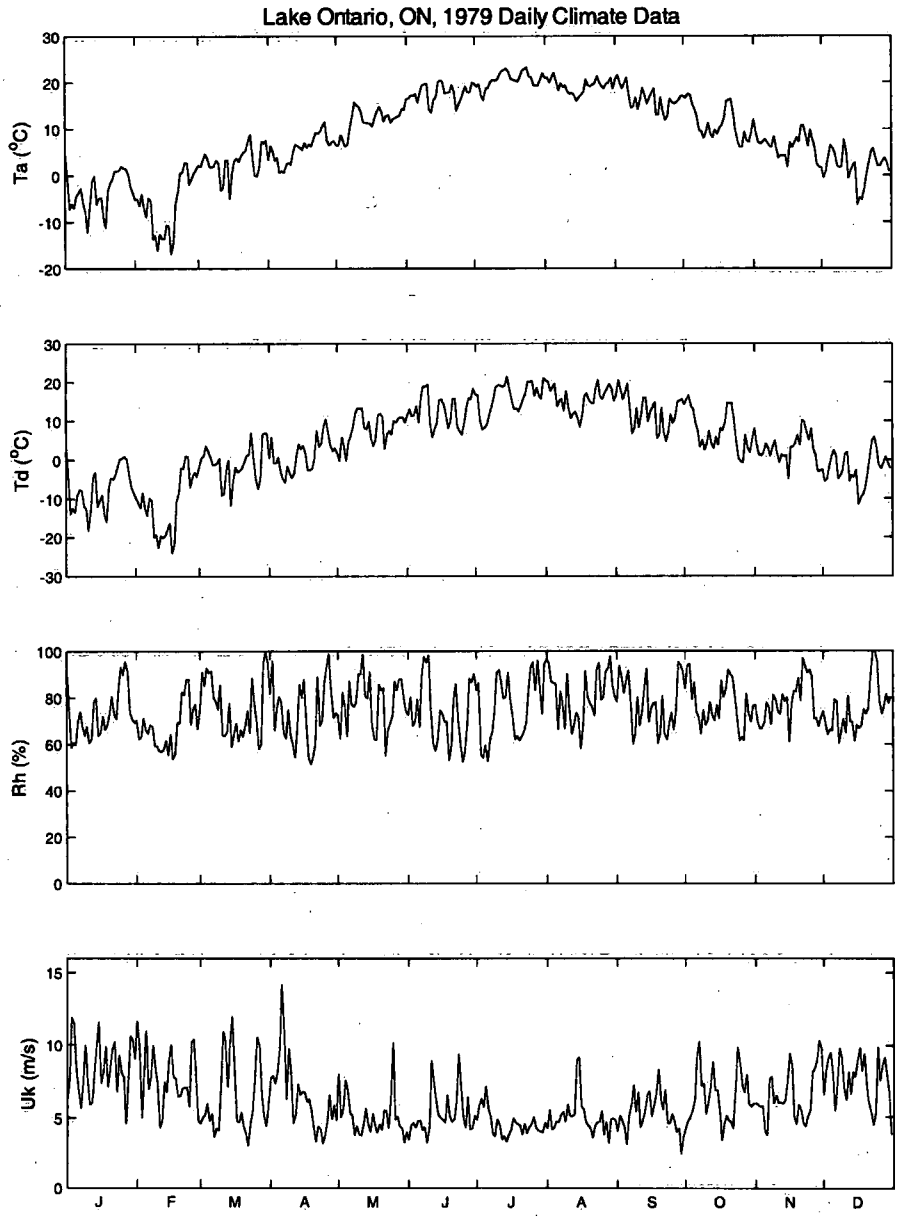
Lake Ontario, ON, 1979 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
F
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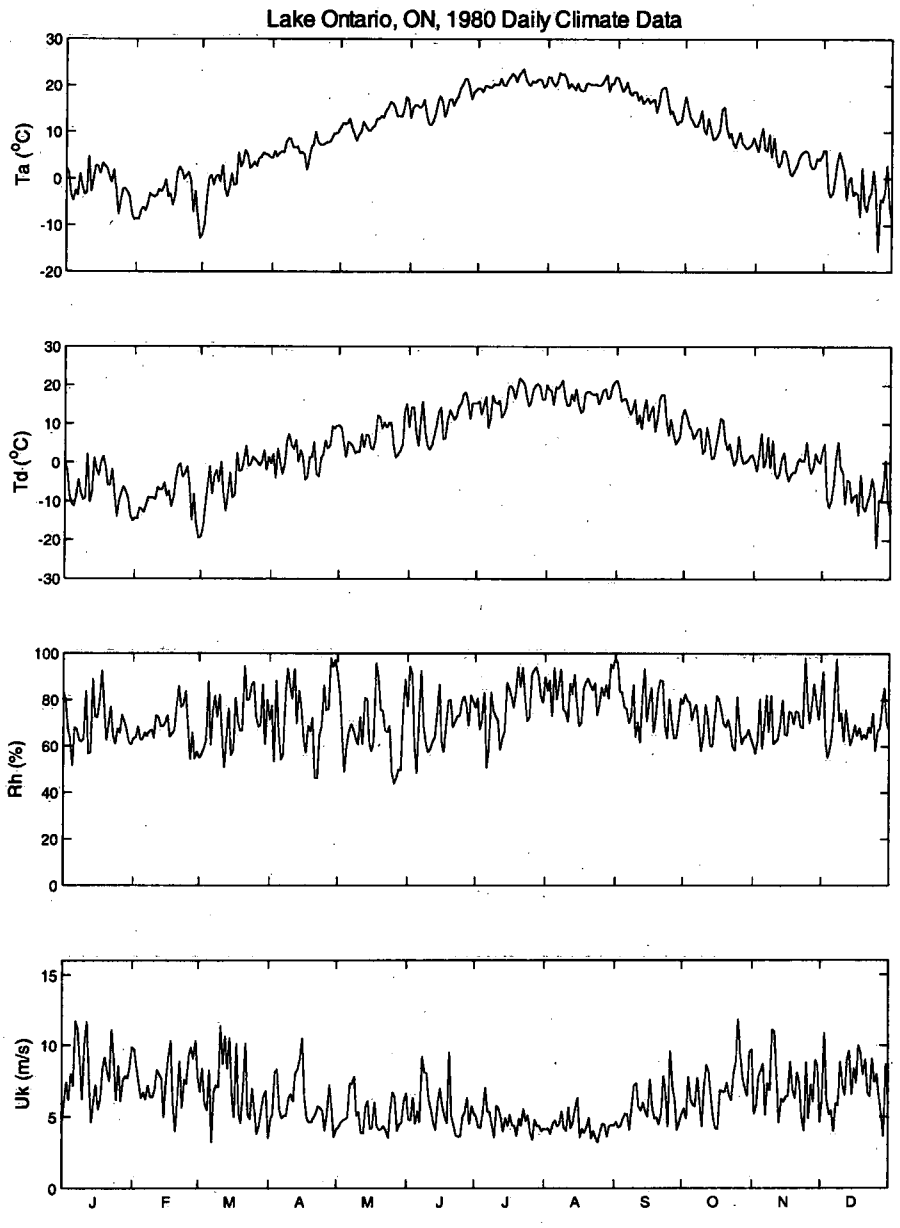
Lake Ontario, ON, 1980 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
F
M
A
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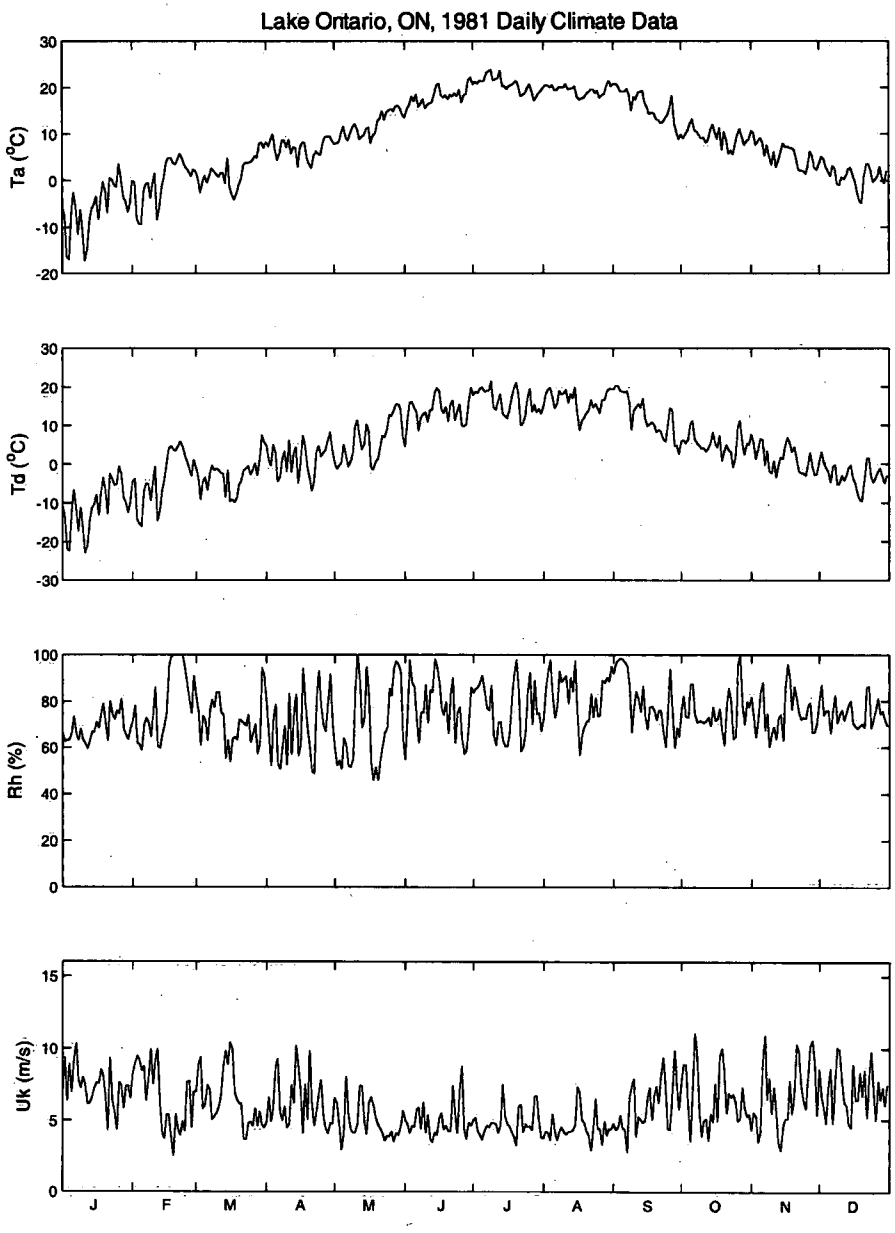
Lake Ontario, ON, 1981 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
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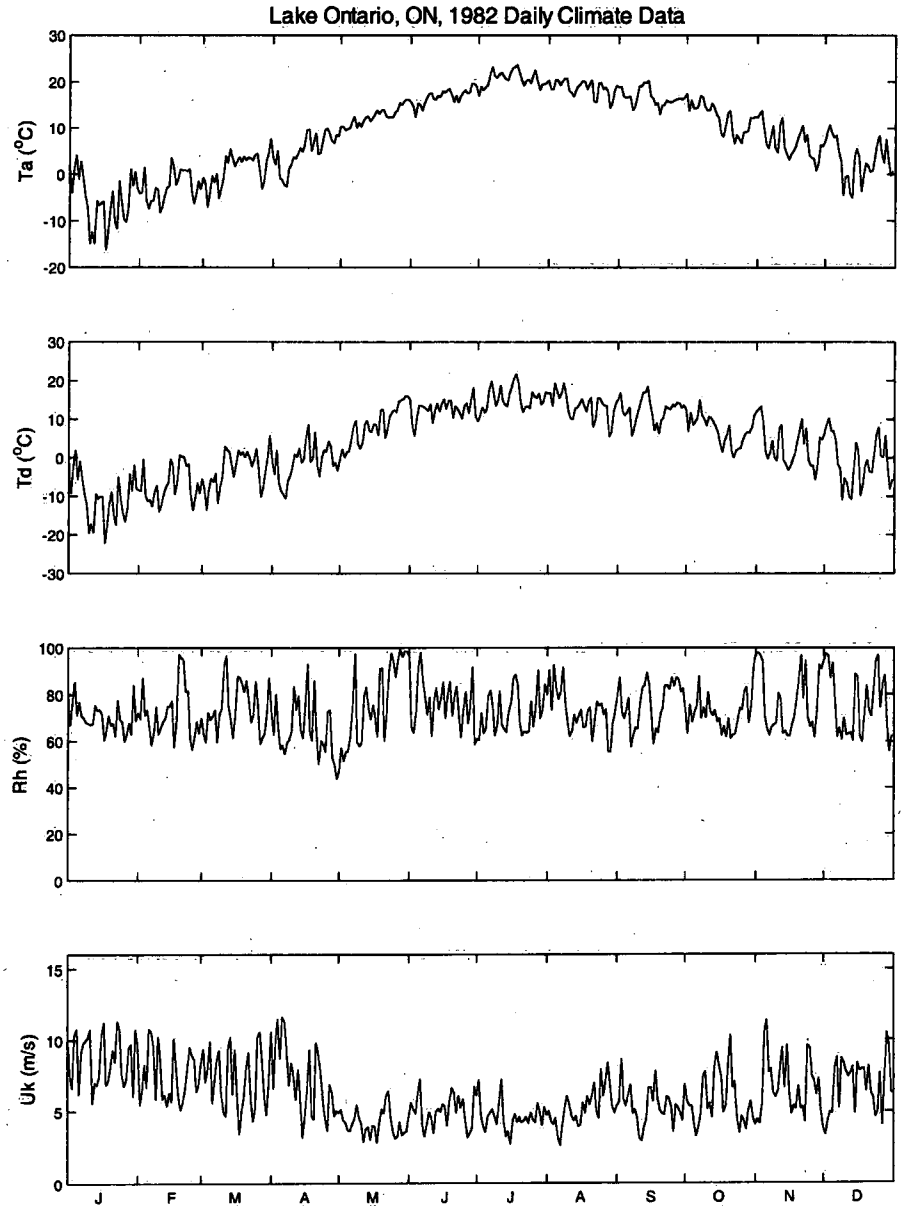
Lake Ontario, ON, 1982 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Ük (m/s)
J
F
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A
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A
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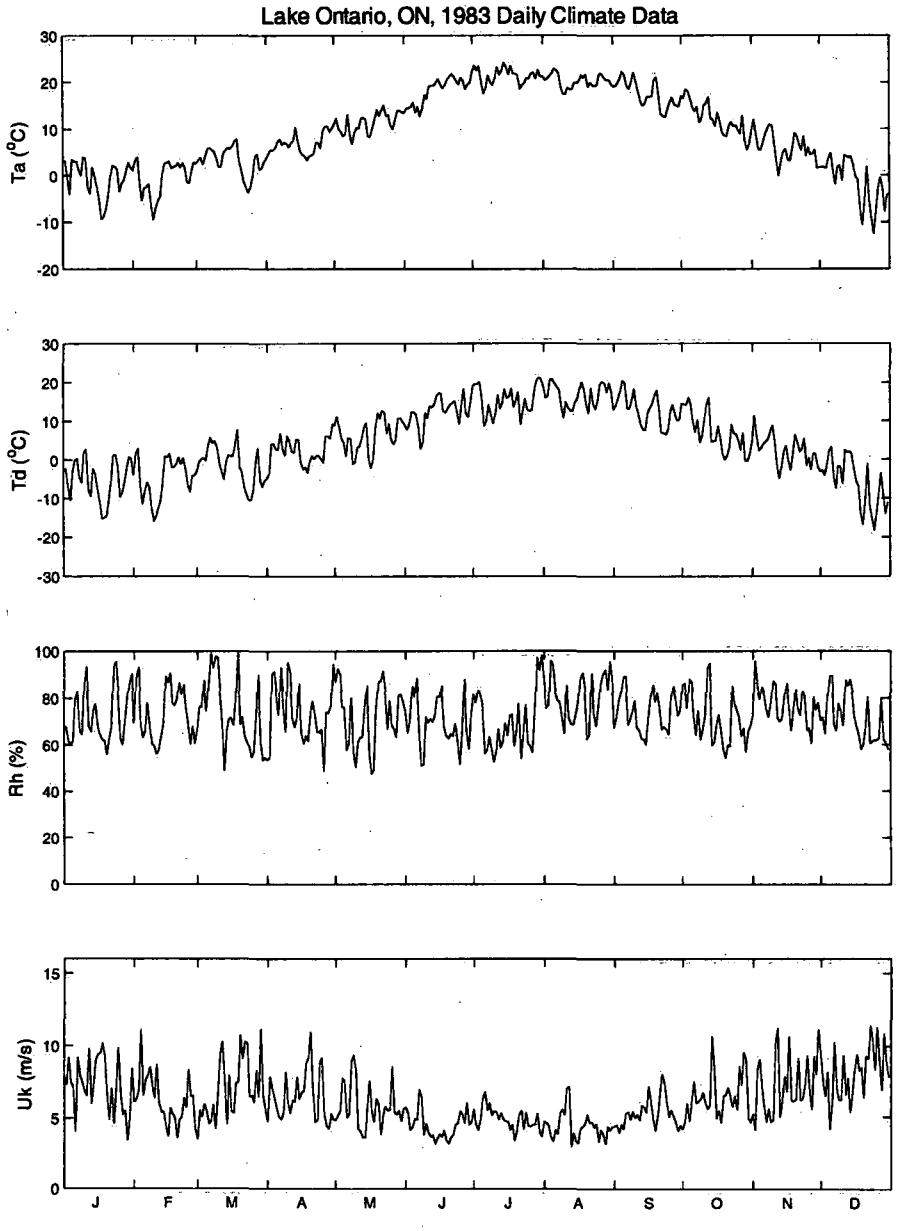
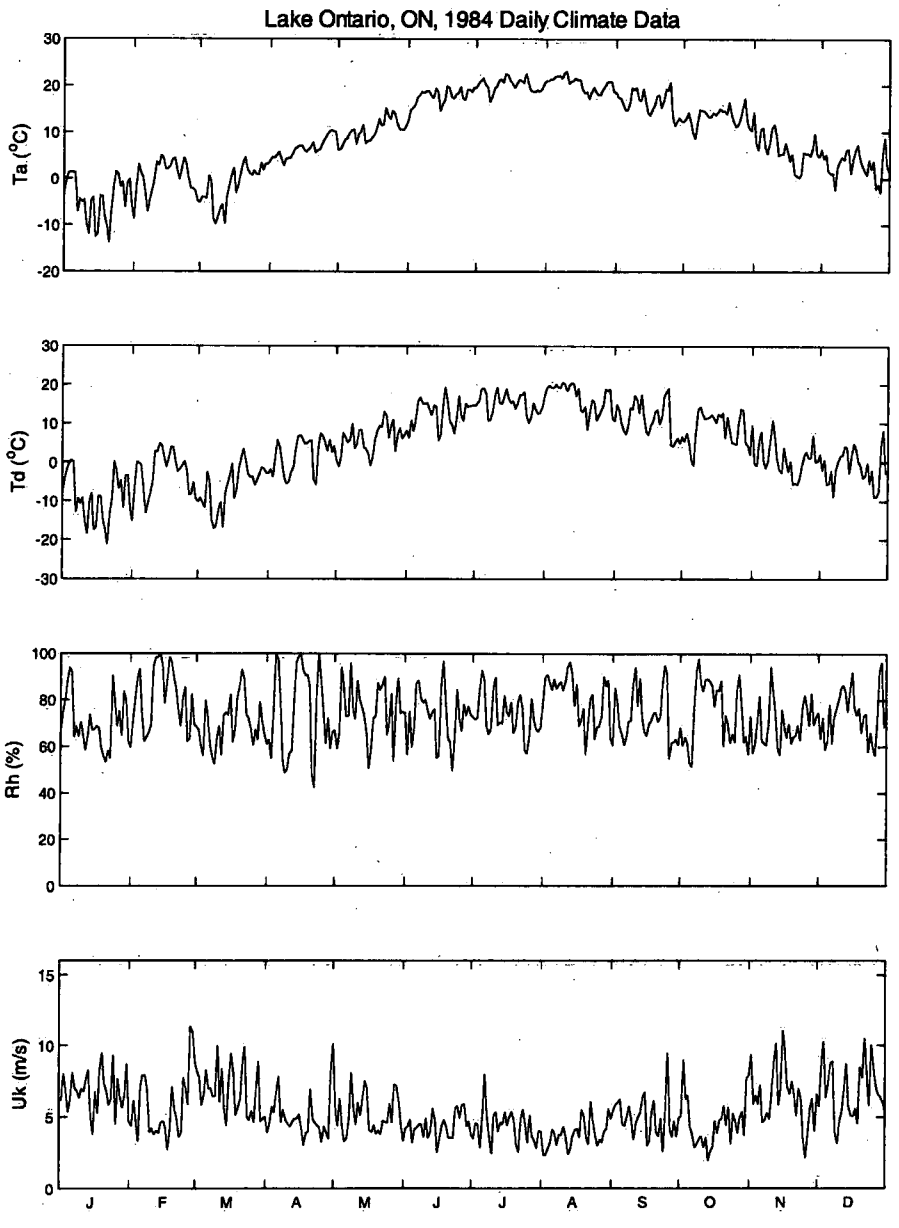
N
D


Lake Ontario, ON, 1983 Daily Climate Data
Ta (°C)
30
20
10
0
-10
-20
Td (°C)
30
20
10
0
-10
-20
-30
Rh (%)
100
80
60
40
20
0
Uk (m/s)
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D


Lake Ontario, ON, 1984 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
F
M
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J
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S
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N
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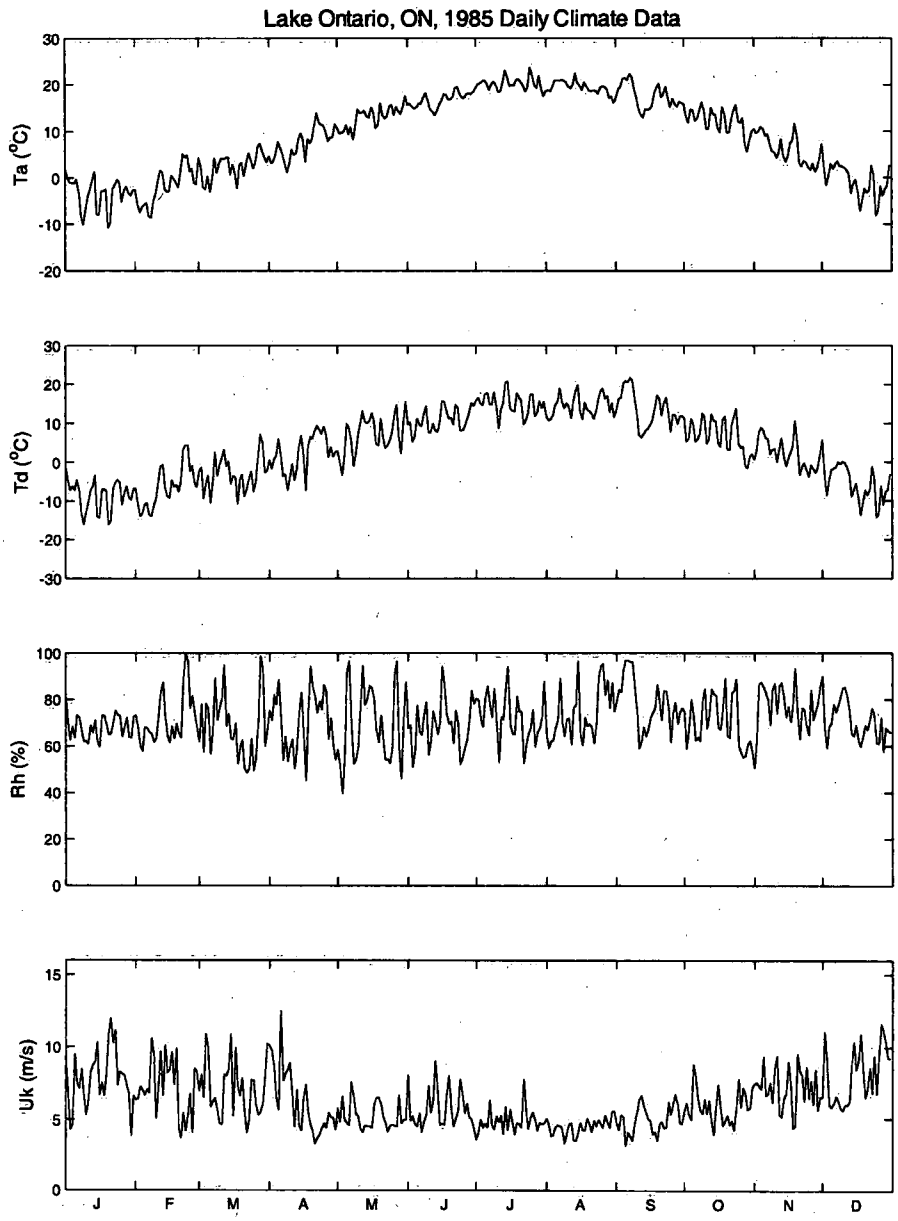
Lake Ontario, ON, 1985 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
F
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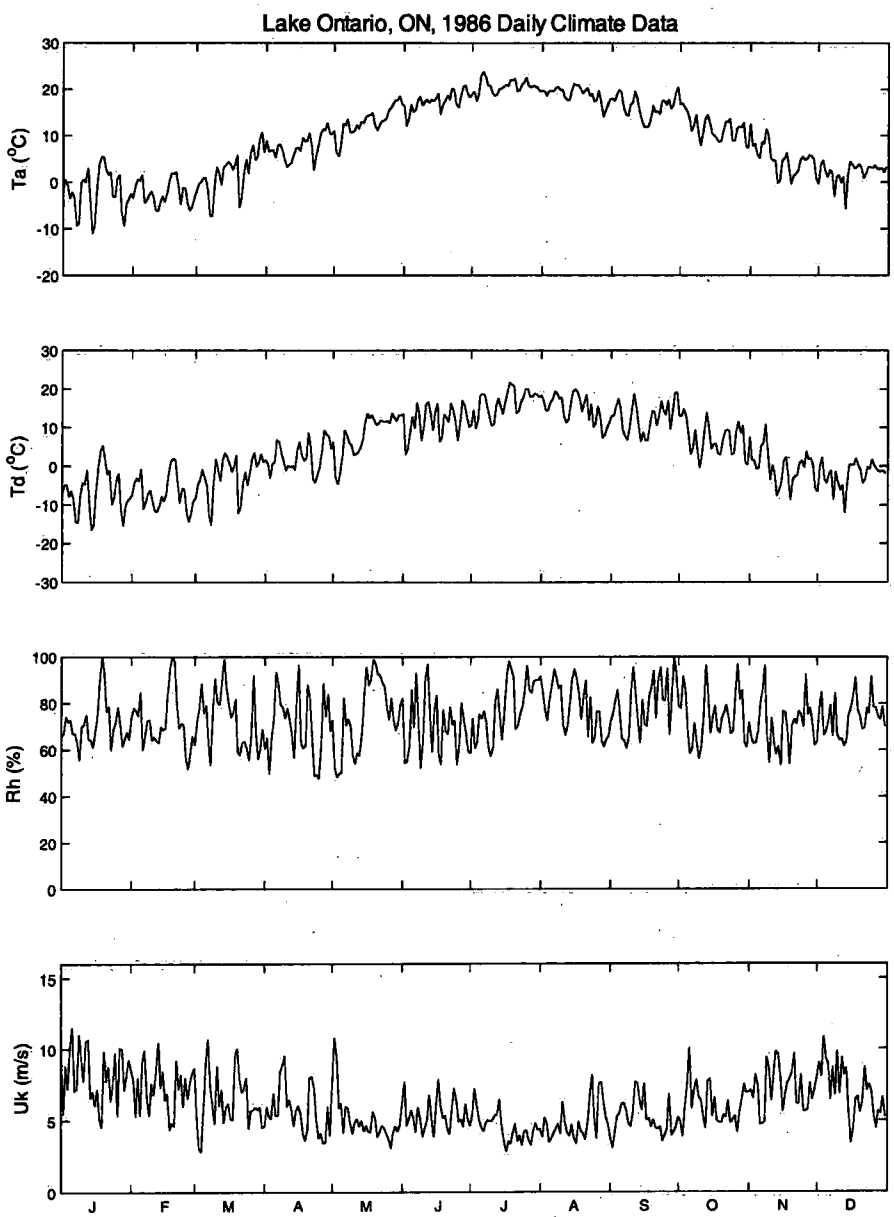
Lake Ontario, ON, 1986 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
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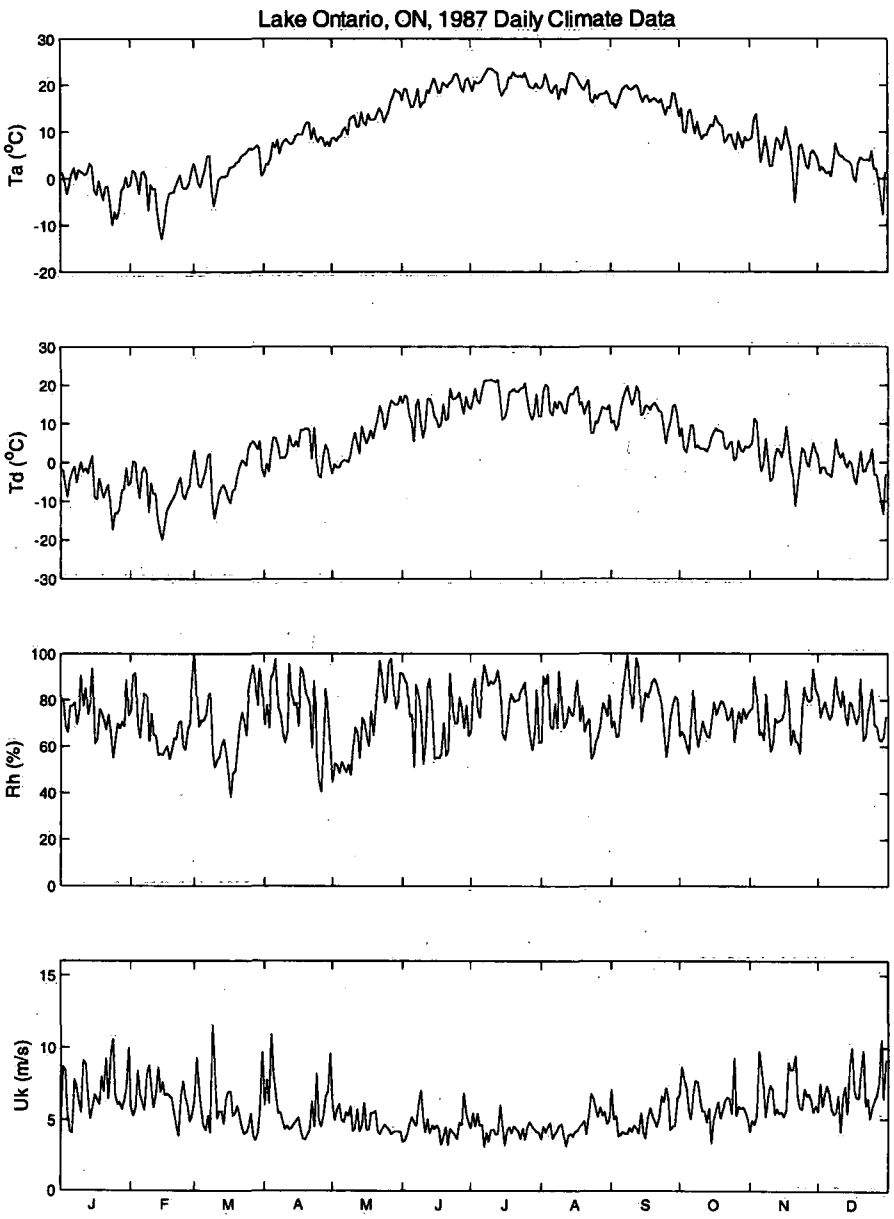
Lake Ontario, ON, 1987 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
F
M
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M
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N
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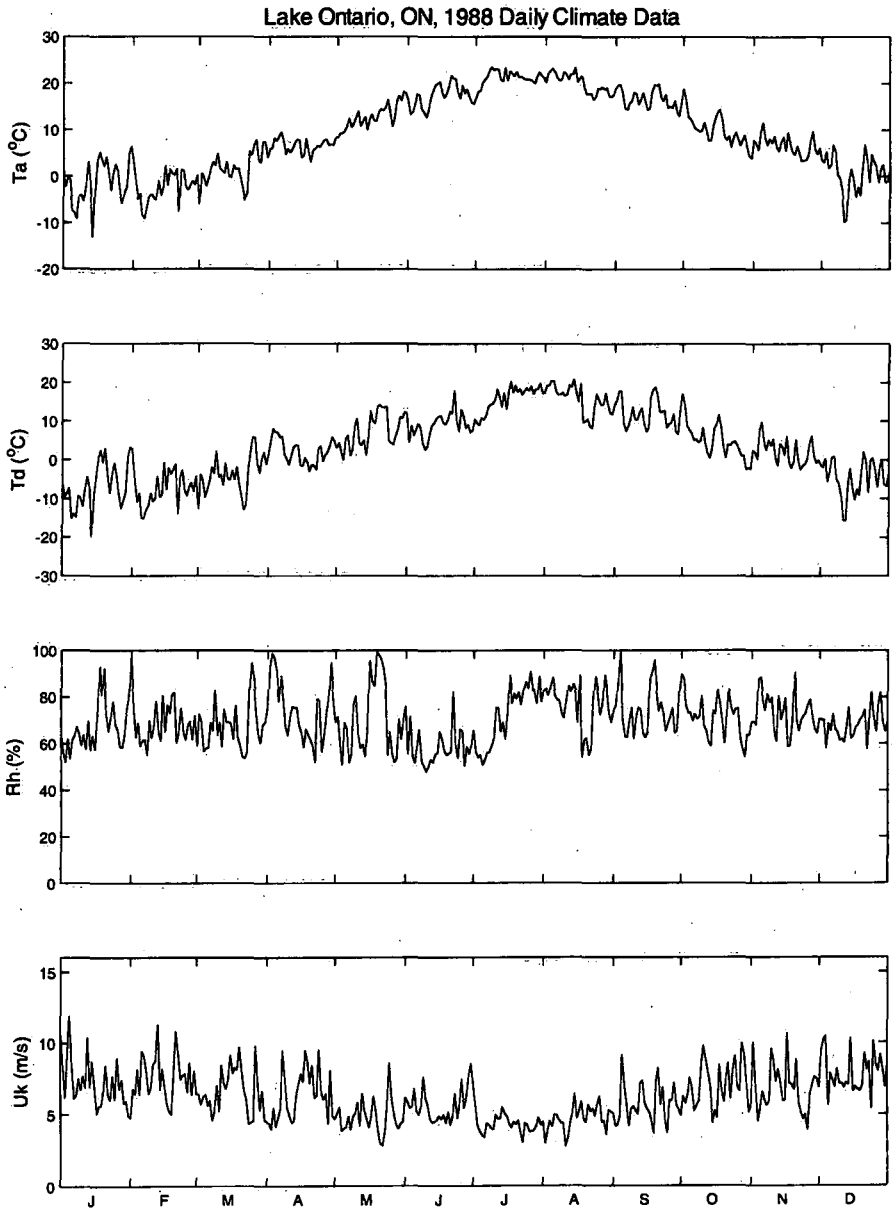
Lake Ontario, ON, 1988 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
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M
A
M
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J
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S
O
N
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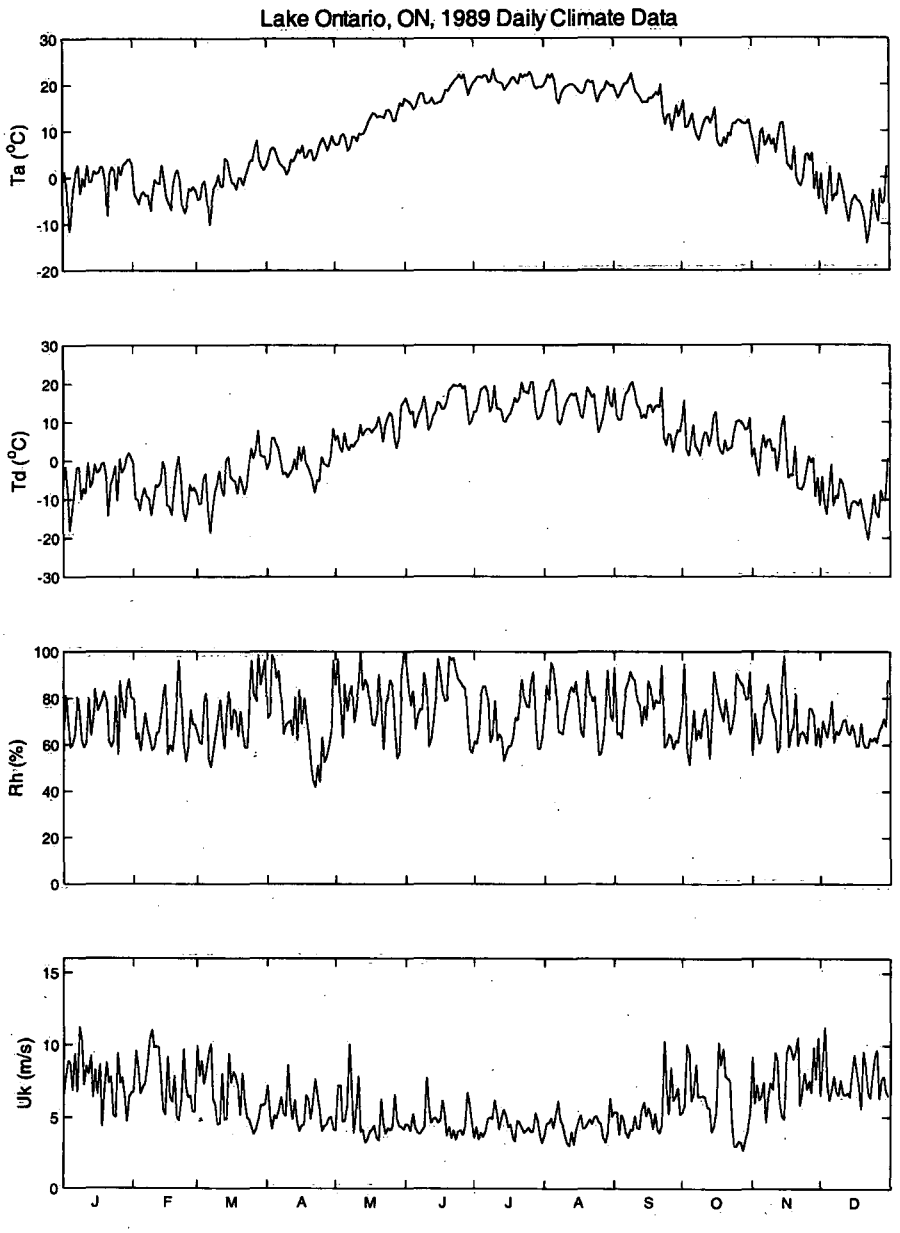
Lake Ontario, ON, 1989 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
F
M
A
M
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J
A
S
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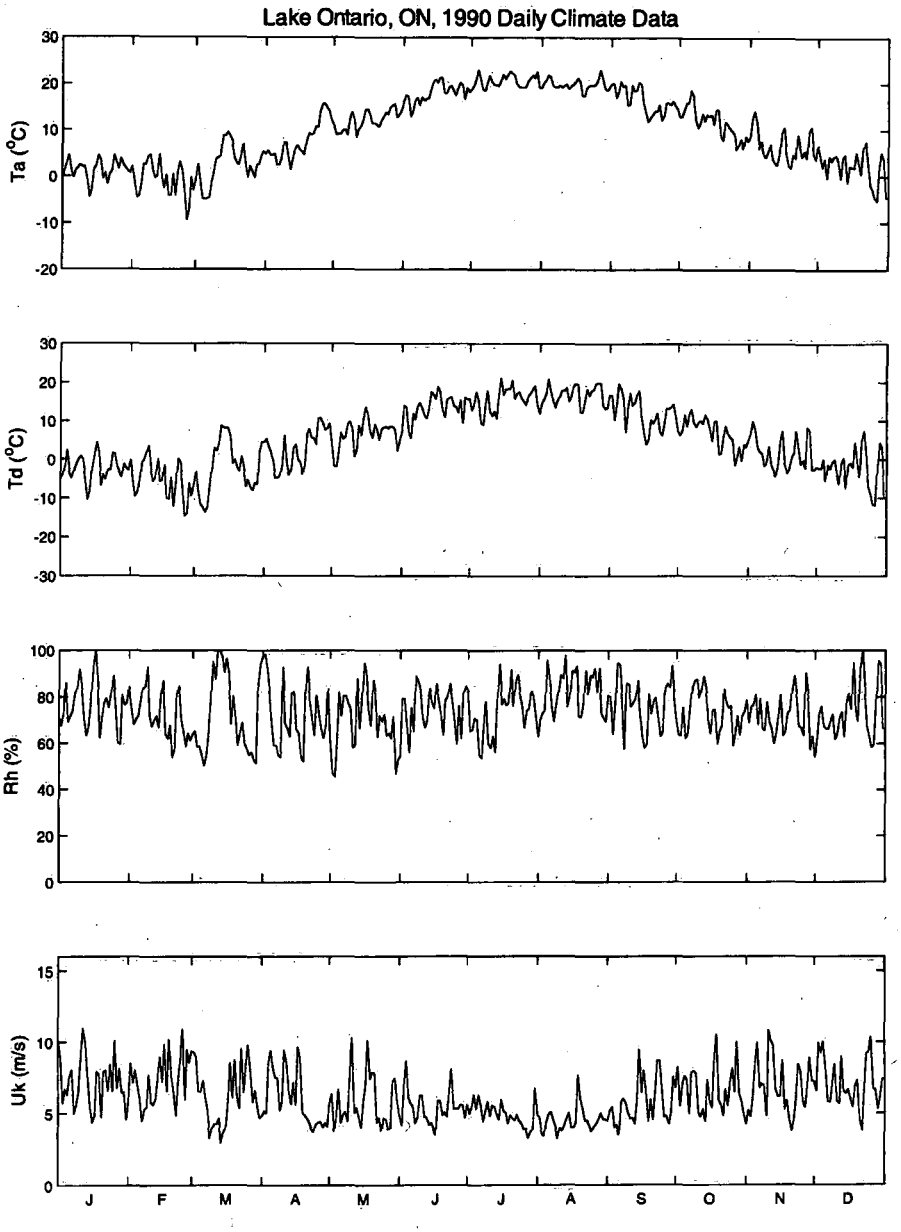
N
D


Lake Ontario, ON, 1990 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
F
M
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S
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N
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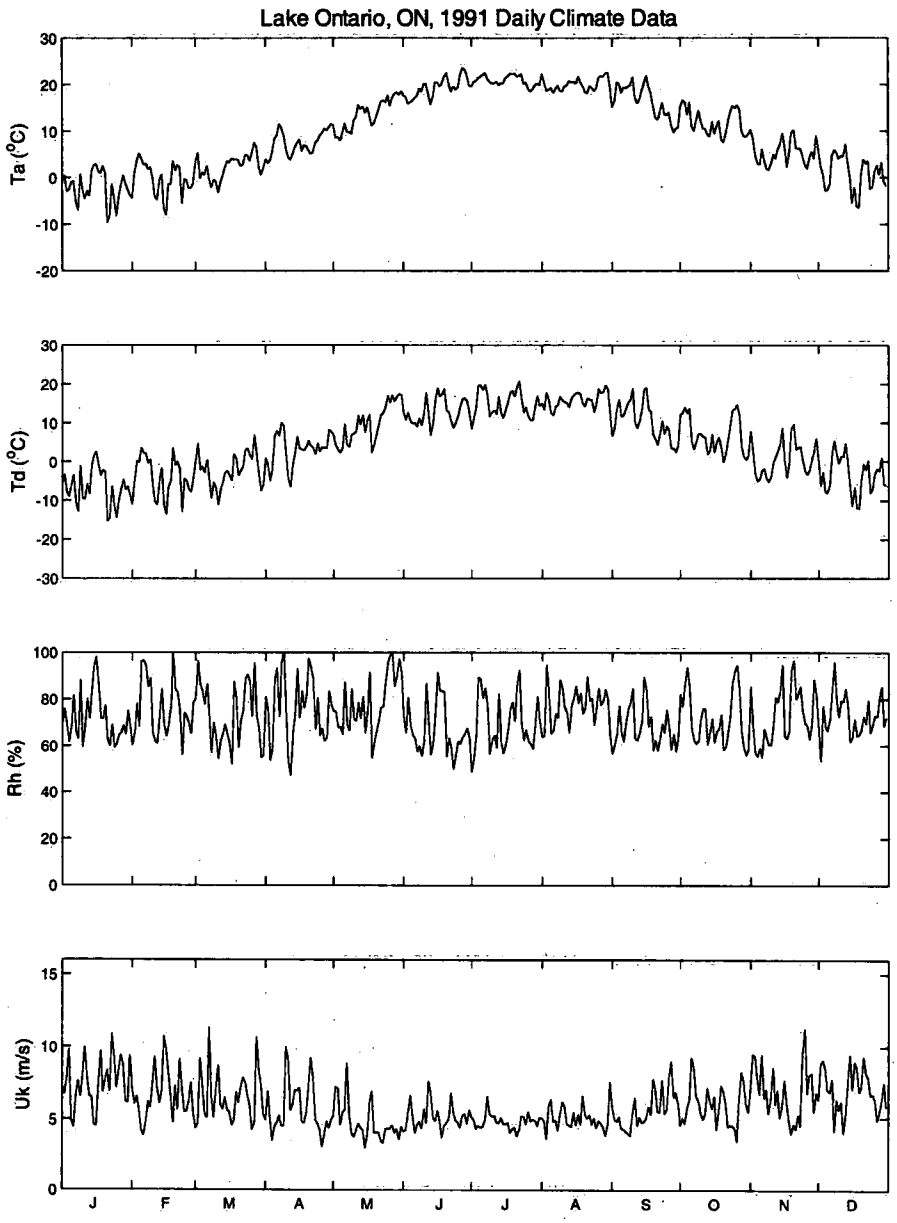
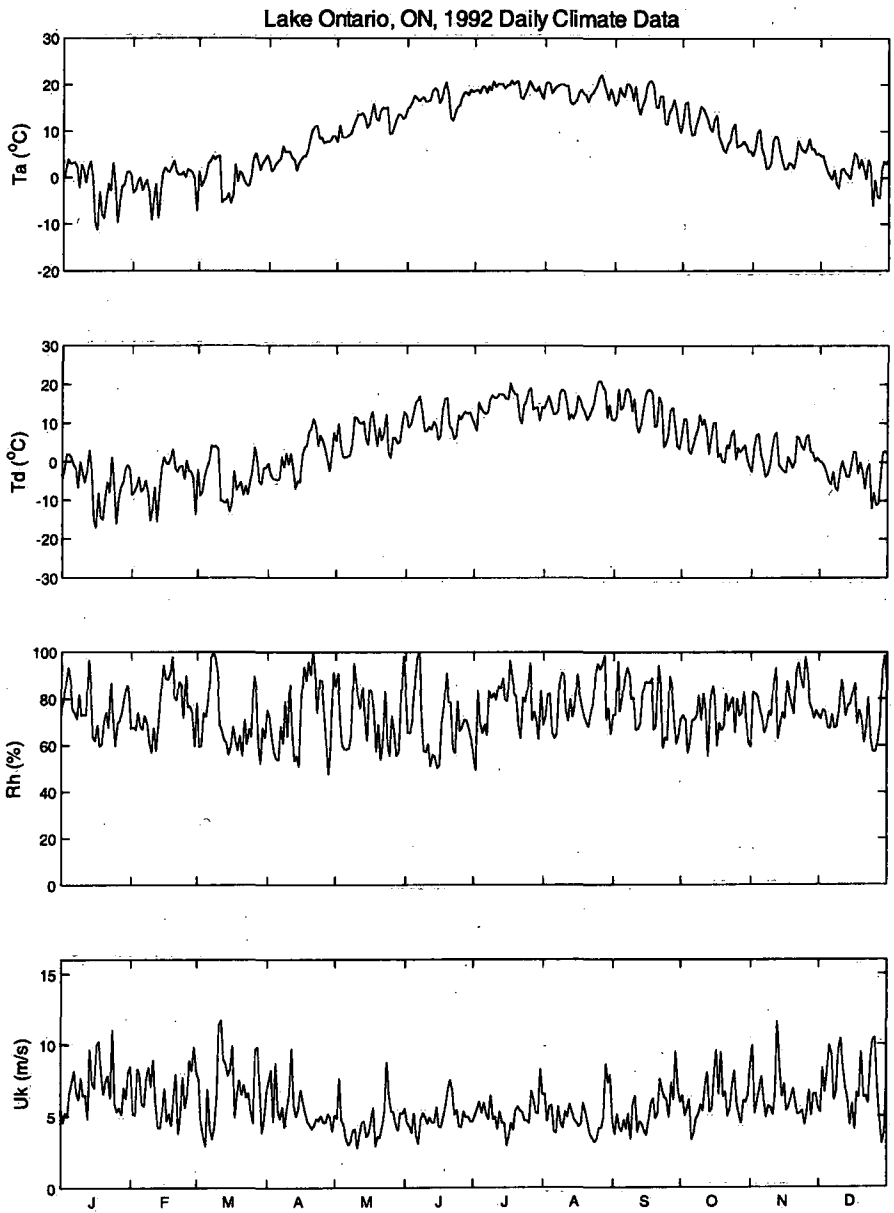

Lake Ontario, ON, 1991 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
F
M
A
M
J
J
A
S
O
N
D


Lake Ontario, ON, 1992 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
F
M
A
M
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J
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S
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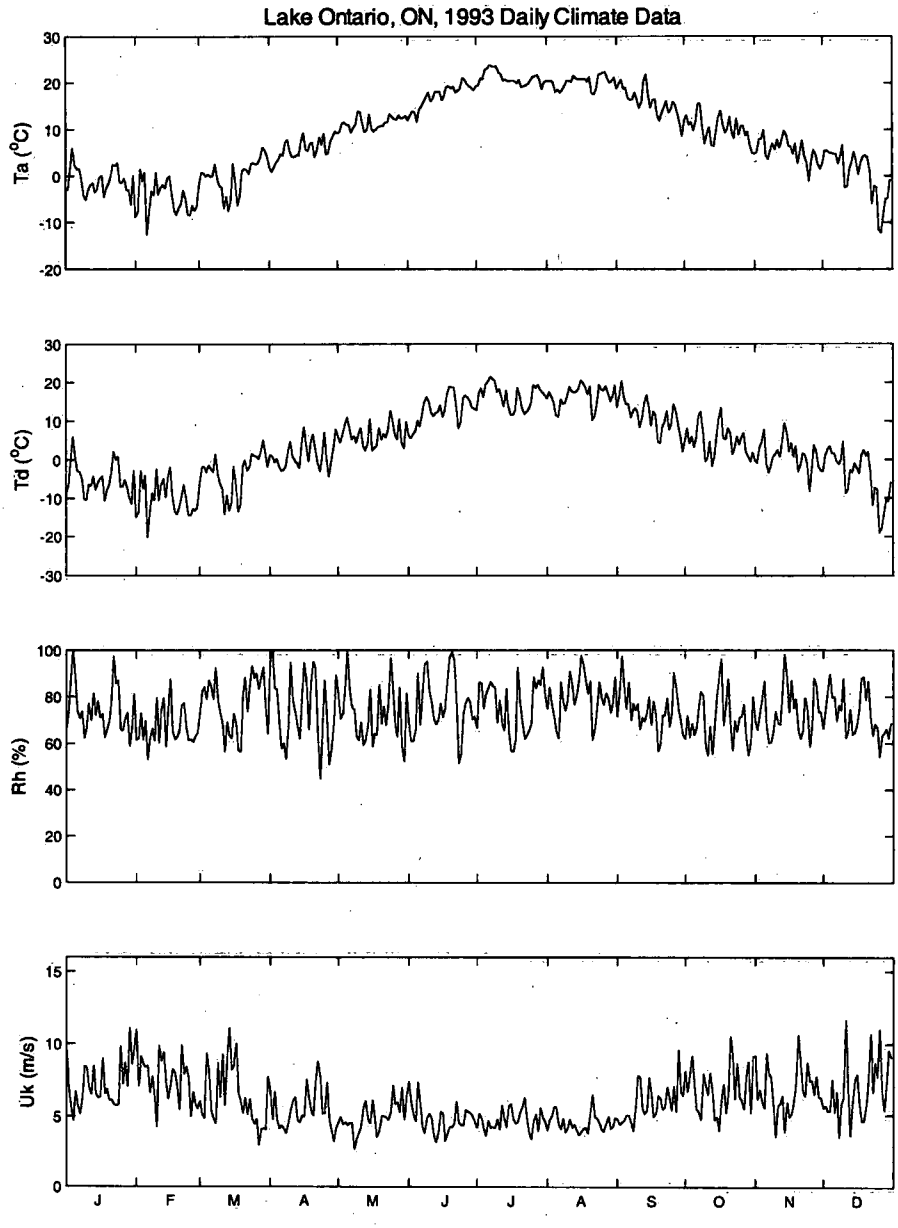
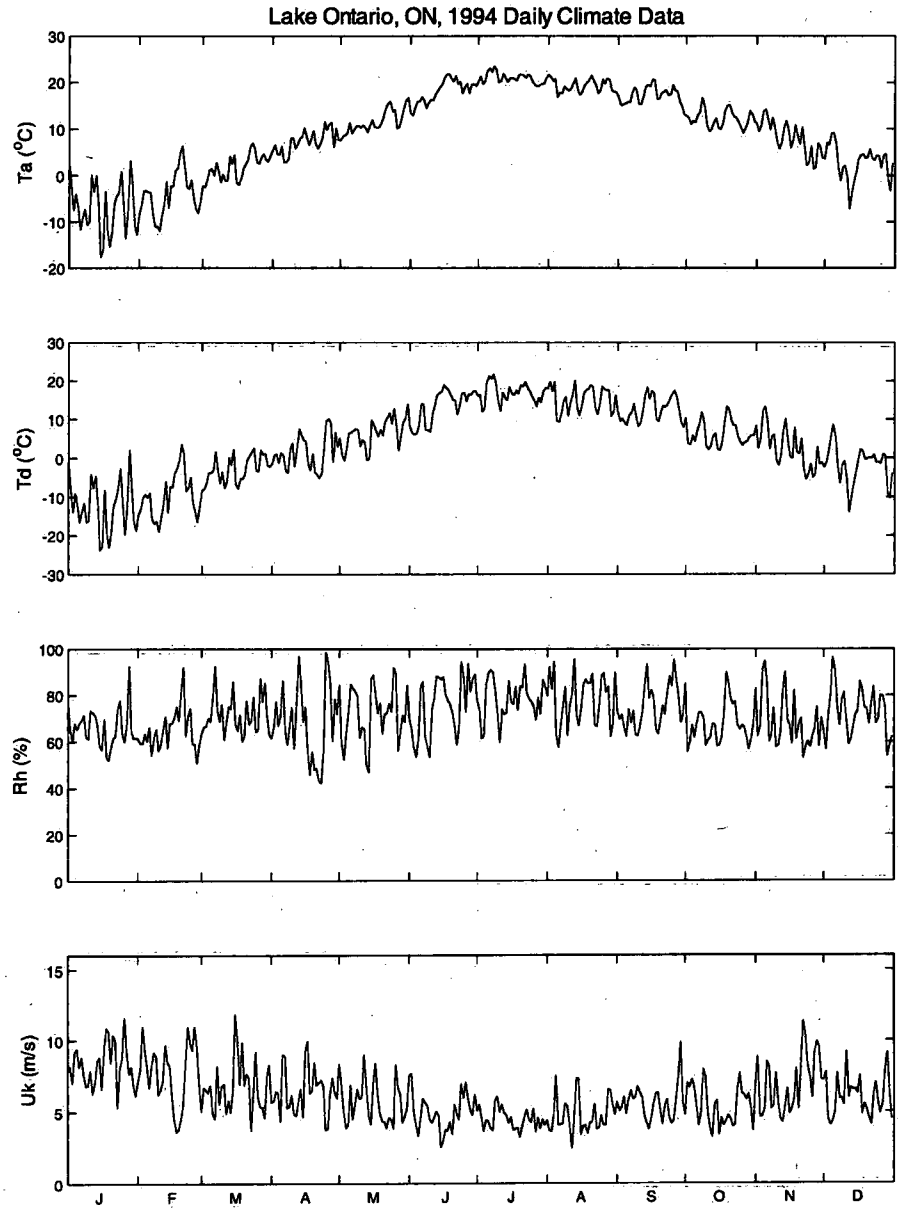
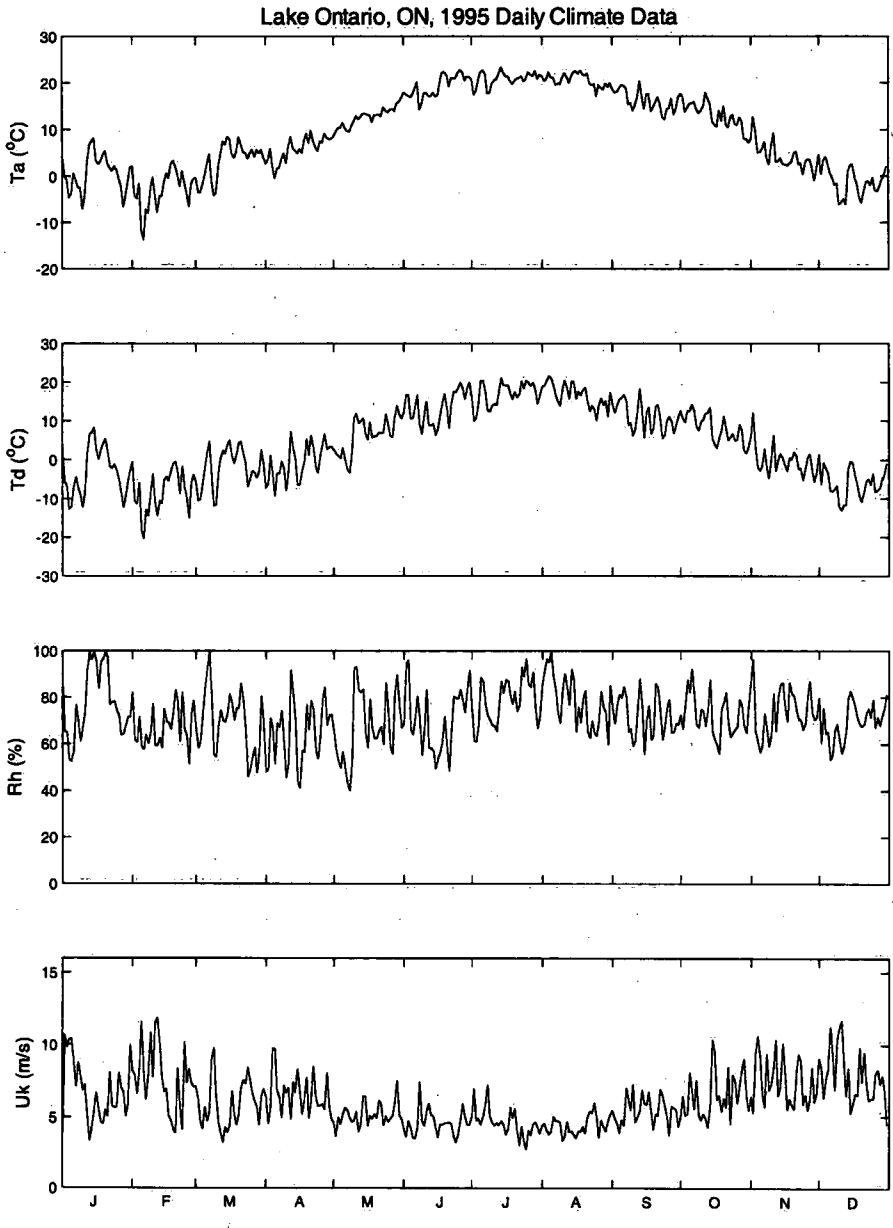
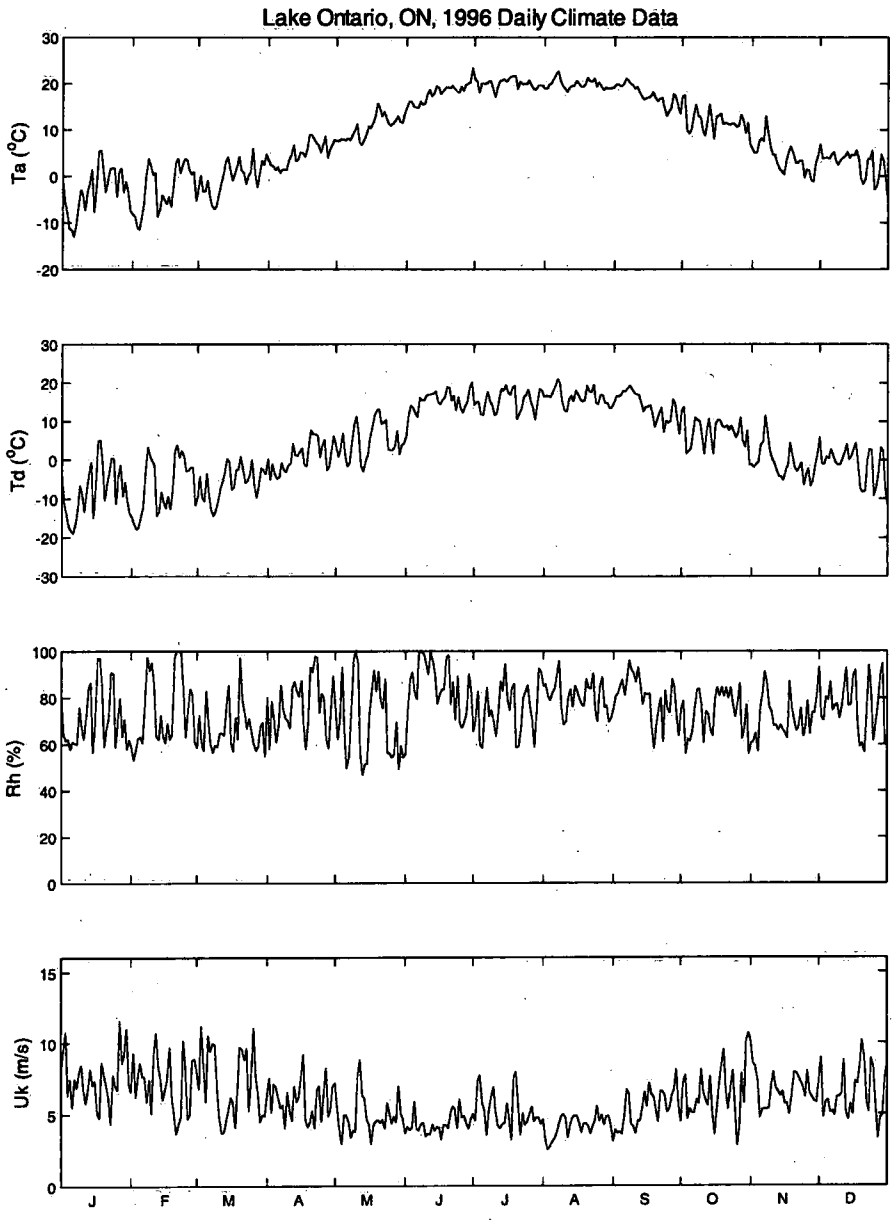
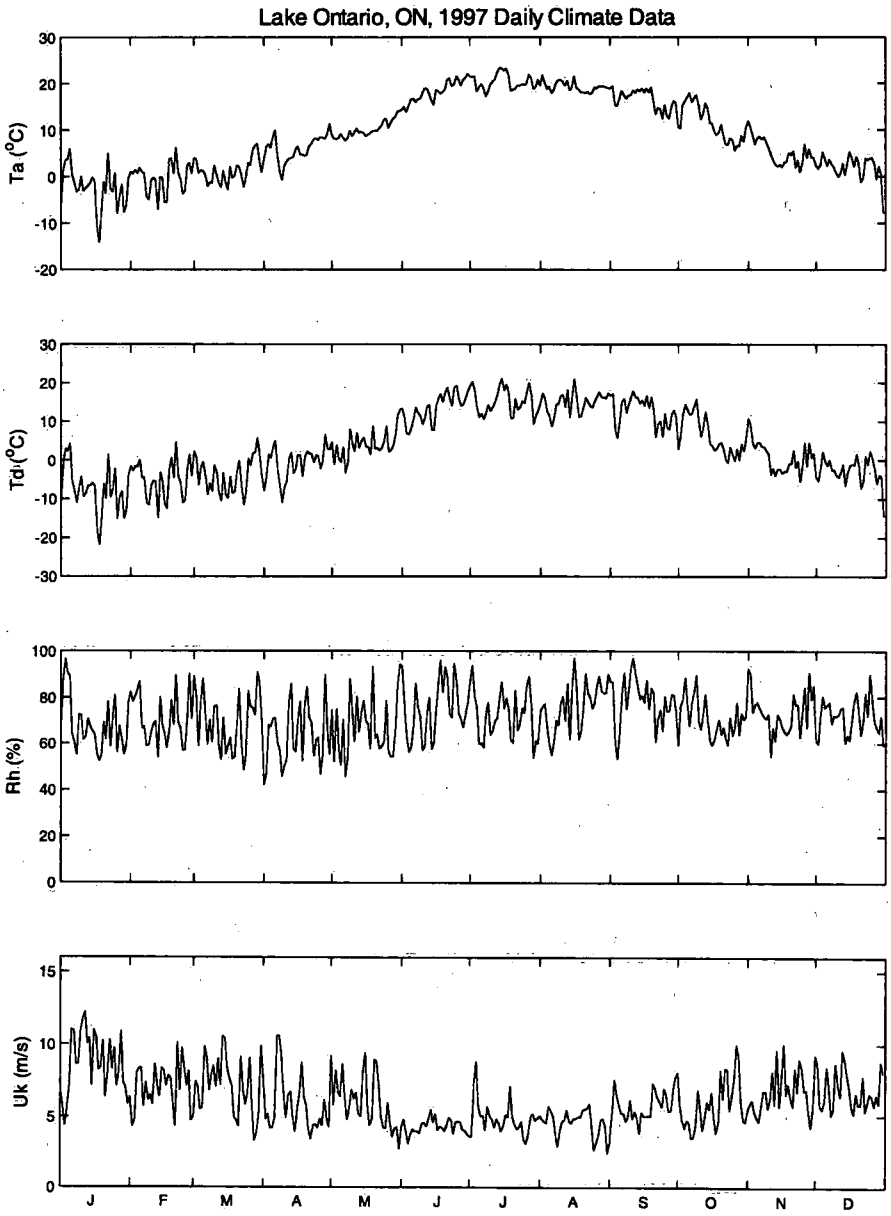
N
D


Lake Ontario, ON, 1993 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
F
M
A
M
J
J
A
S
O
N
D


Lake Ontario, ON, 1994 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
F
M
A
M
J
J
A
S
O
N
D


Lake Ontario, ON, 1995 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
F
M
A
M
J
J
A
S
O
N
D


Lake Ontario, ON, 1996 Daily Climate Data
Ta (°C)
Td (°C)
Rh (%)
Uk (m/s)
J
F
M
A
M
J
J
A
S
O
N
D


Lake Ontario, ON, 1997 Daily Climate Data
Ta (°C)
Tdv(°C)
Rh (%)
Uk (m/s)
J
F
M
A
M
J
J
A
S
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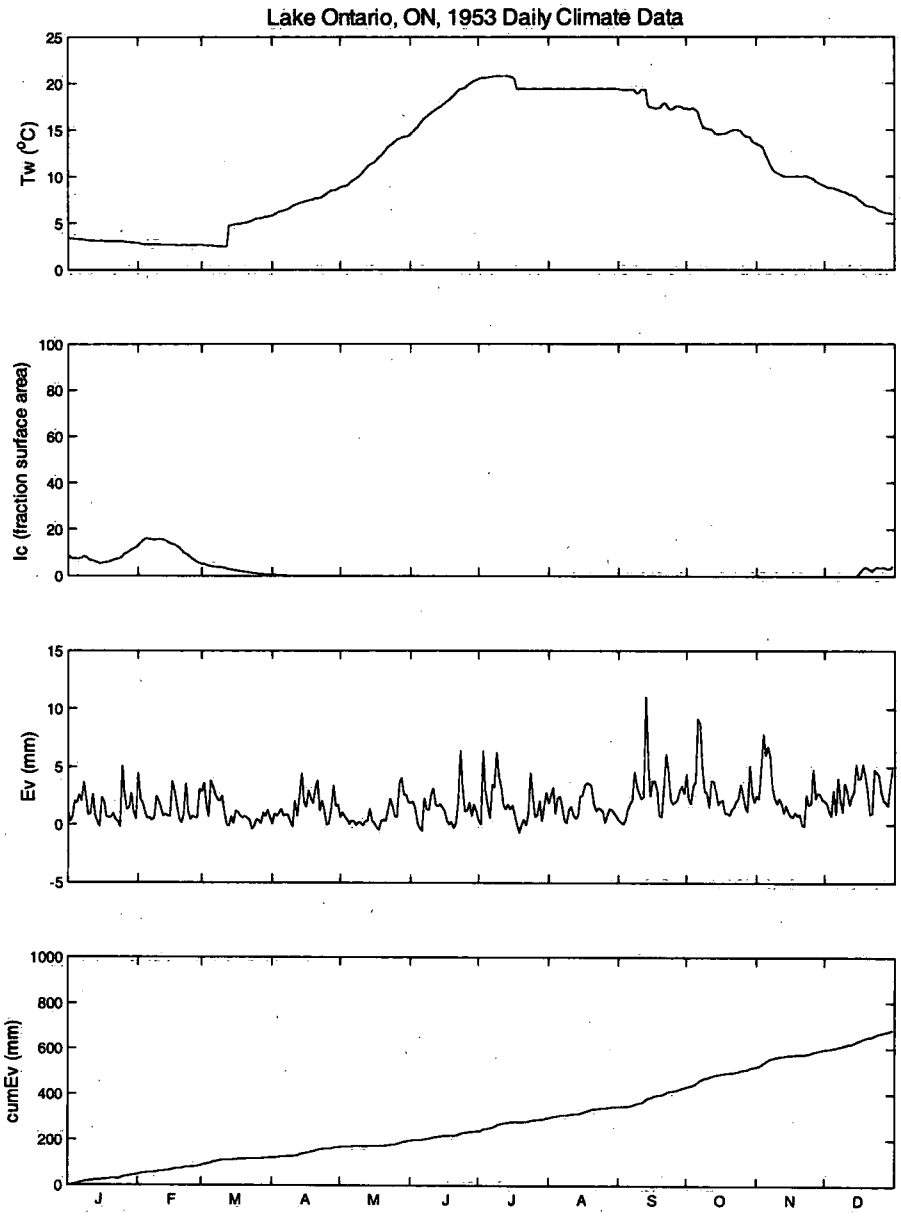
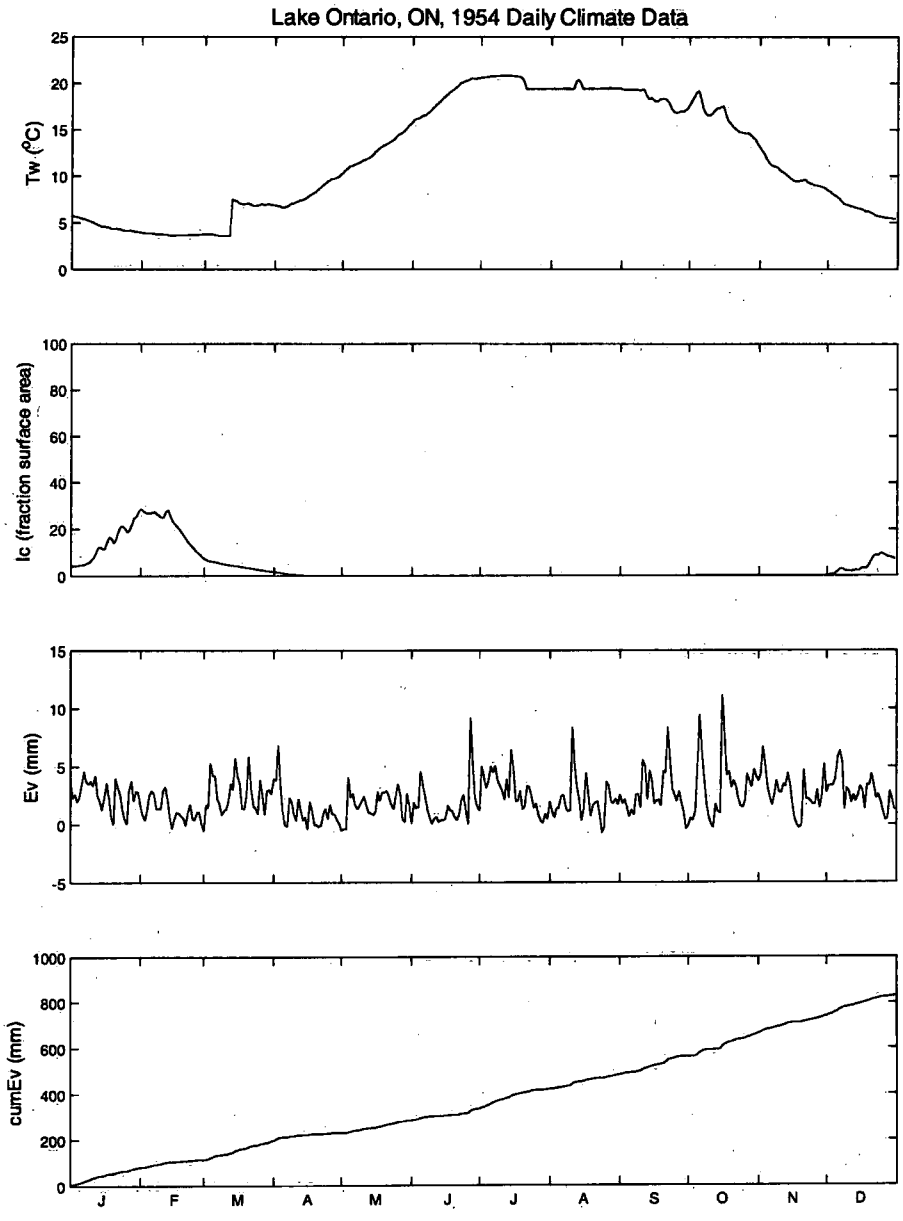
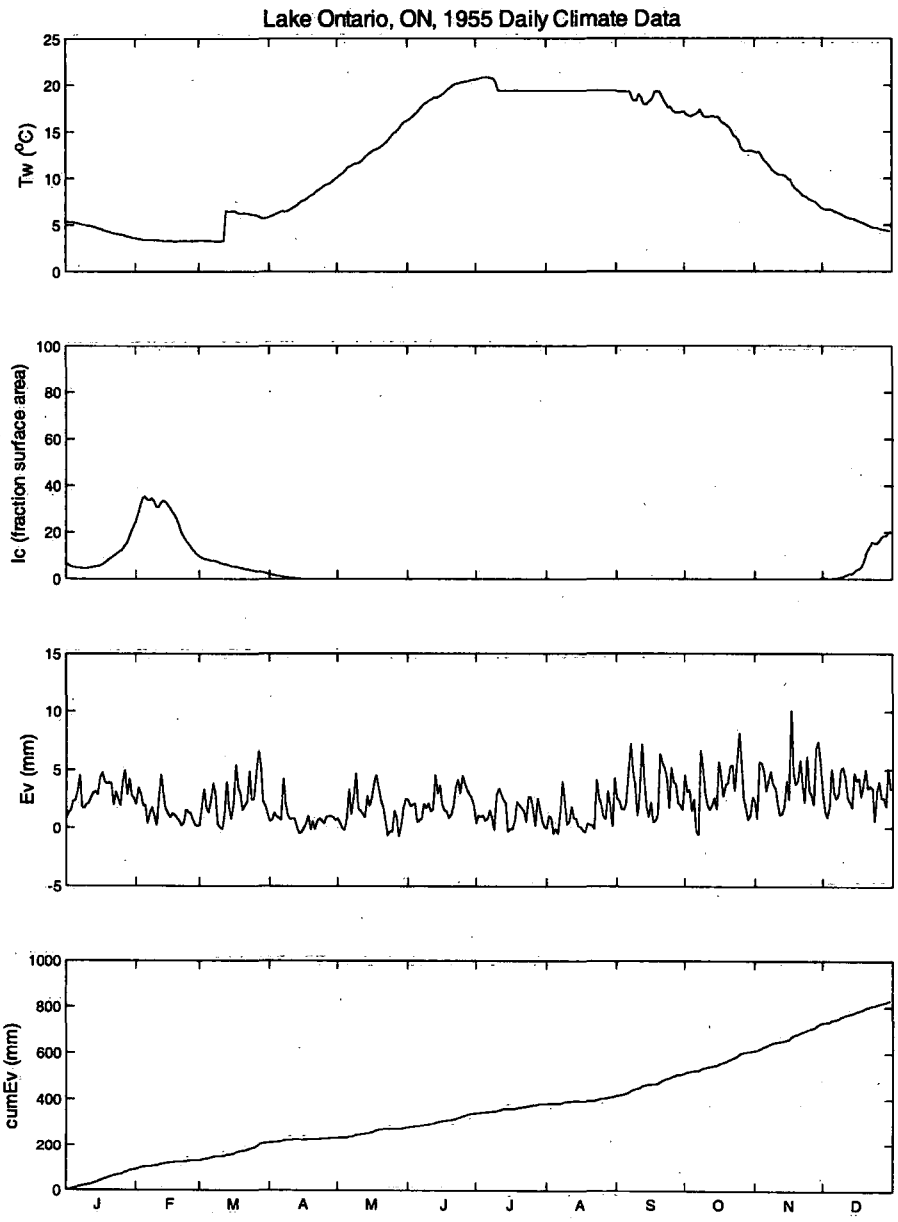
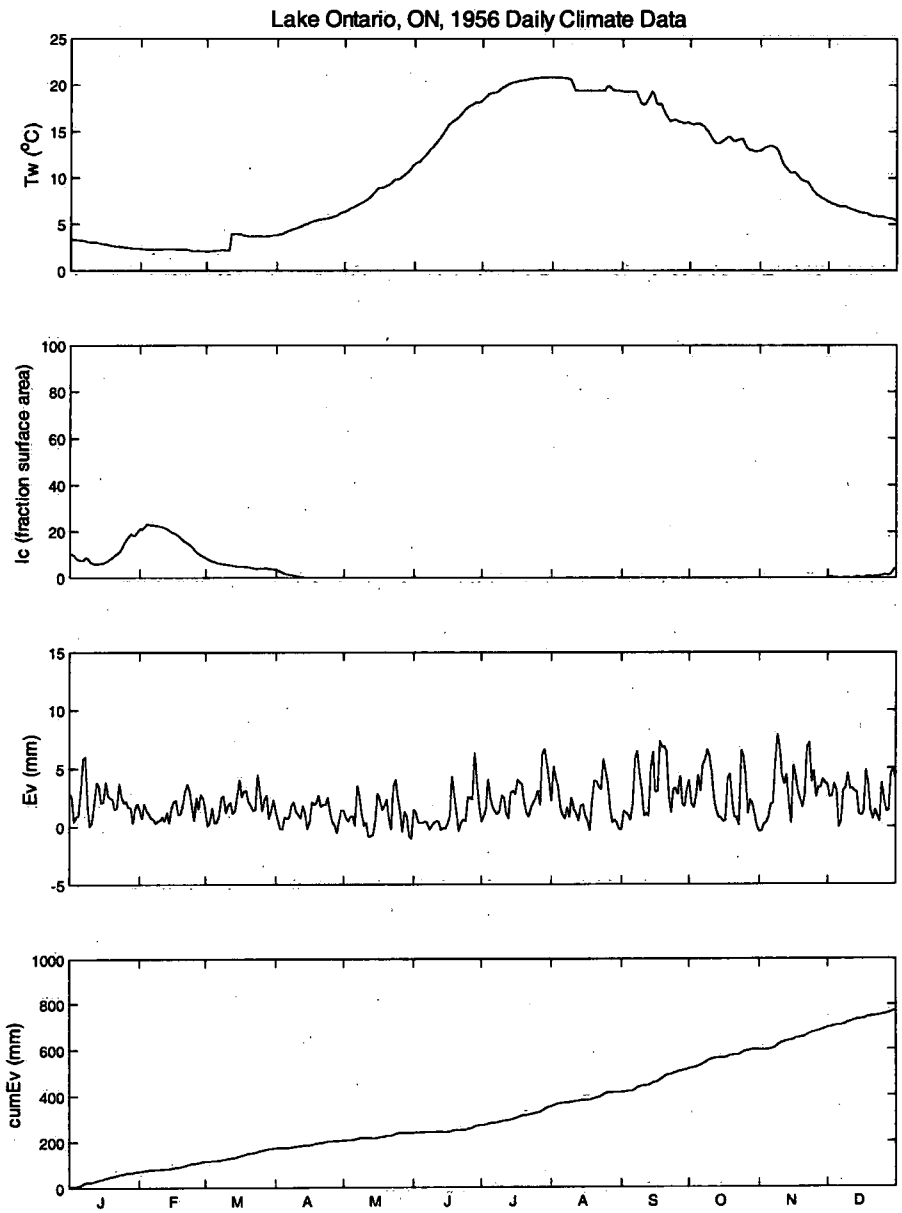
N
D

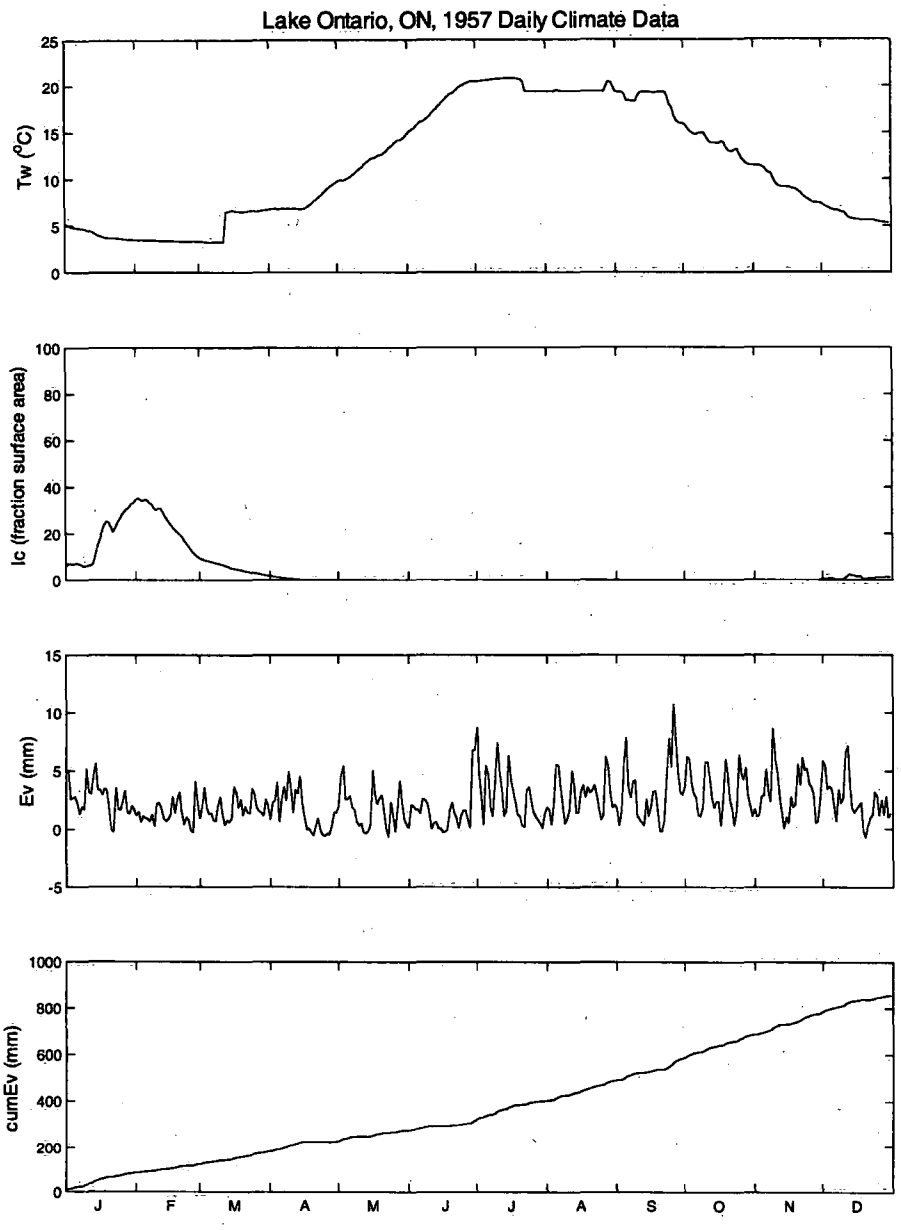
Appendix 6
Evaporation

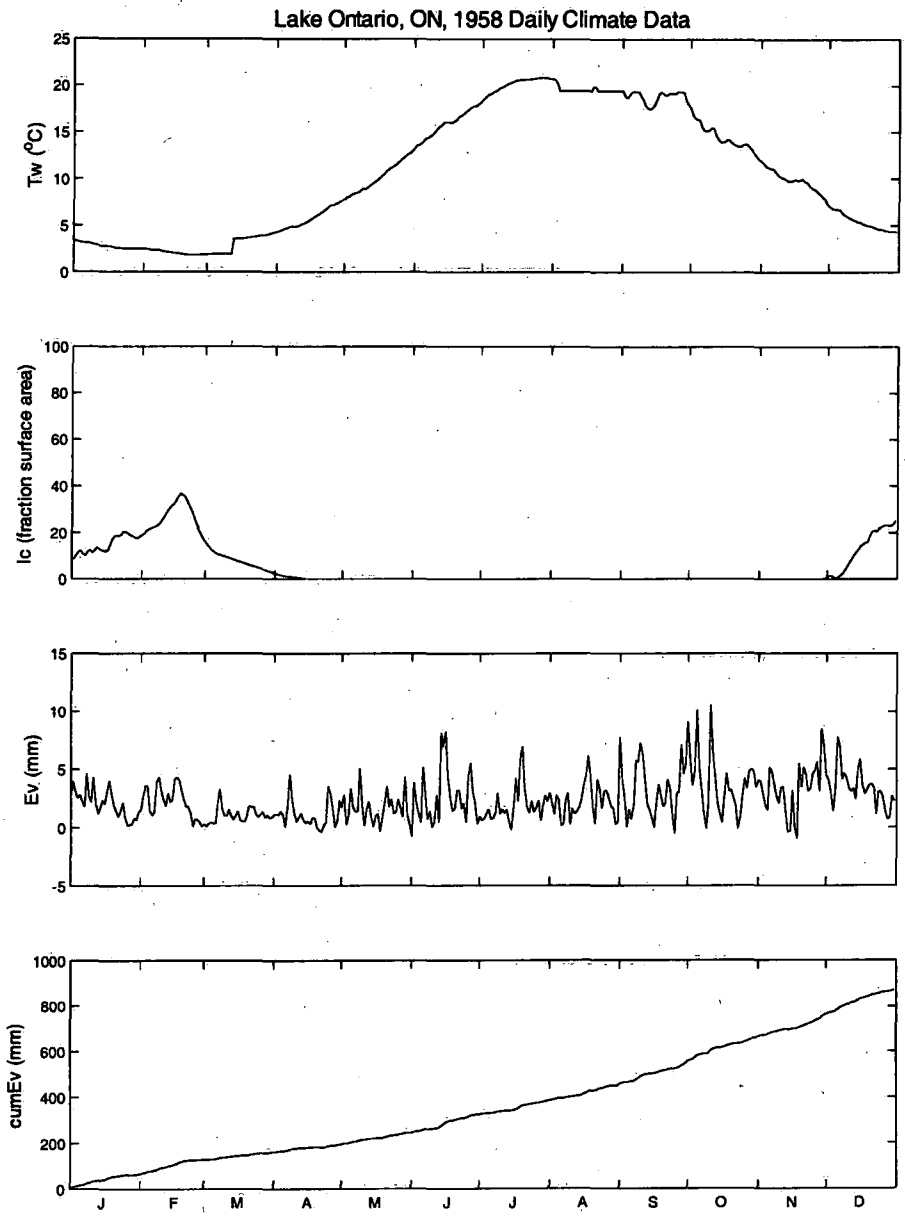


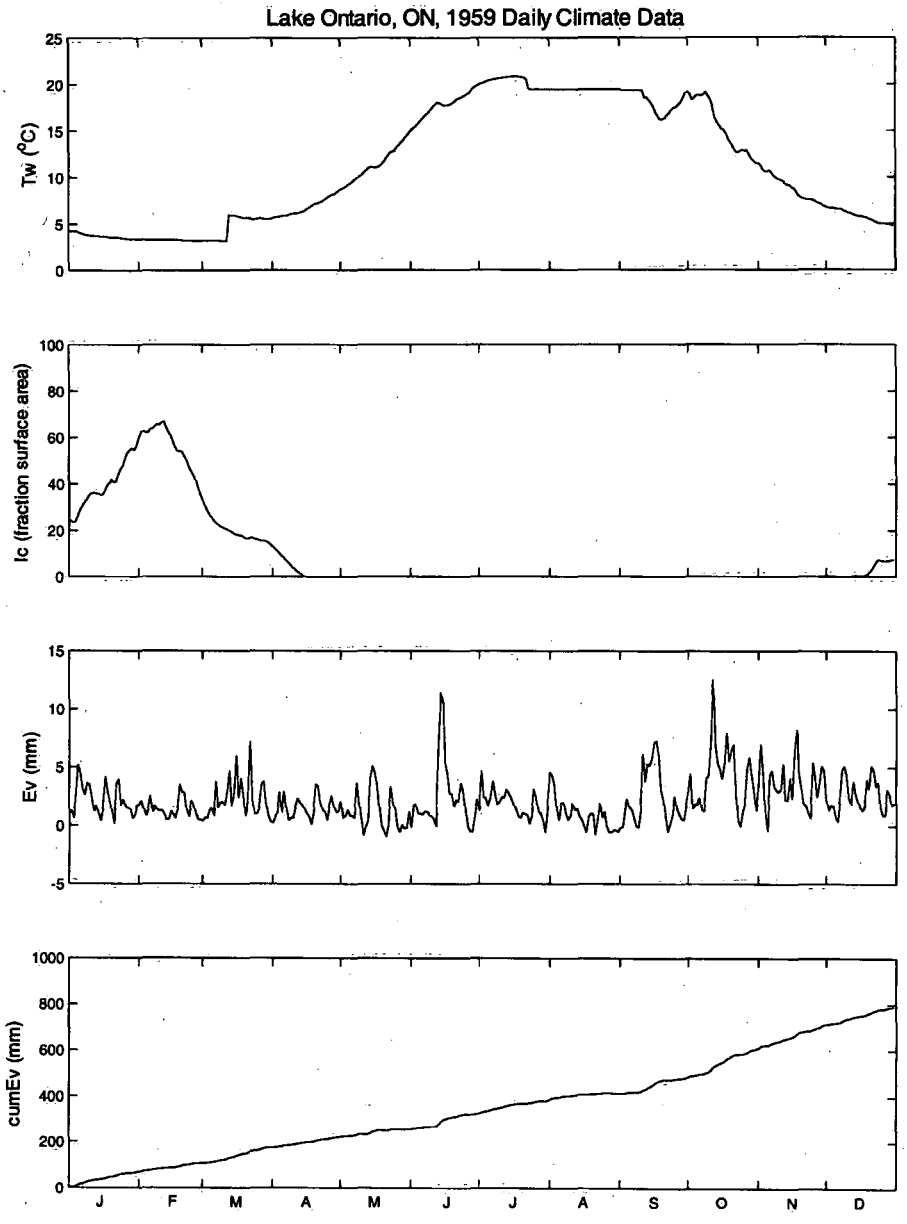

Lake Ontario, ON, 1954 Daily Climate Data
Tw (°C)
Ic (fraction surface area)
Ev (mm)
cumEv (mm)
J
F
M
A
M
J
J
A
S
O
N
D

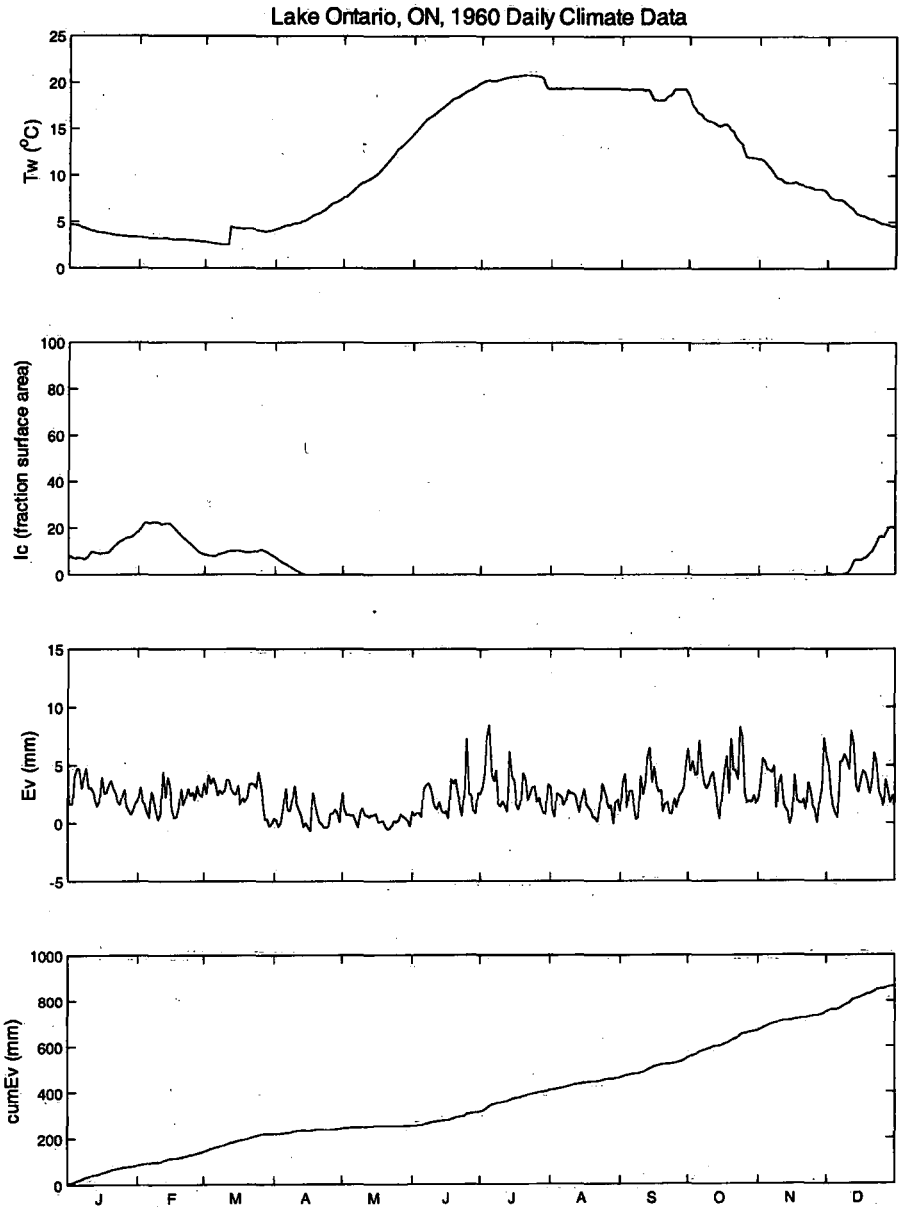

Lake Ontario, ON, 1955 Daily Climate Data
Tw (°C)
Ic (fraction surface area)
Ev (mm)
cumEv (mm)
J
F
M
A
M
J
J
A
S
O
N
D


Lake Ontario, ON, 1956 Daily Climate Data
Tw (°C)
Ic (fraction surface area)
Ev (mm)
cumEv (mm)
J
F
M
A
M
J
J
A
S
O
N
D


Lake Ontario, ON, 1957 Daily Climate Data
Tw (°C)
Ic (fraction surface area)
Ev (mm)
cumEv (mm)
J
F
M
A
M
J
J
A
S
O
N
D


Lake Ontario, ON, 1958 Daily Climate Data
Tw (°C)
Ic (fraction surface area)
Ev (mm)
cumEv (mm)
J
F
M
A
M
J
J
A
S
O
N
D


Lake Ontario, ON, 1959 Daily Climate Data
Tw (°C)
Ic (fraction surface area)
Ev (mm)
cumEv (mm)
J
F
M
A
M
J
J
A
S
O
N
D


Lake Ontario, ON, 1960 Daily Climate Data
Tw (°C)
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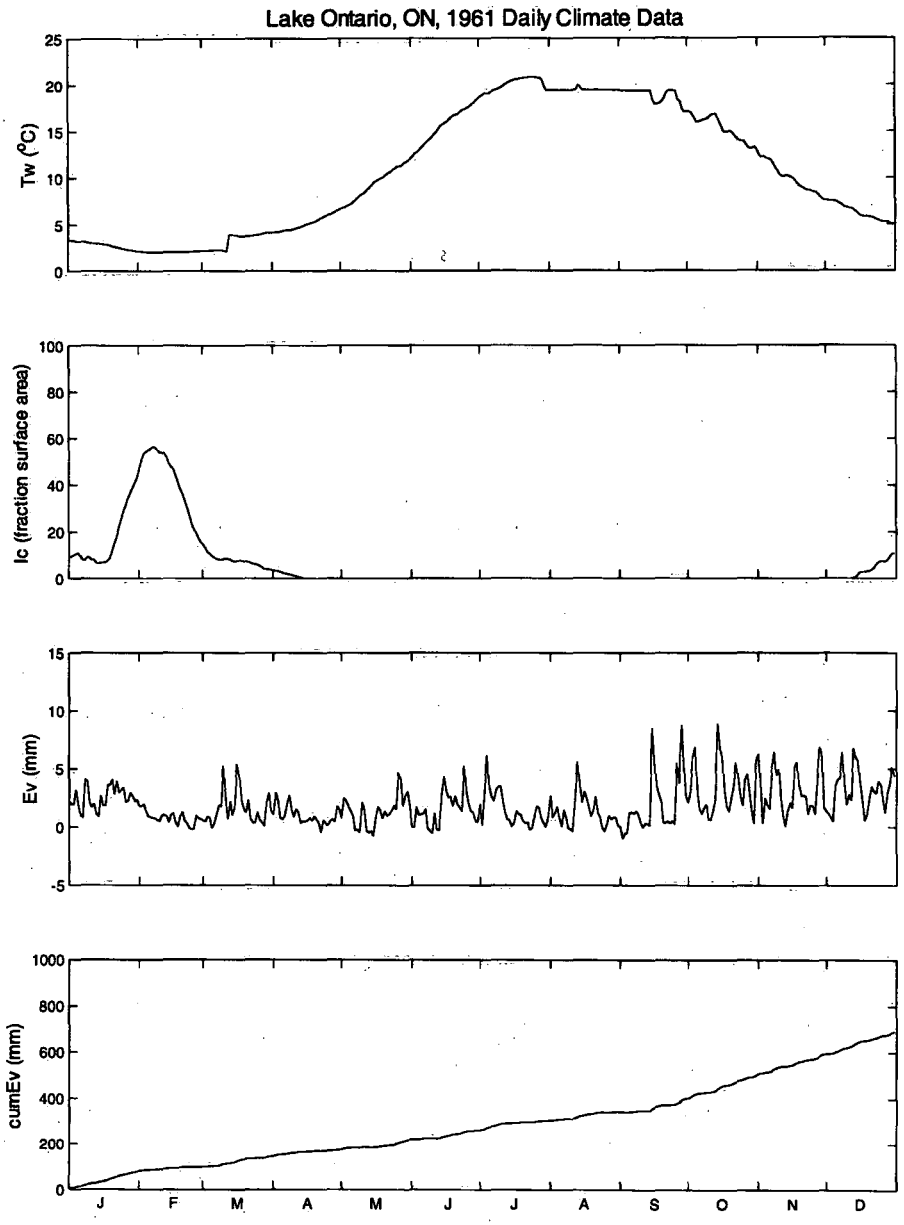
Lake Ontario, ON, 1961 Daily Climate Data
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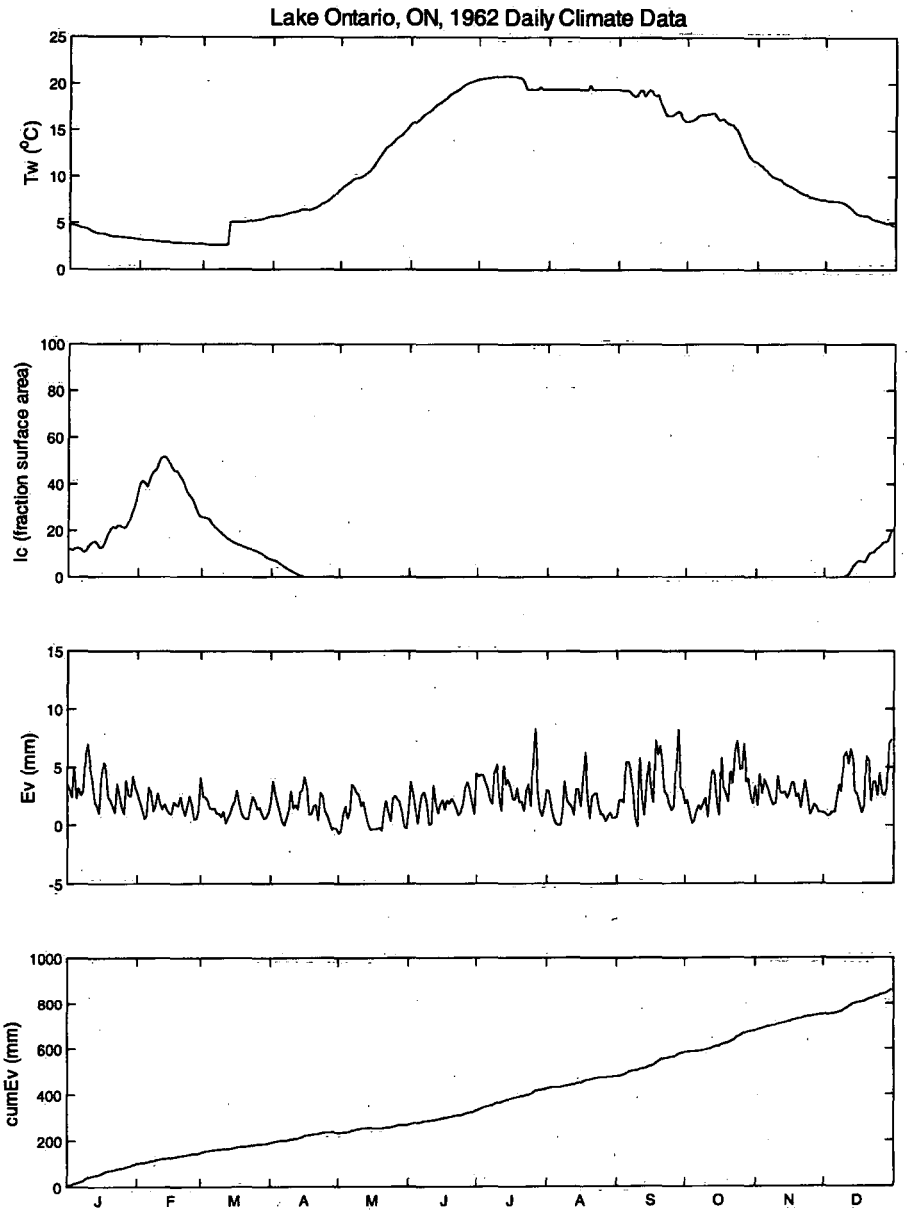
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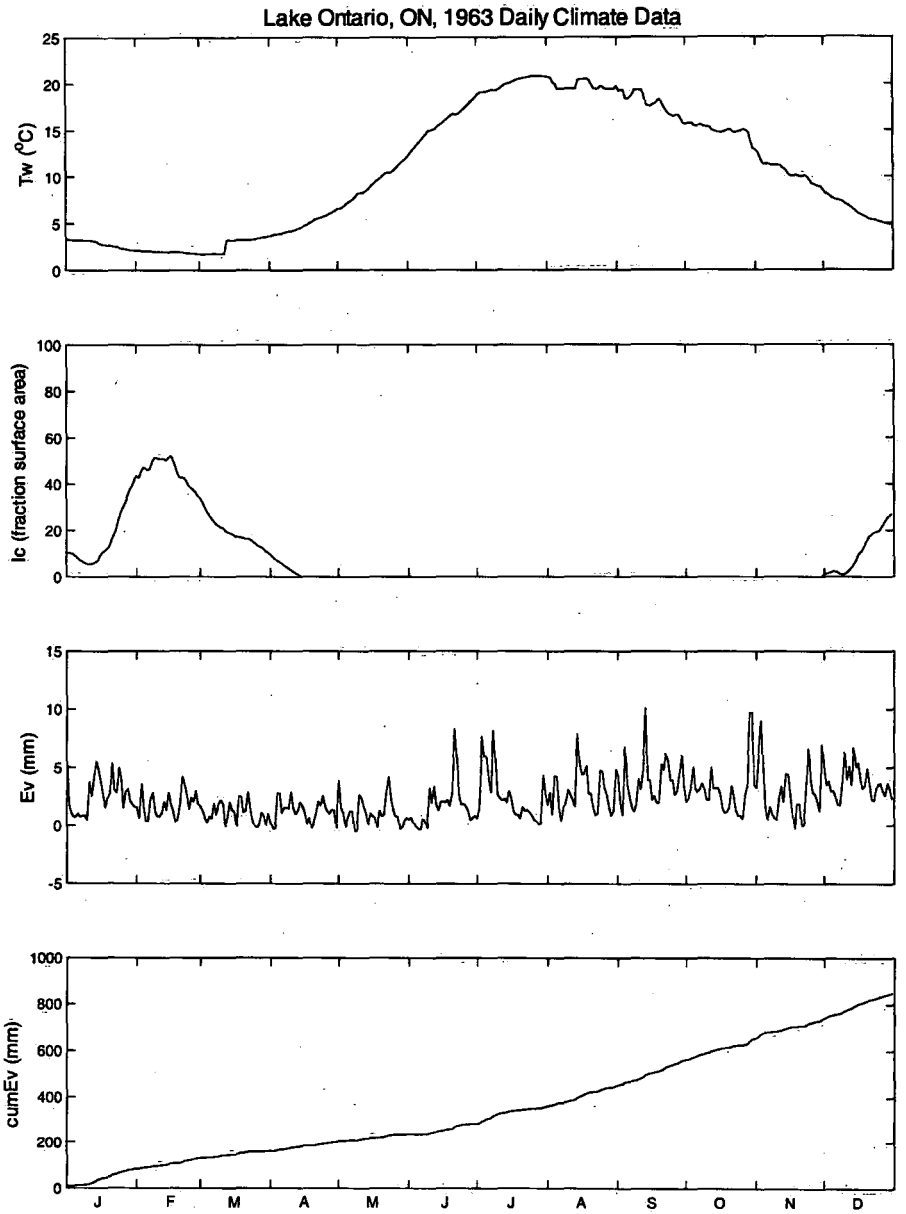
Lake Ontario, ON, 1963 Daily Climate Data
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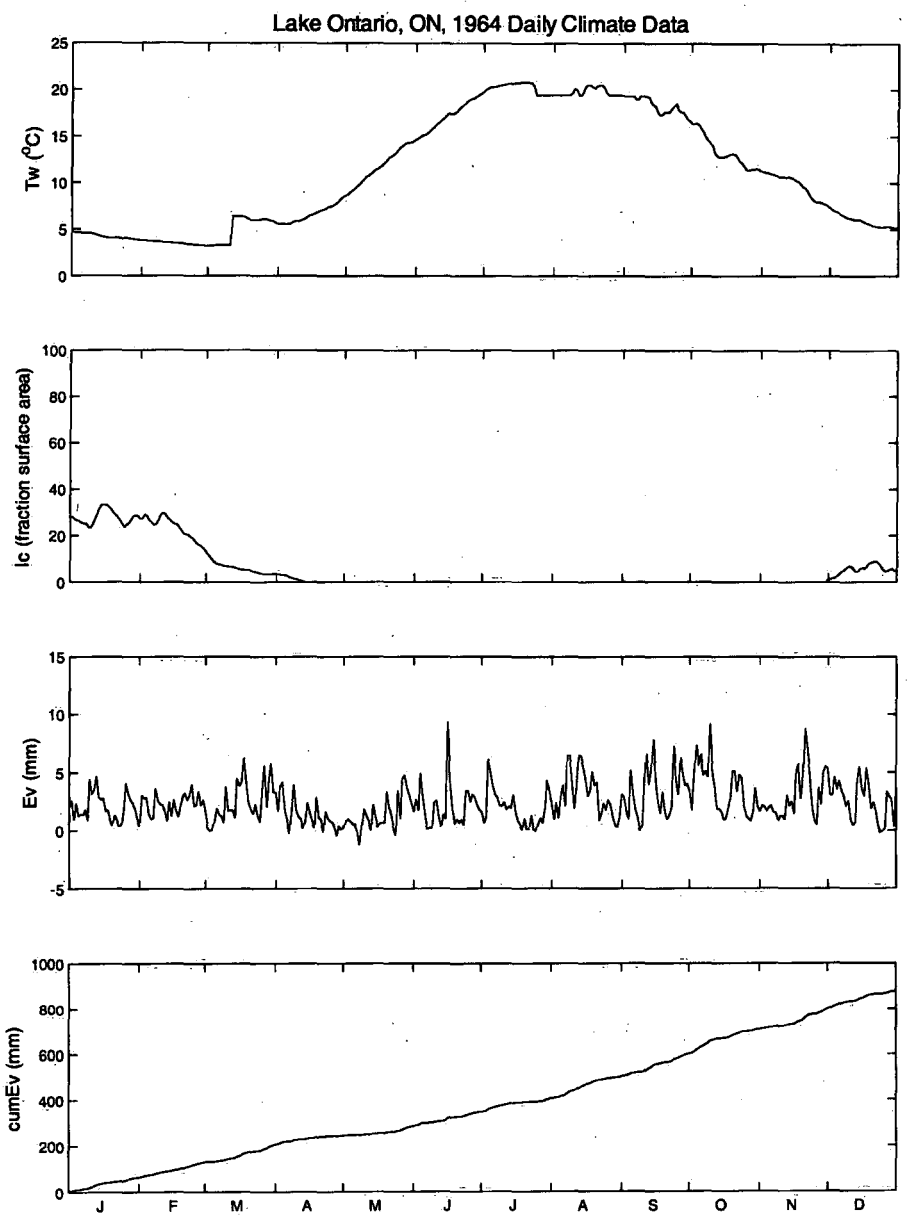
Lake Ontario, ON, 1964 Daily Climate Data
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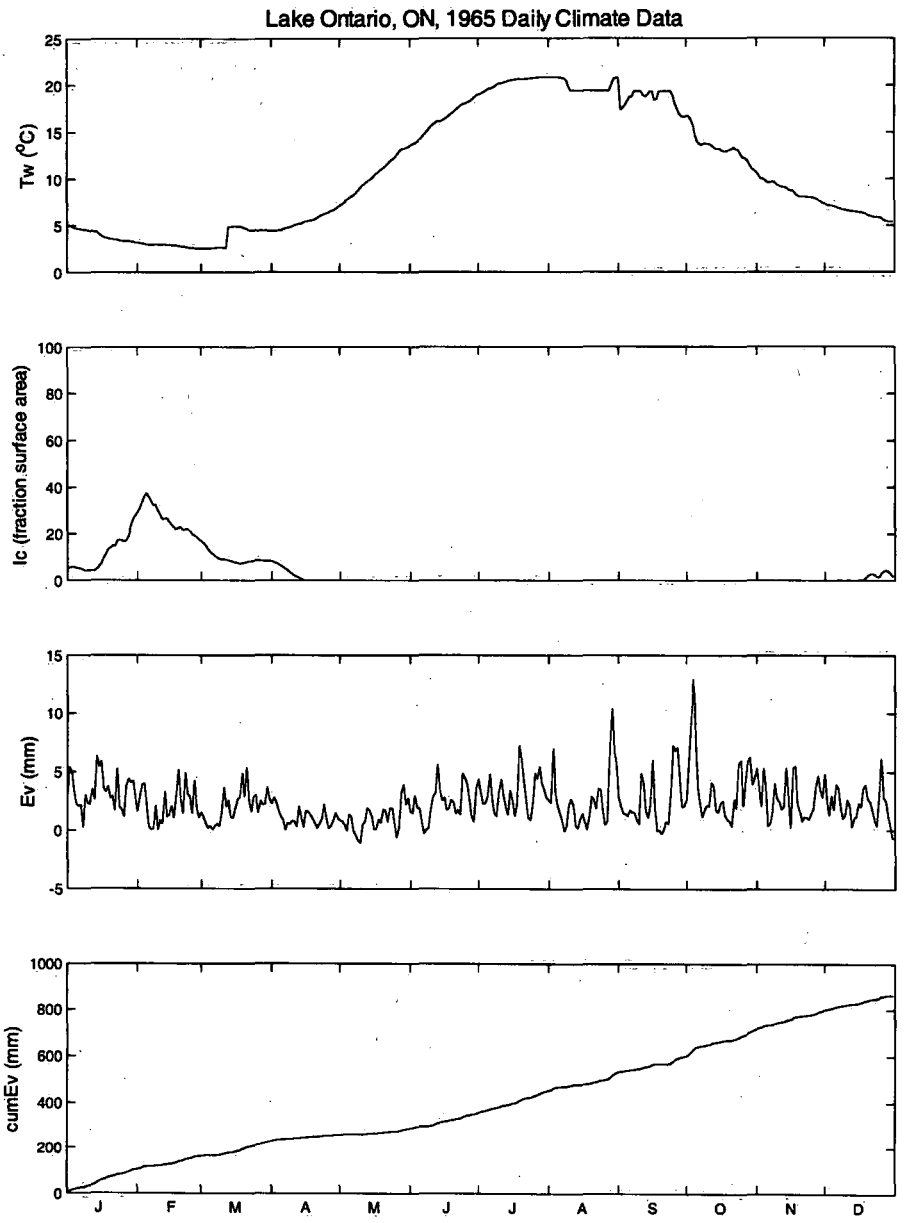
Lake Ontario, ON, 1965 Daily Climate Data
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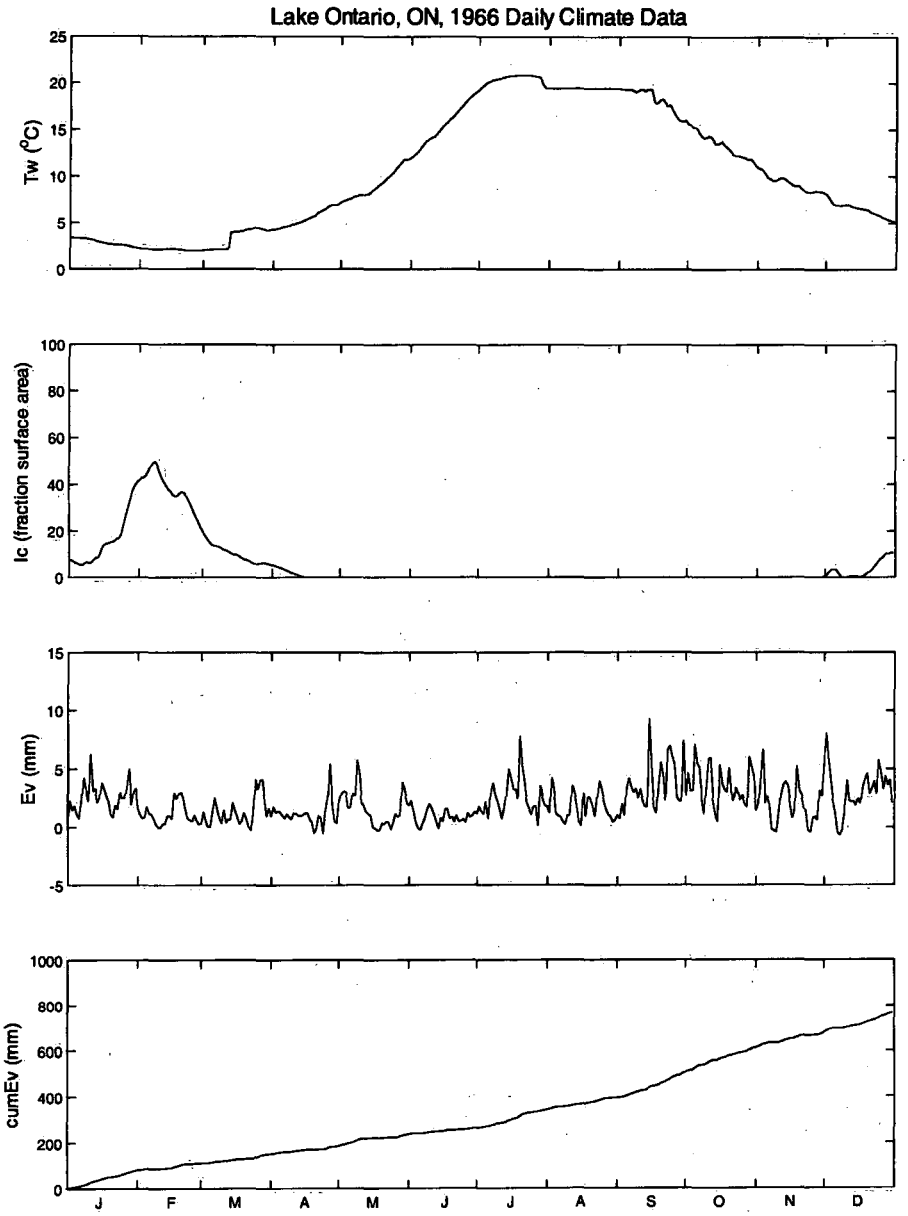
Lake Ontario, ON, 1966 Daily Climate Data
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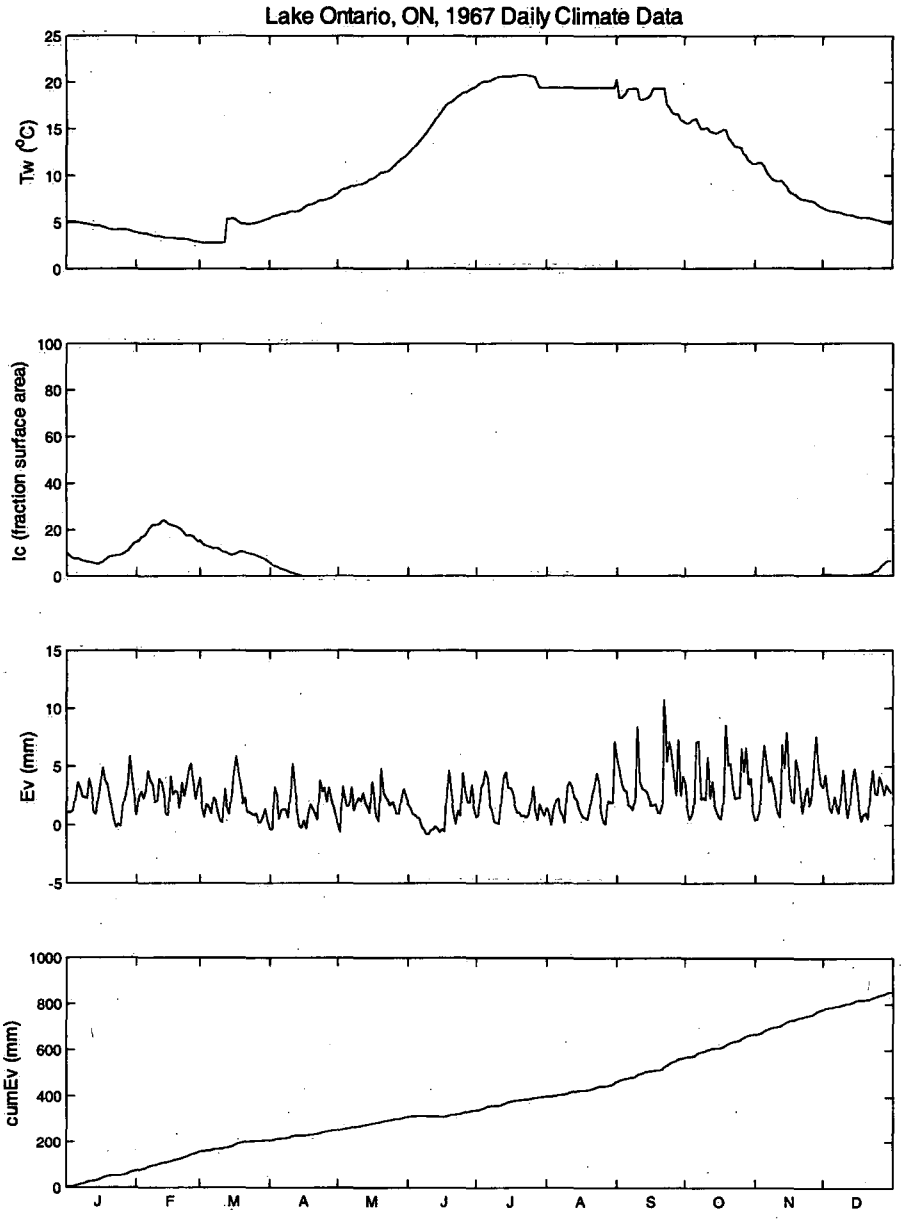
Lake Ontario, ON, 1967 Daily Climate Data
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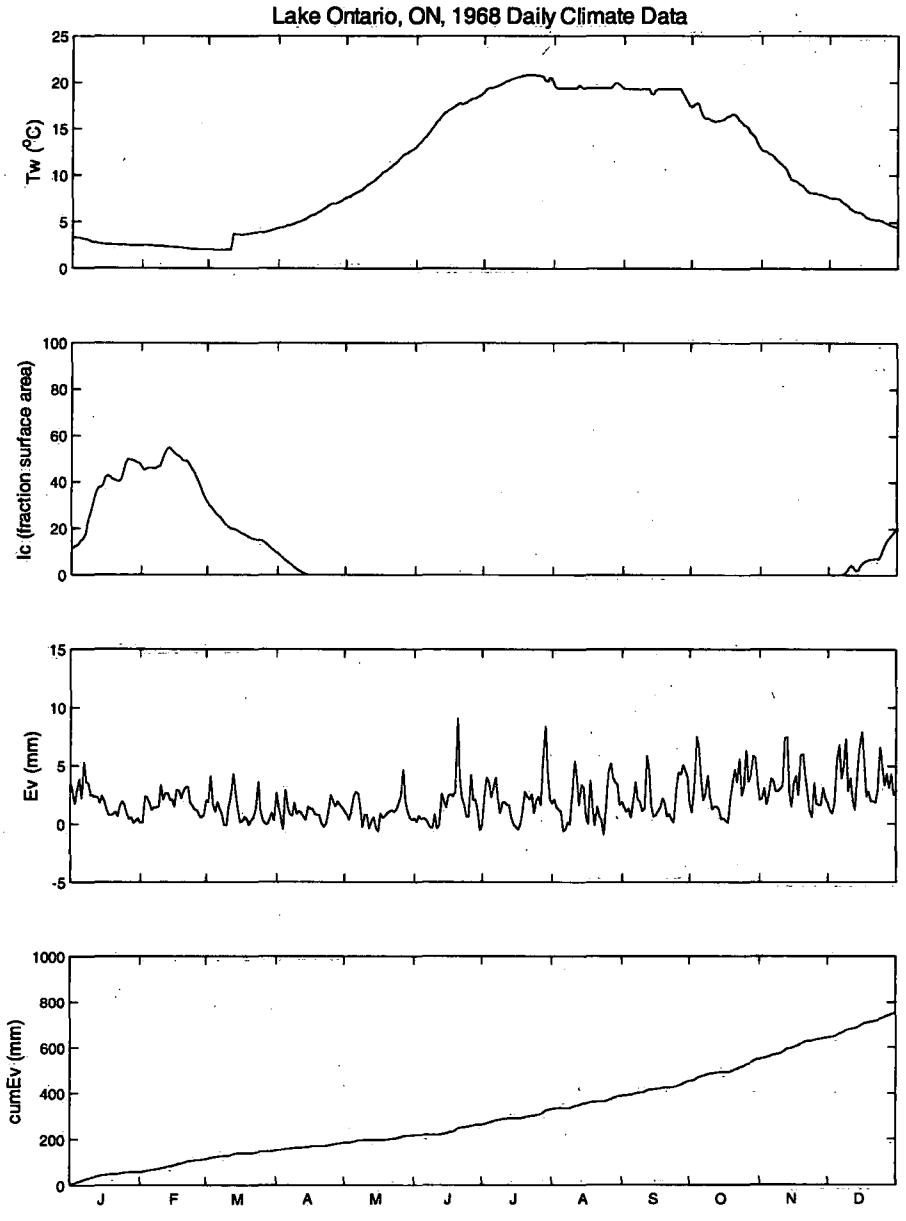
Lake Ontario, ON, 1968 Daily Climate Data
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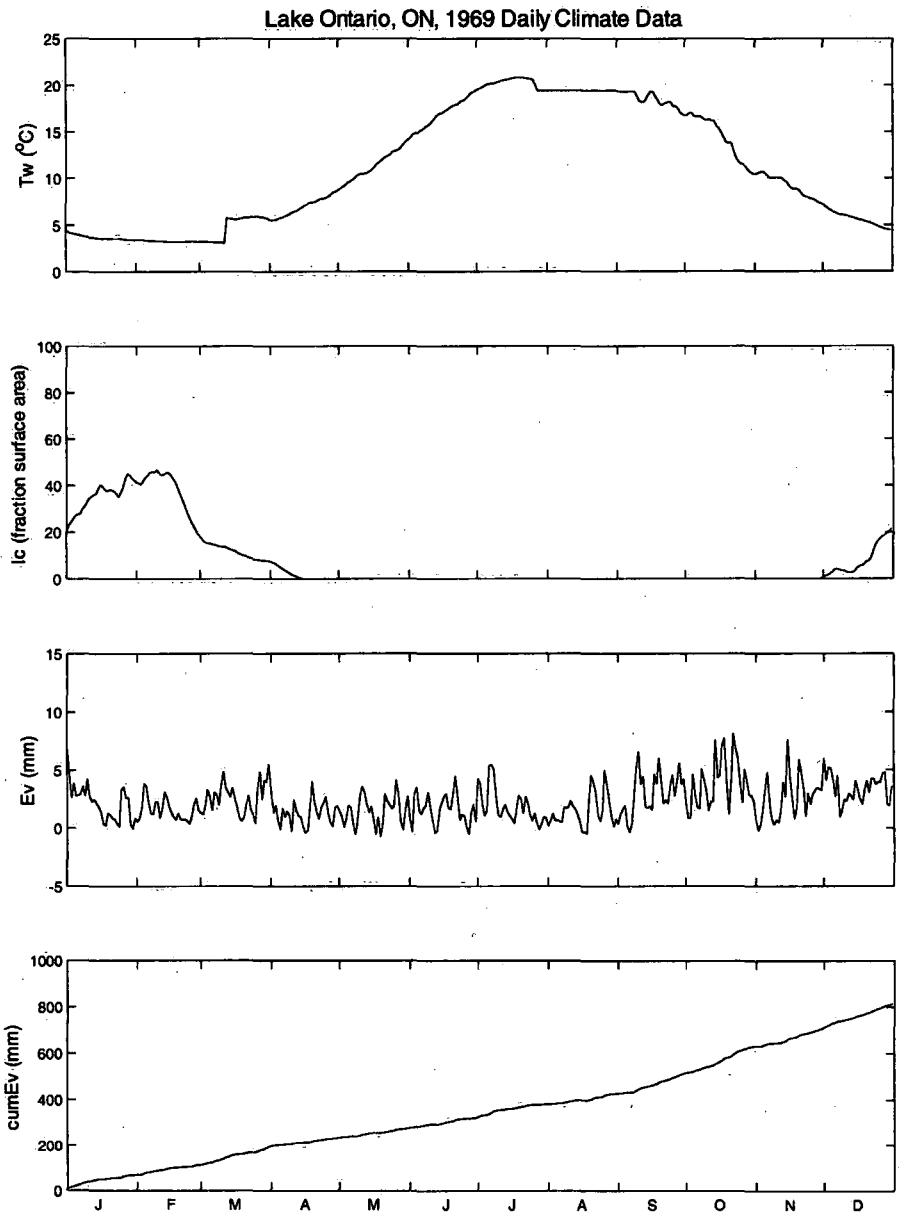
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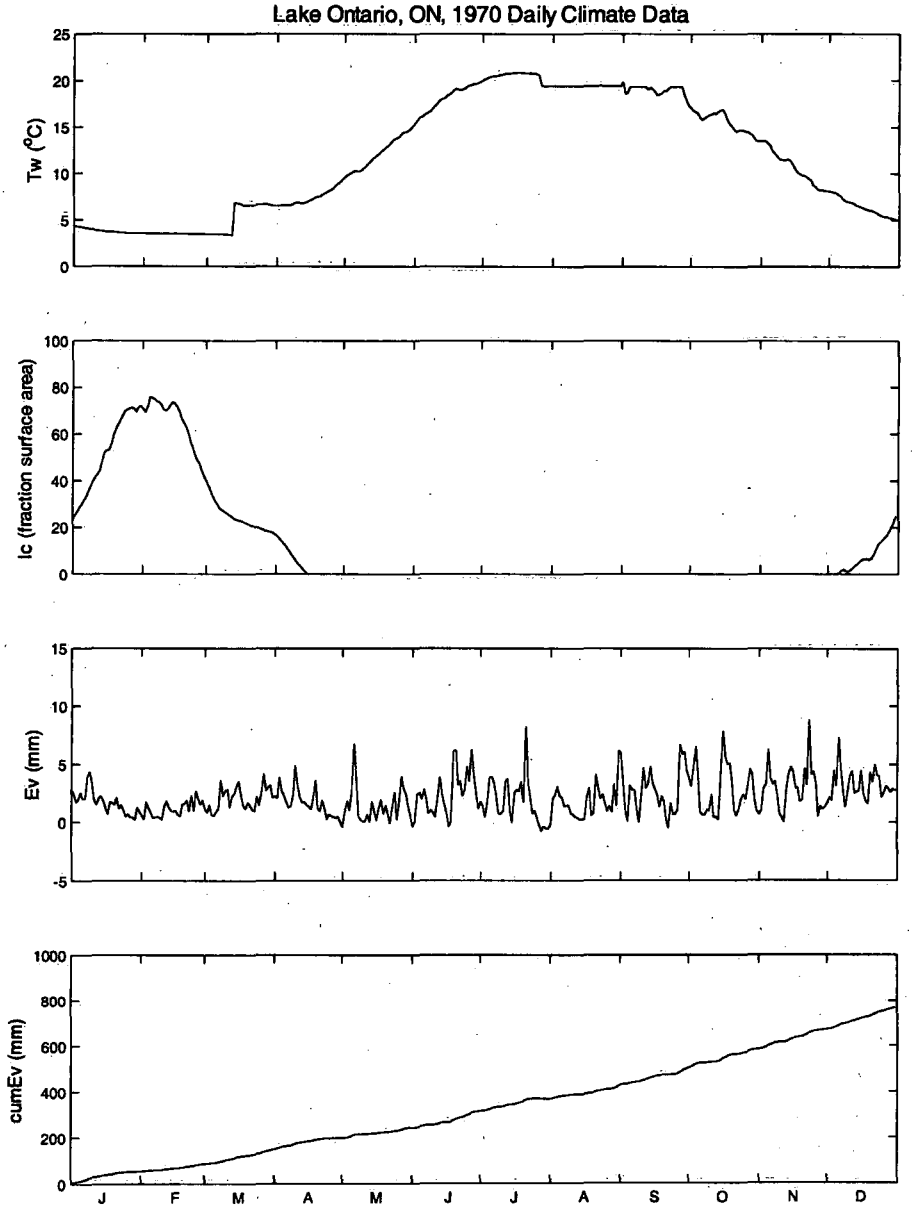
Lake Ontario, ON, 1970 Daily Climate Data
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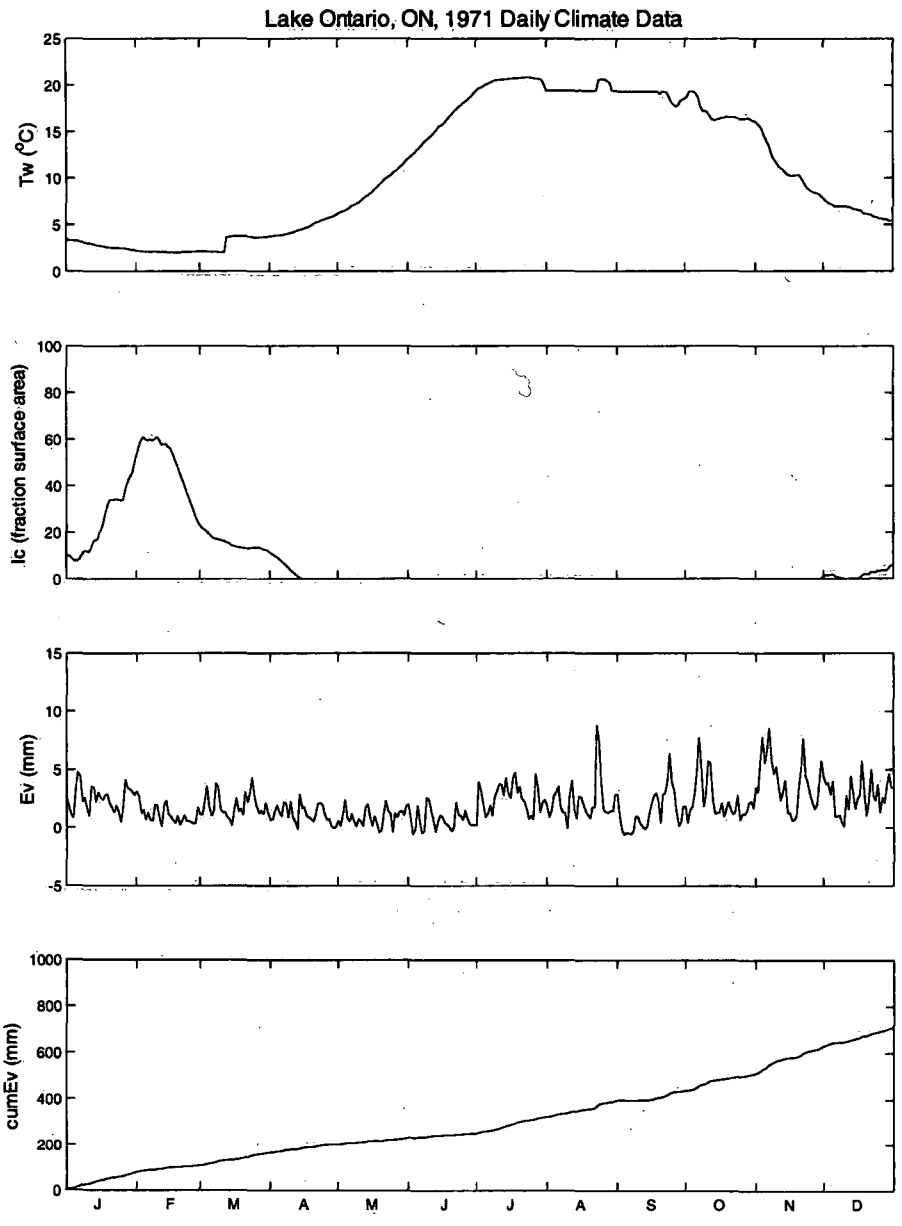
Lake Ontario, ON, 1971 Daily Climate Data
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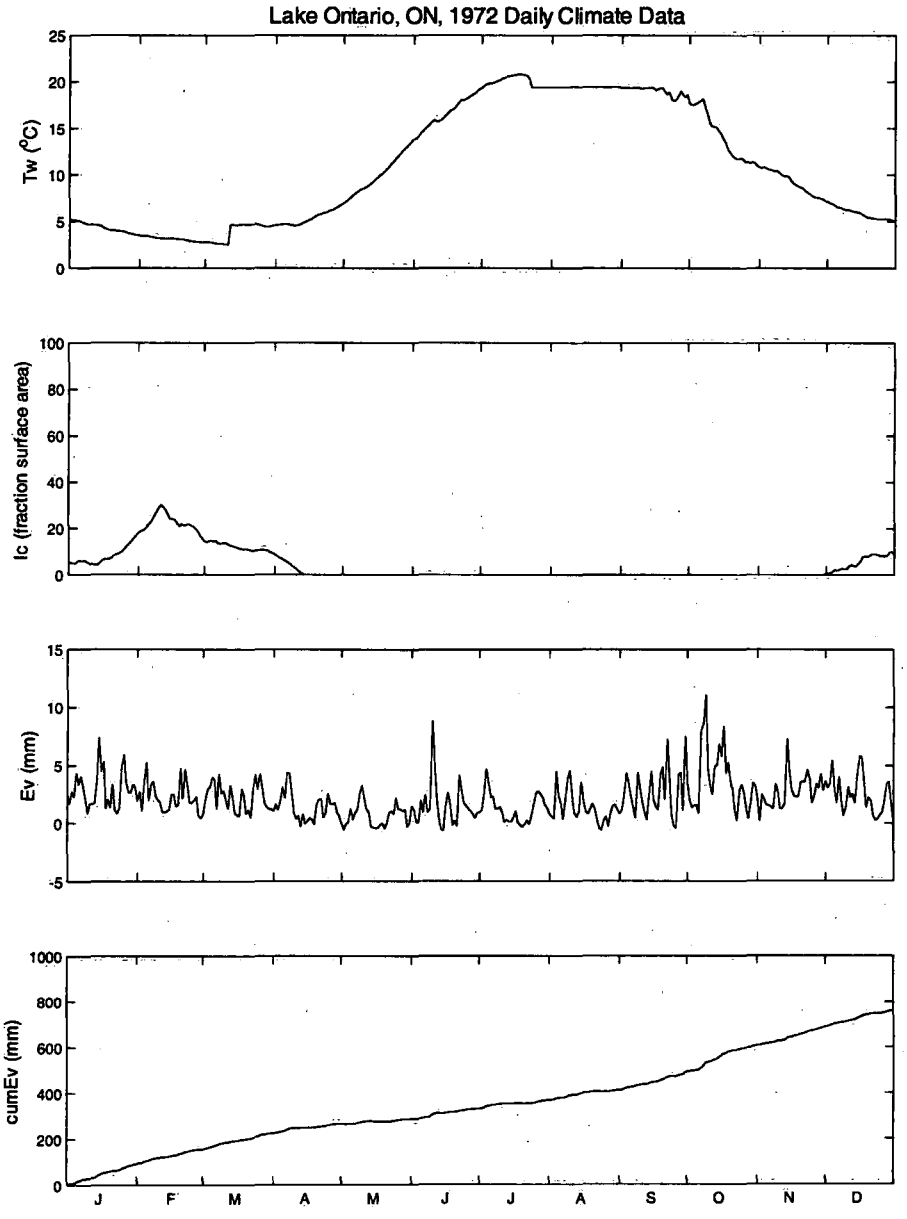
Lake Ontario, ON, 1972 Daily Climate Data
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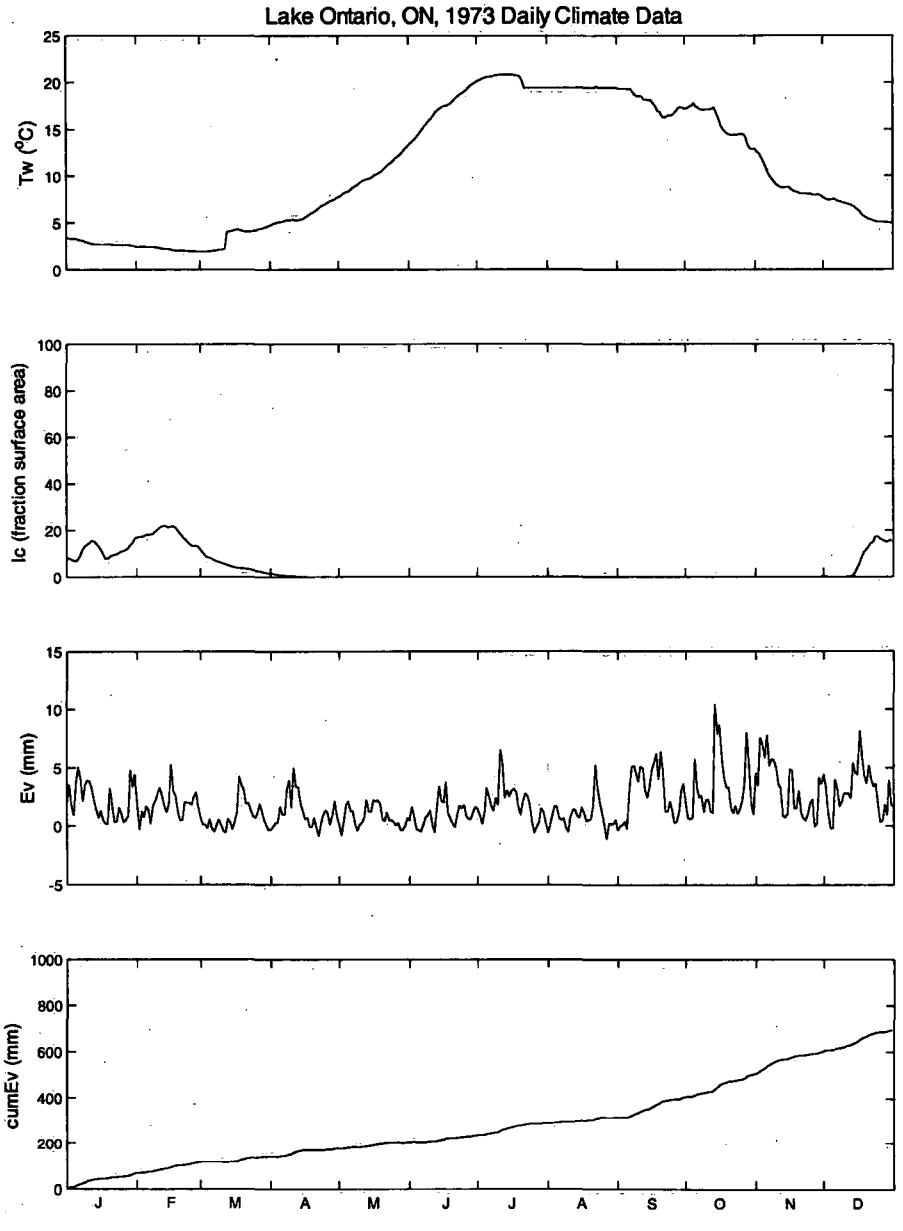
Lake Ontario, ON, 1973 Daily Climate Data
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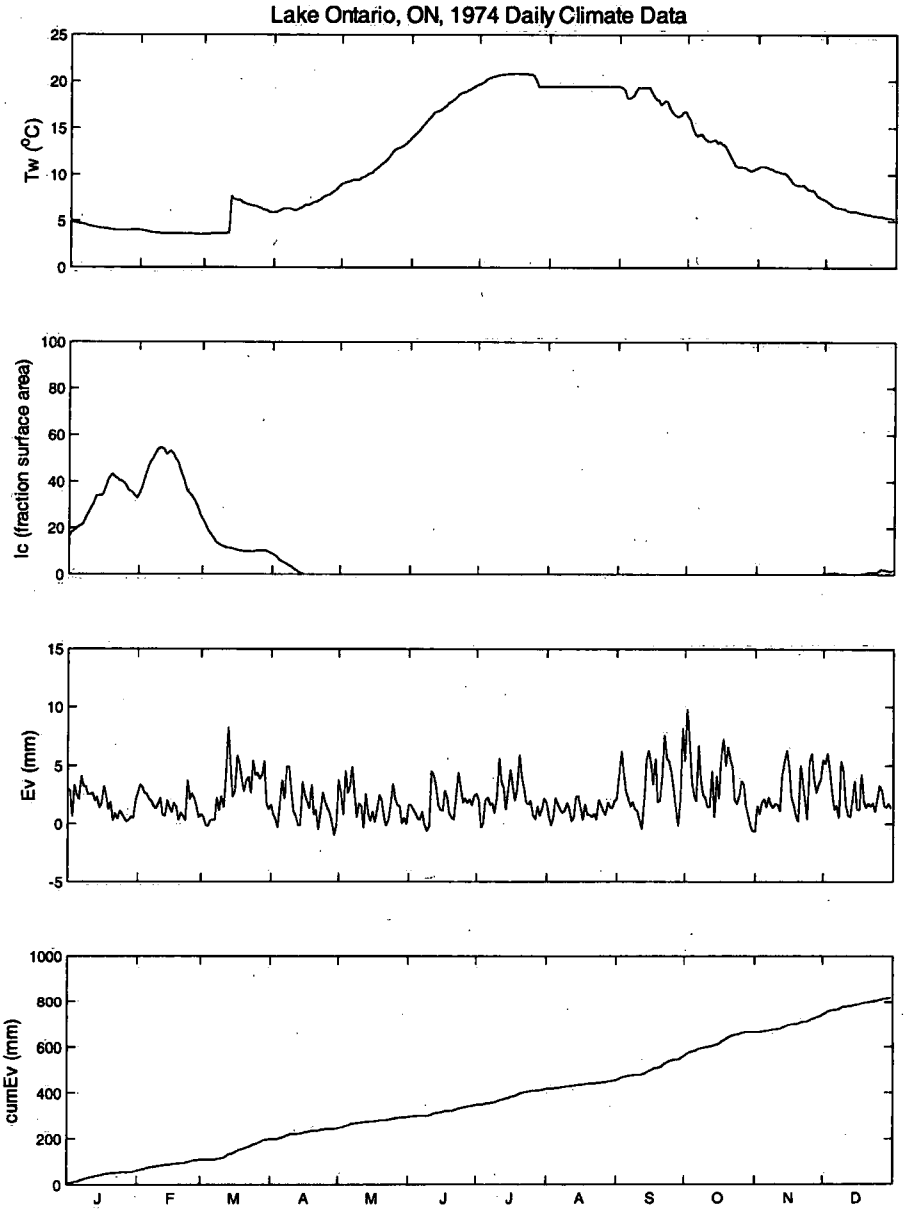
Lake Ontario, ON, 1974 Daily Climate Data
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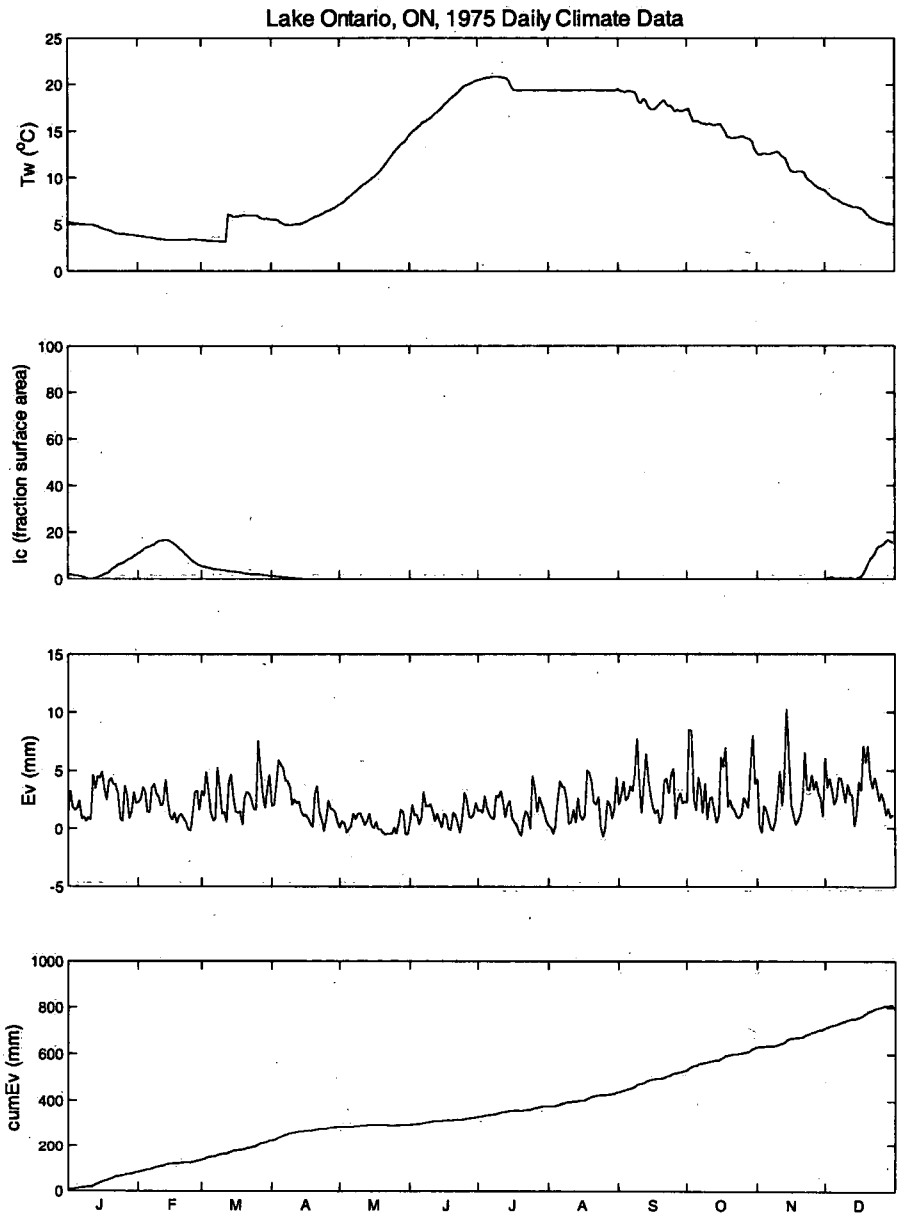
Lake Ontario, ON, 1975 Daily Climate Data
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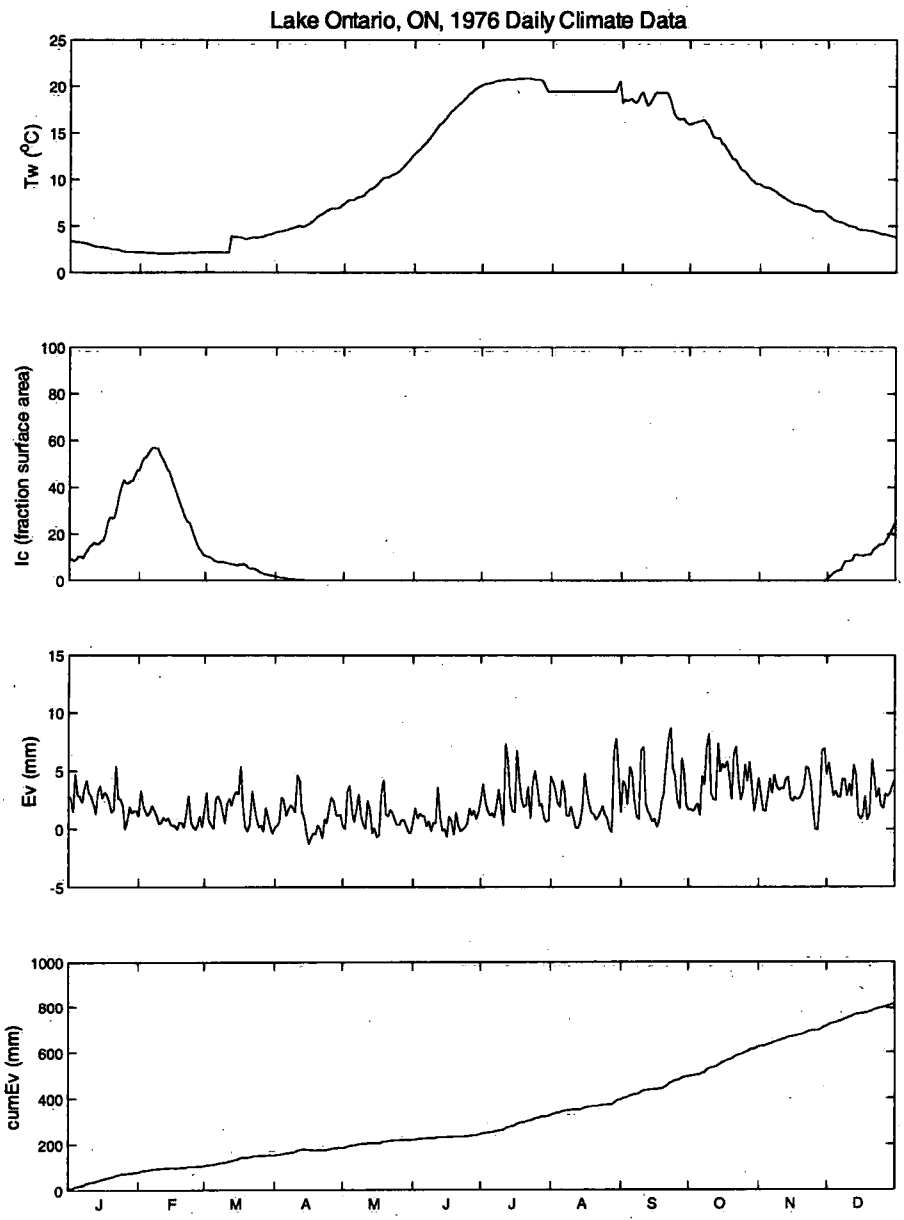
Lake Ontario, ON, 1976 Daily Climate Data
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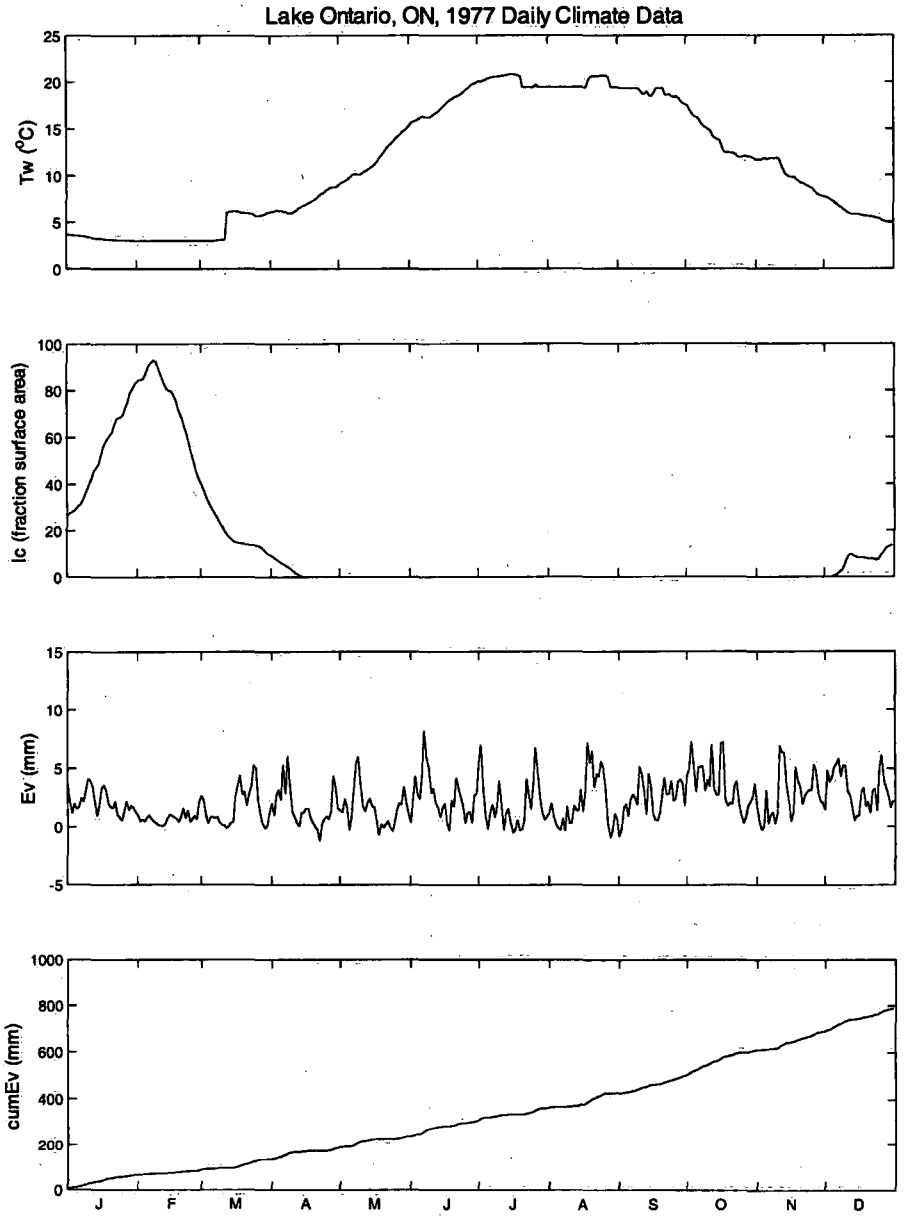
Lake Ontario, ON, 1977 Daily Climate Data
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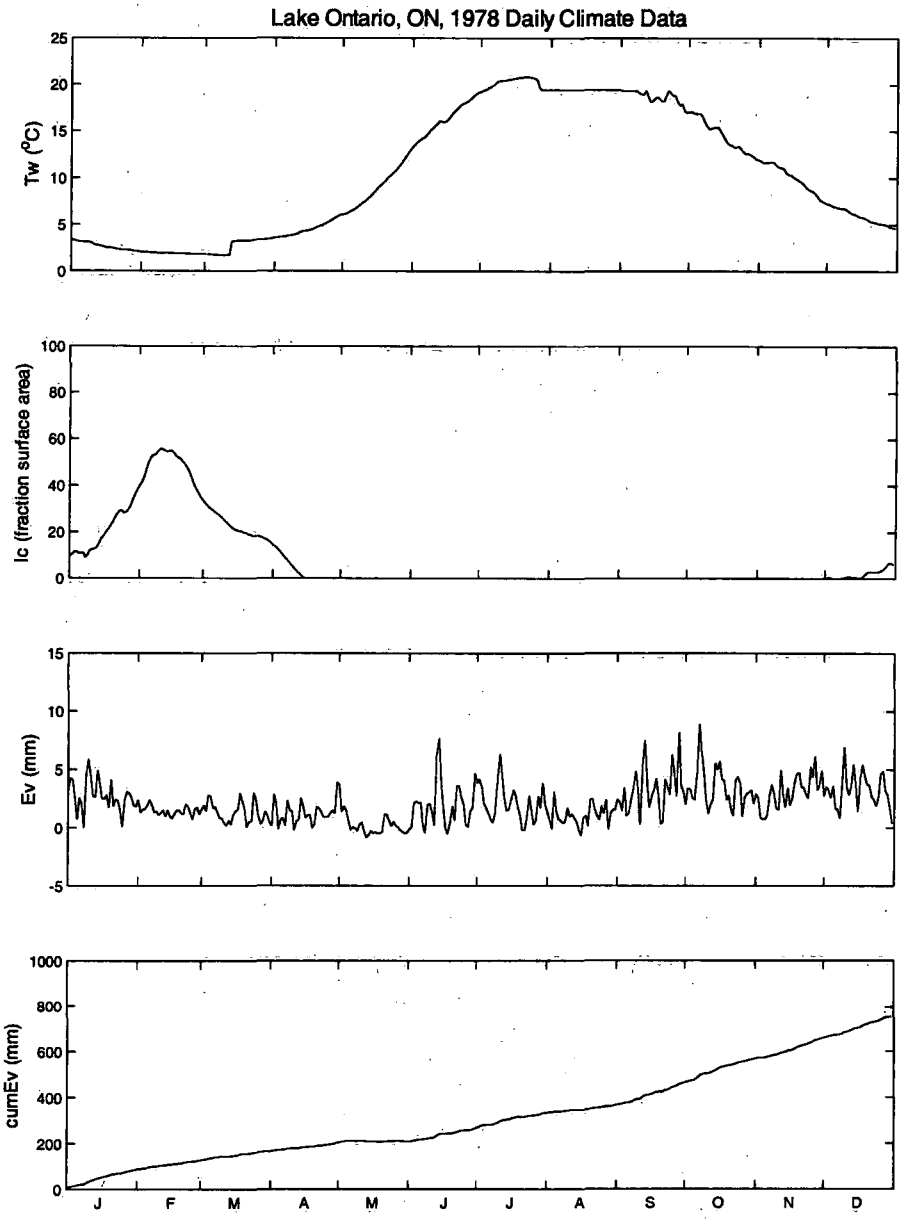
Lake Ontario, ON, 1978 Daily Climate Data
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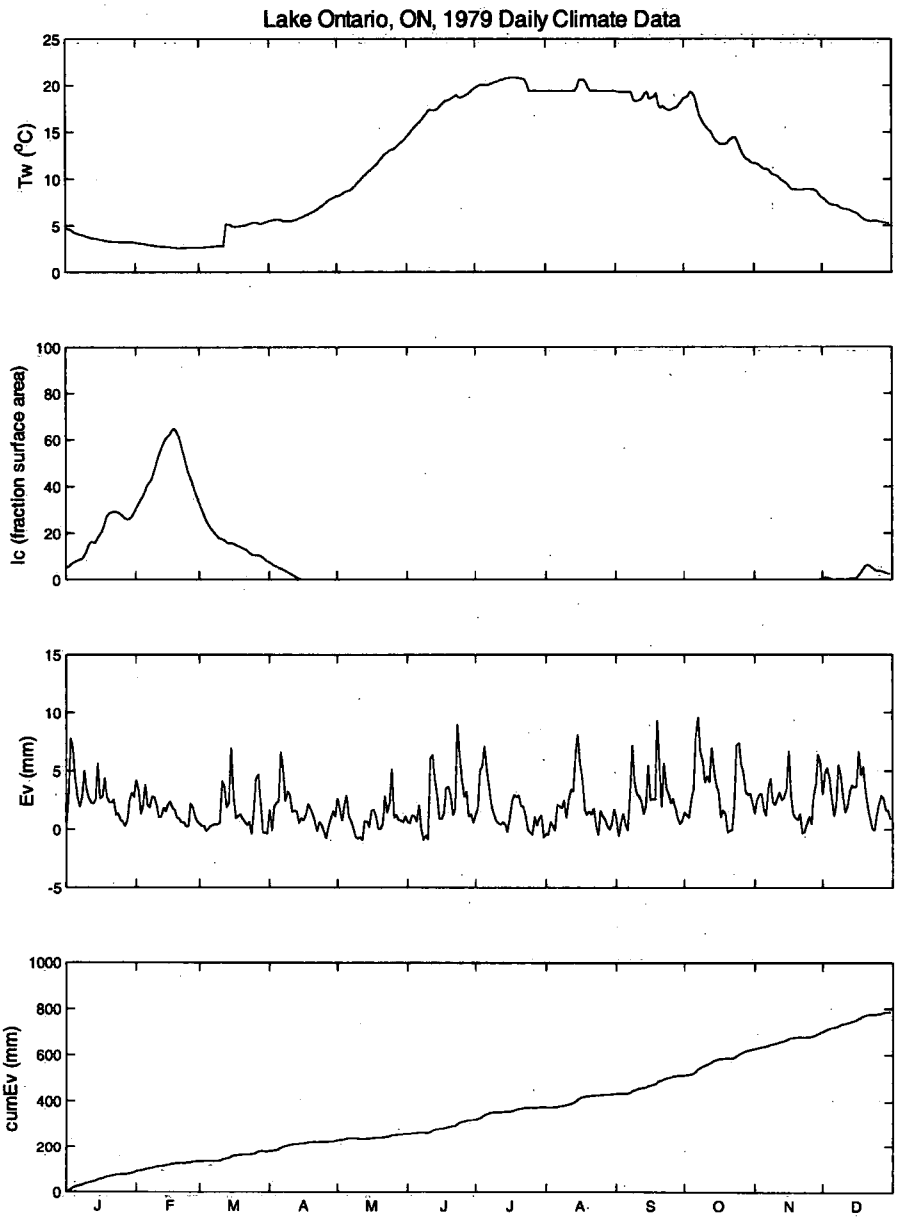
Lake Ontario, ON, 1979 Daily Climate Data
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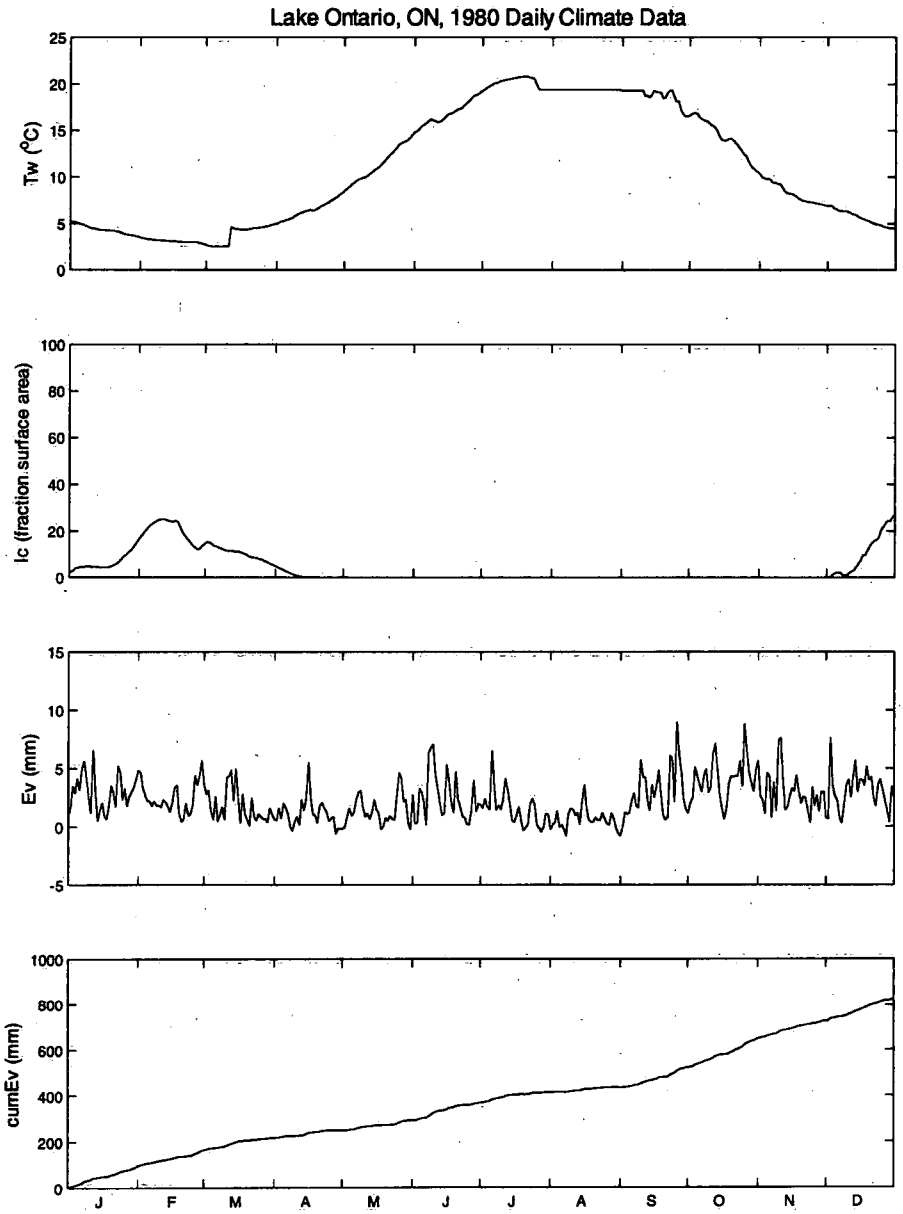
Lake Ontario, ON, 1980 Daily Climate Data
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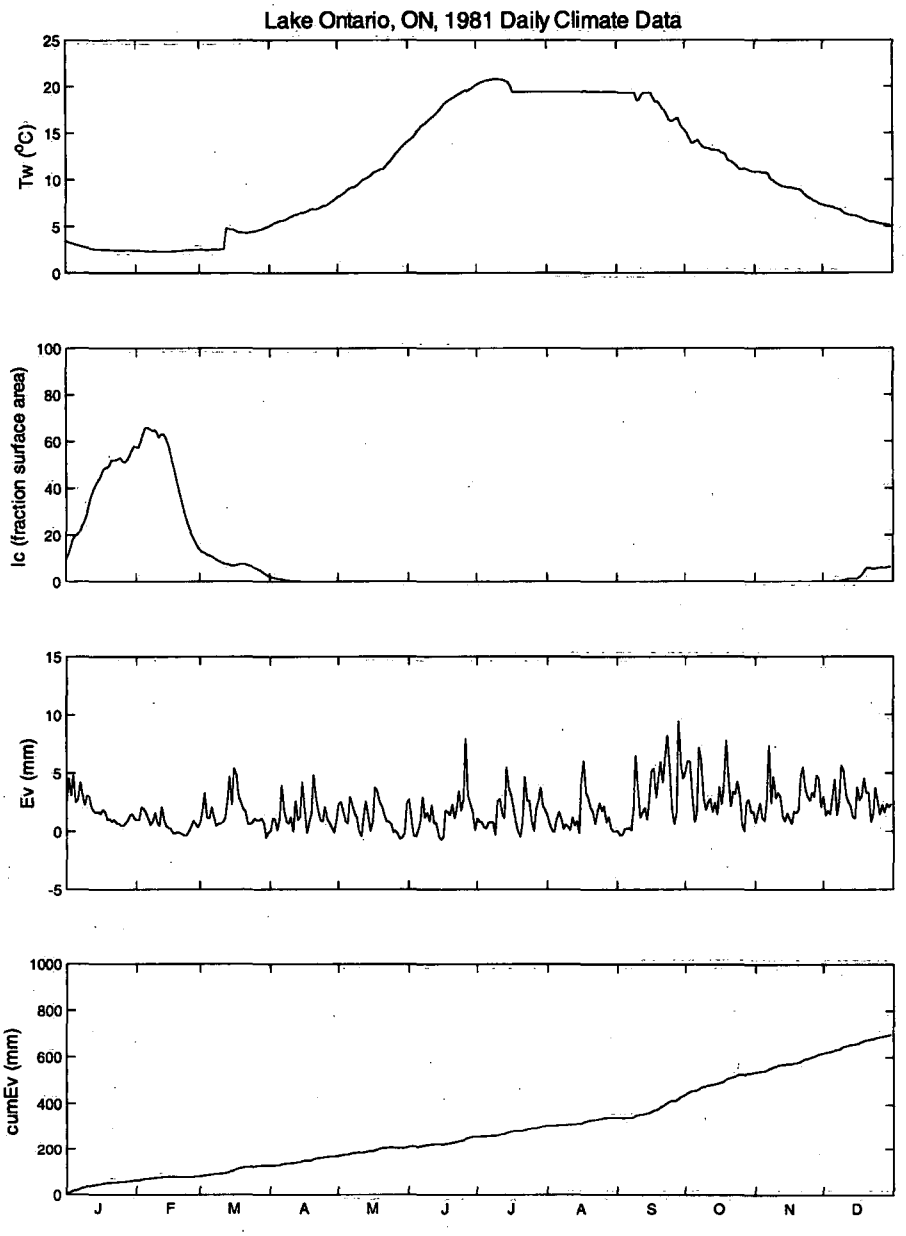
Lake Ontario, ON, 1981 Daily Climate Data
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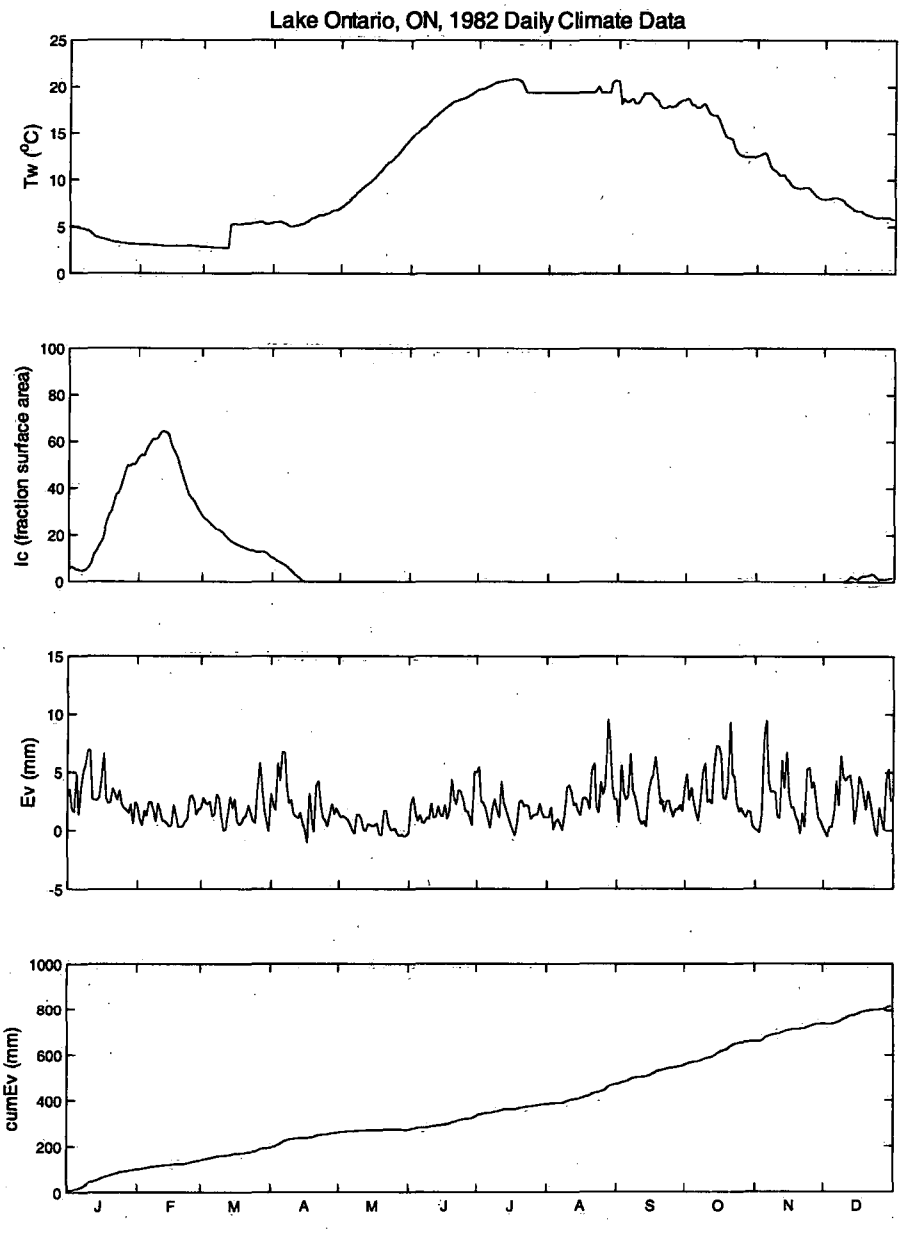
Lake Ontario, ON, 1982 Daily Climate Data
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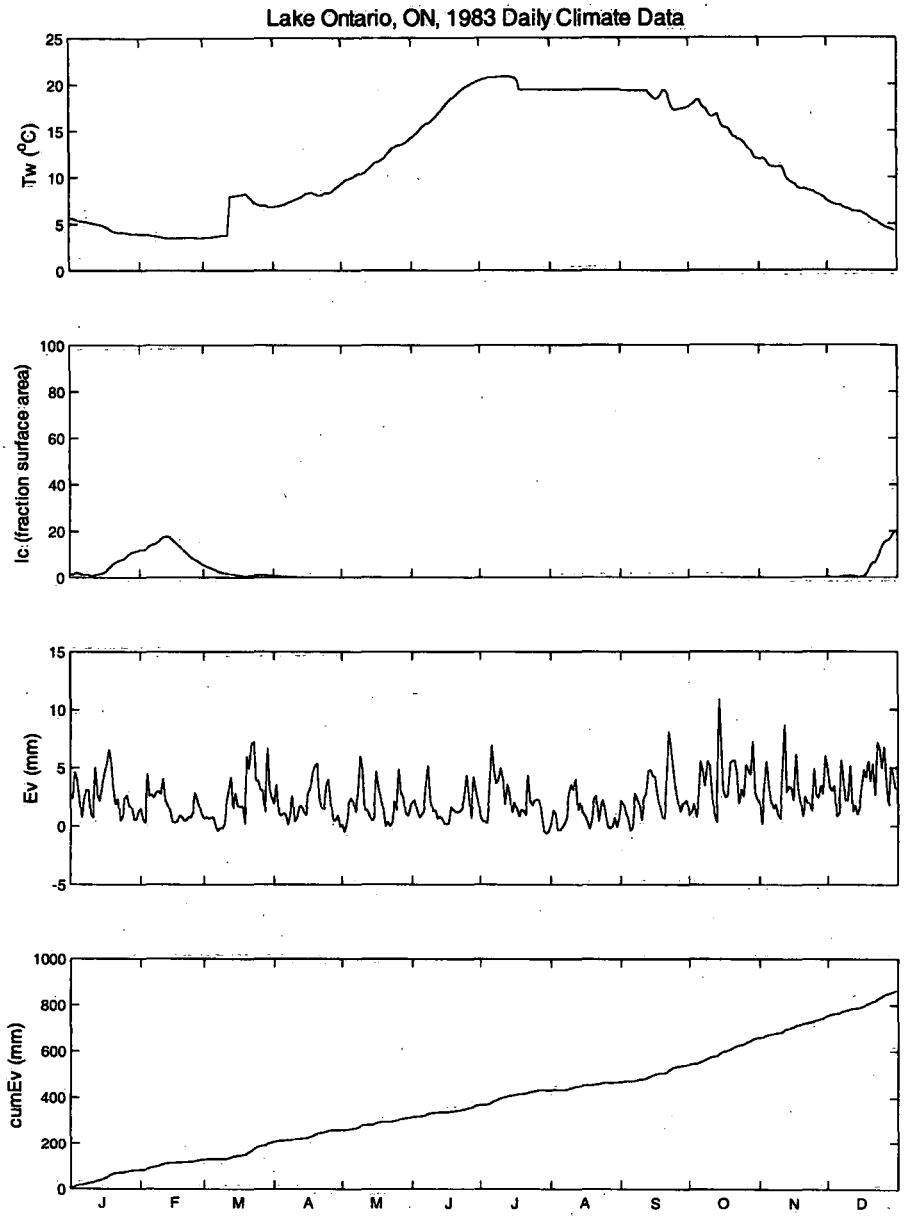
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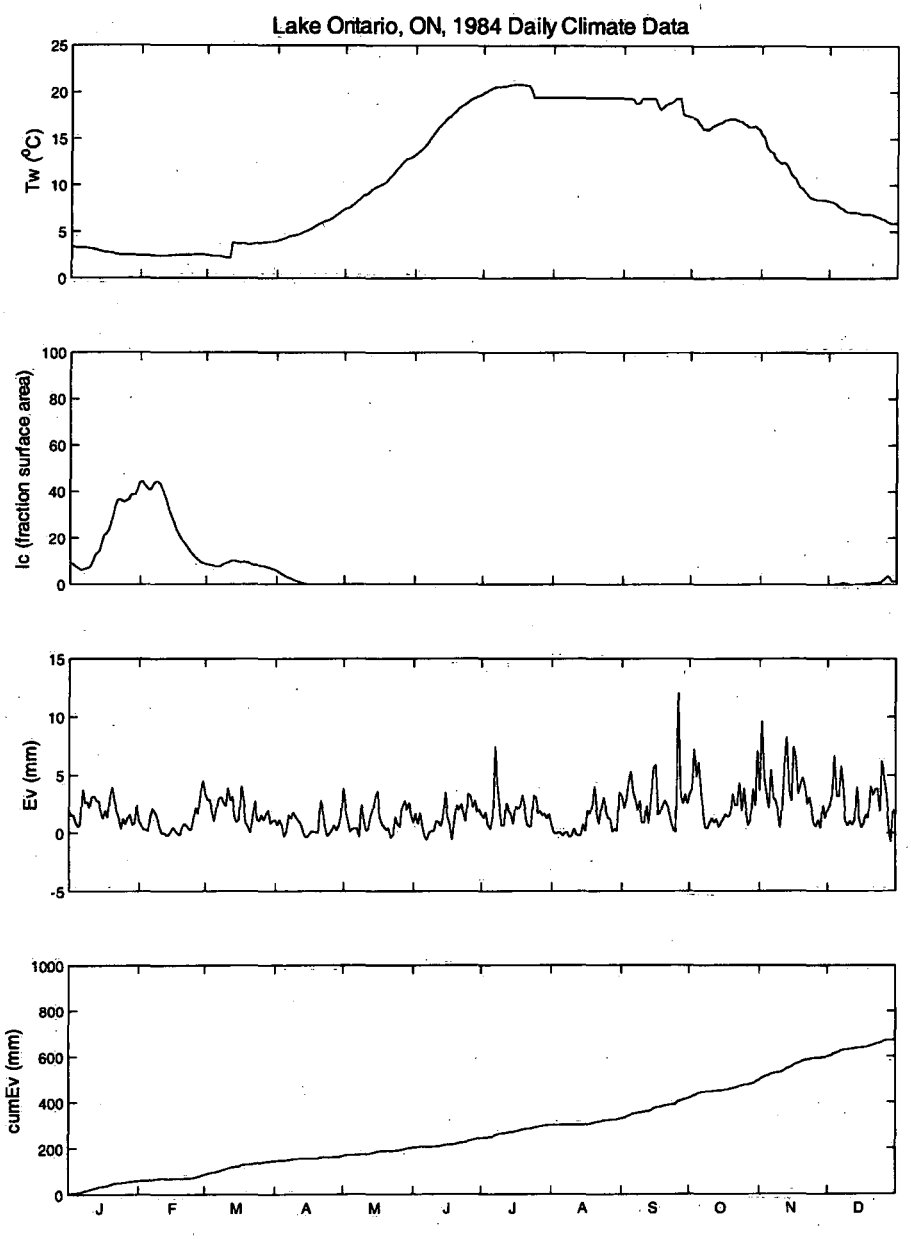
Lake Ontario, ON, 1984 Daily Climate Data
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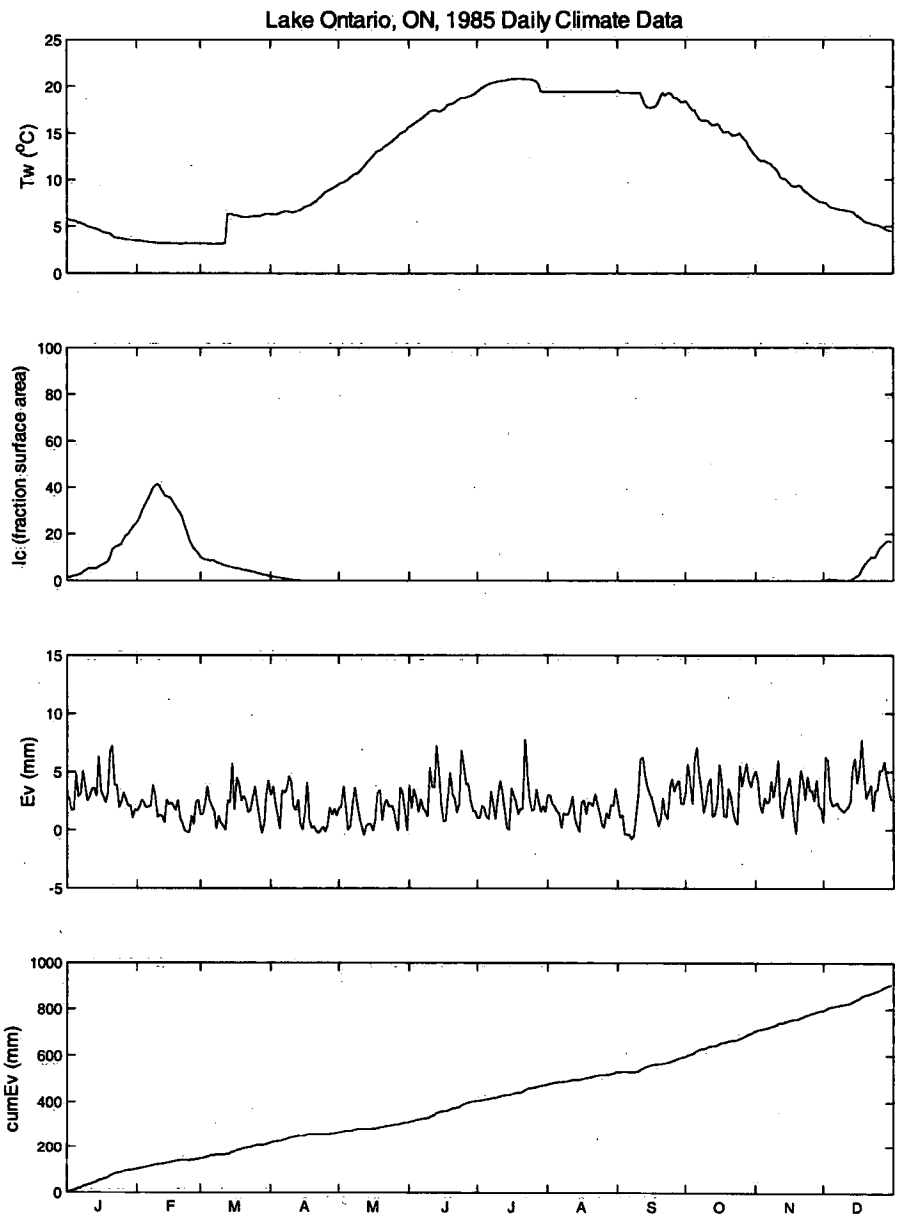
Lake Ontario, ON, 1985 Daily Climate Data
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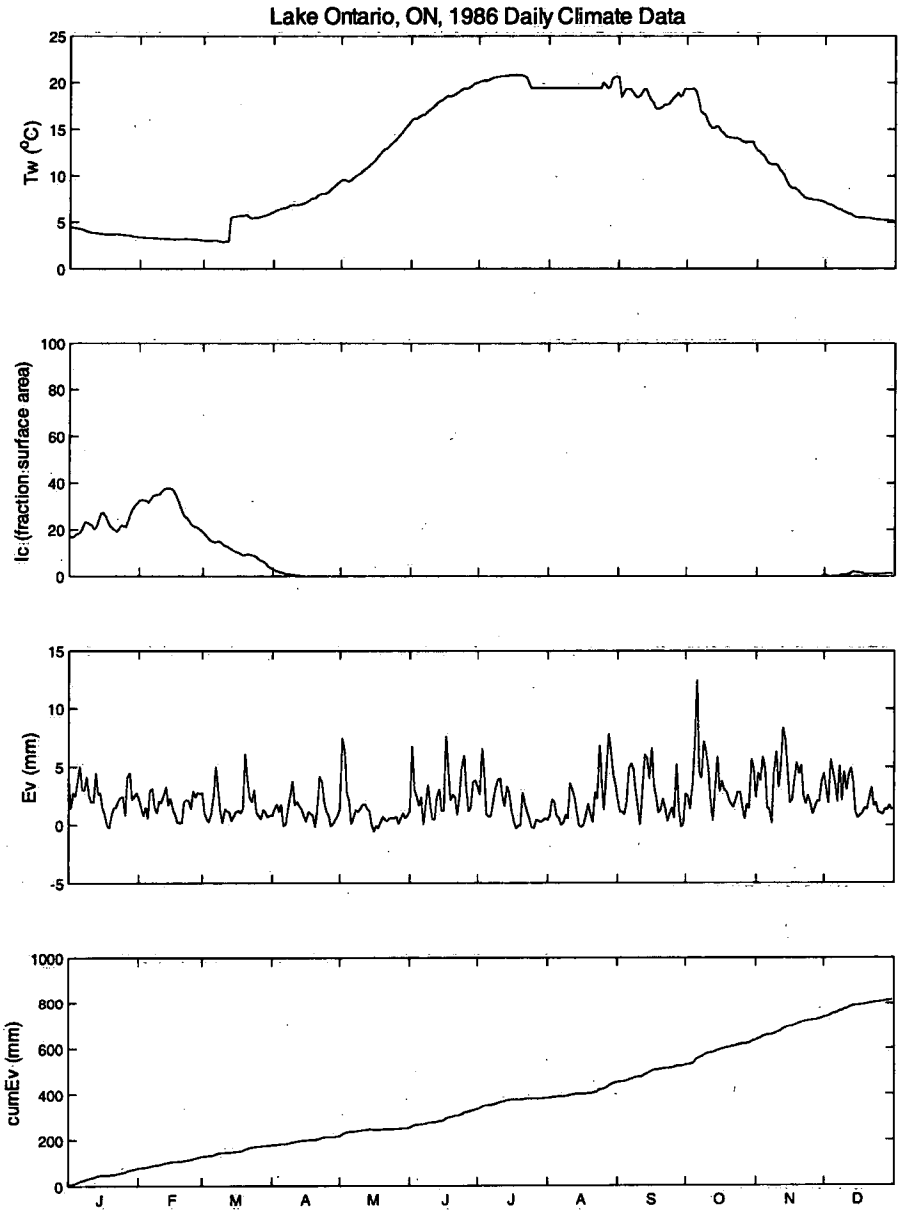
Lake Ontario, ON, 1986 Daily Climate Data
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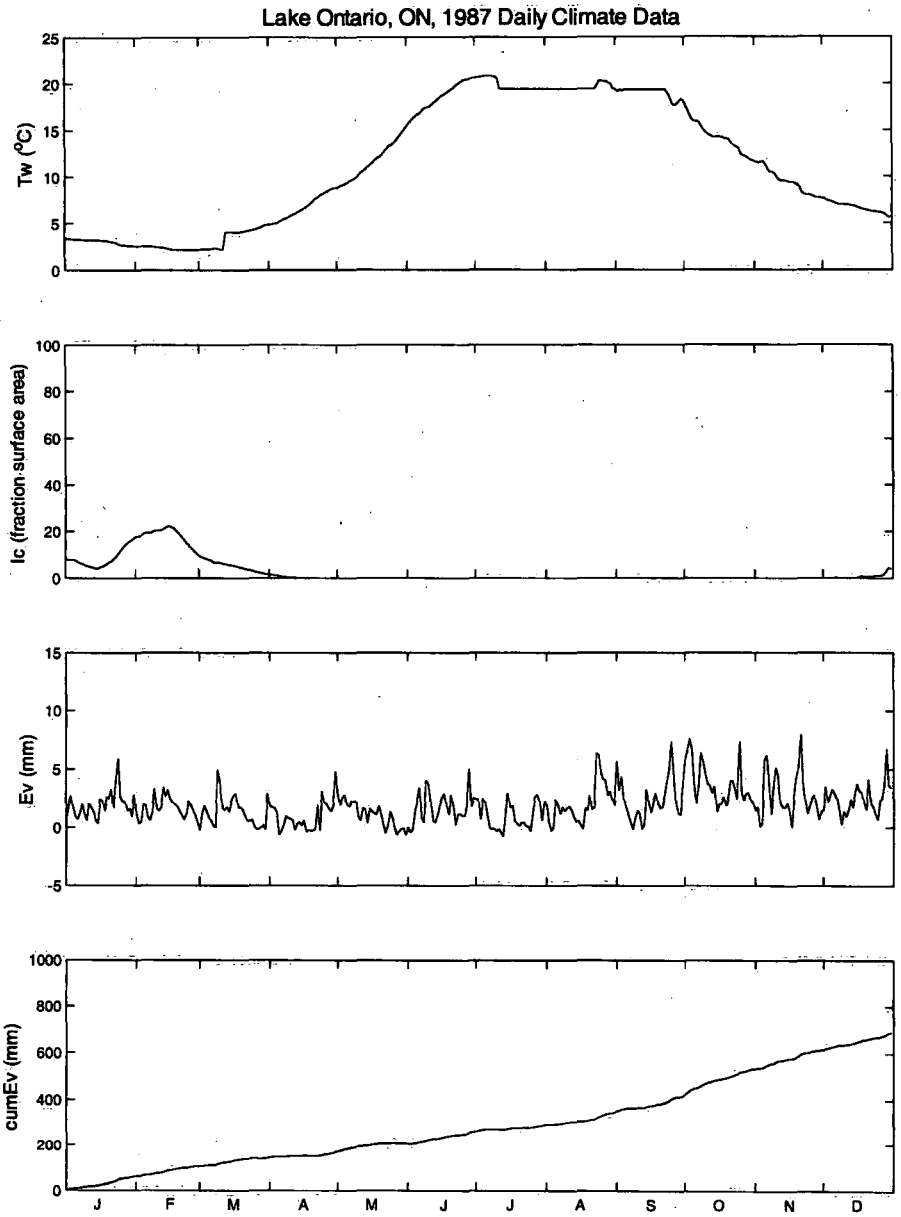
Lake Ontario, ON, 1987 Daily Climate Data
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Ic (fraction surface area)
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cumEv (mm)
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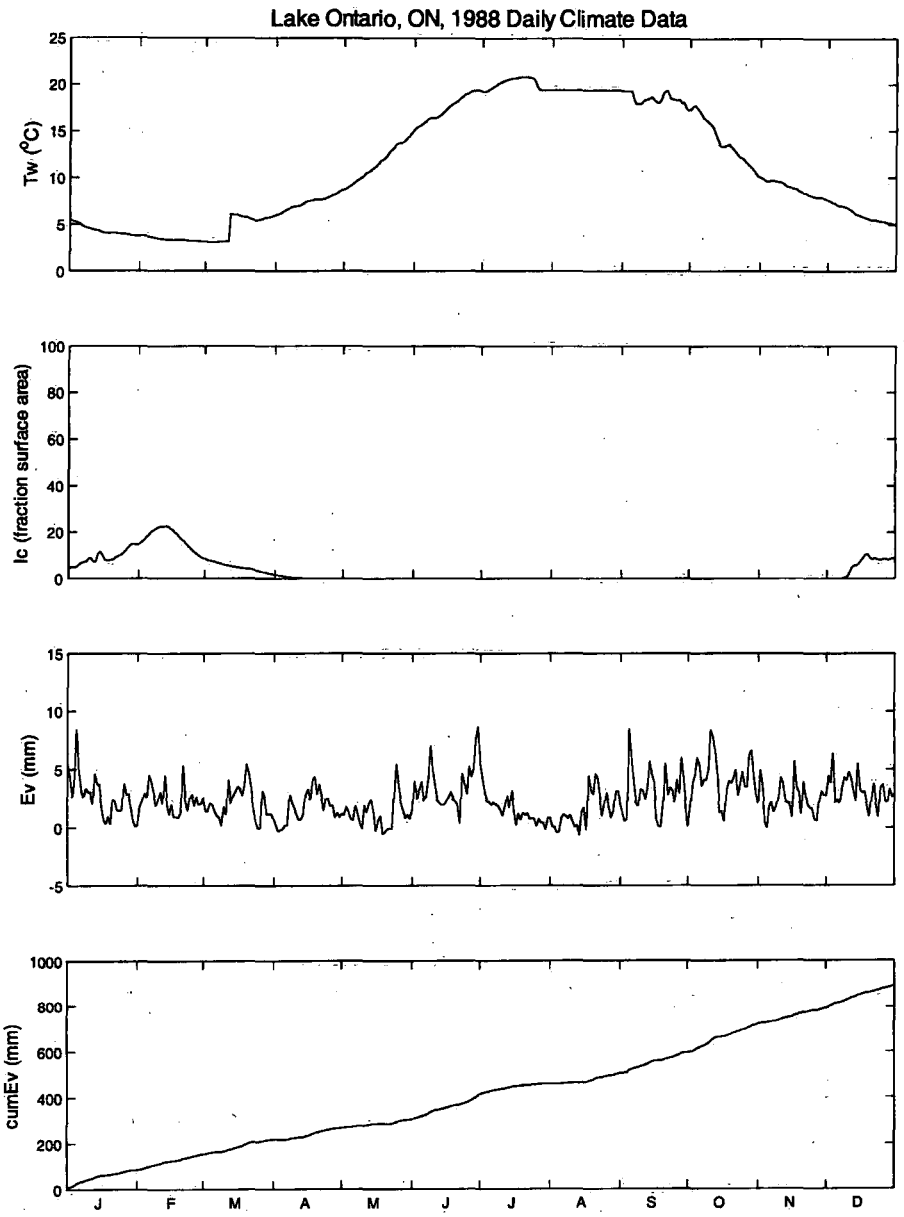
Lake Ontario, ON, 1988 Daily Climate Data
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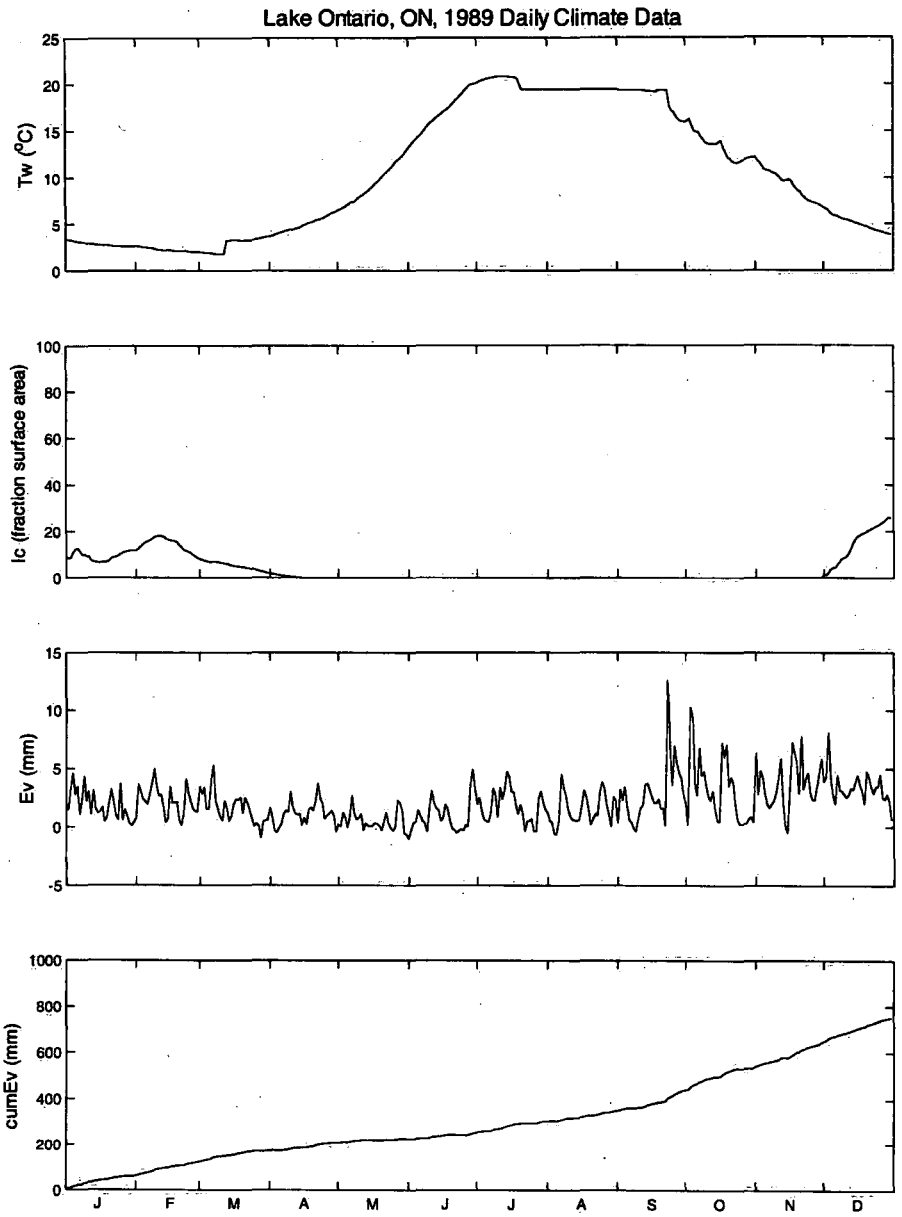
Lake Ontario, ON, 1989 Daily Climate Data
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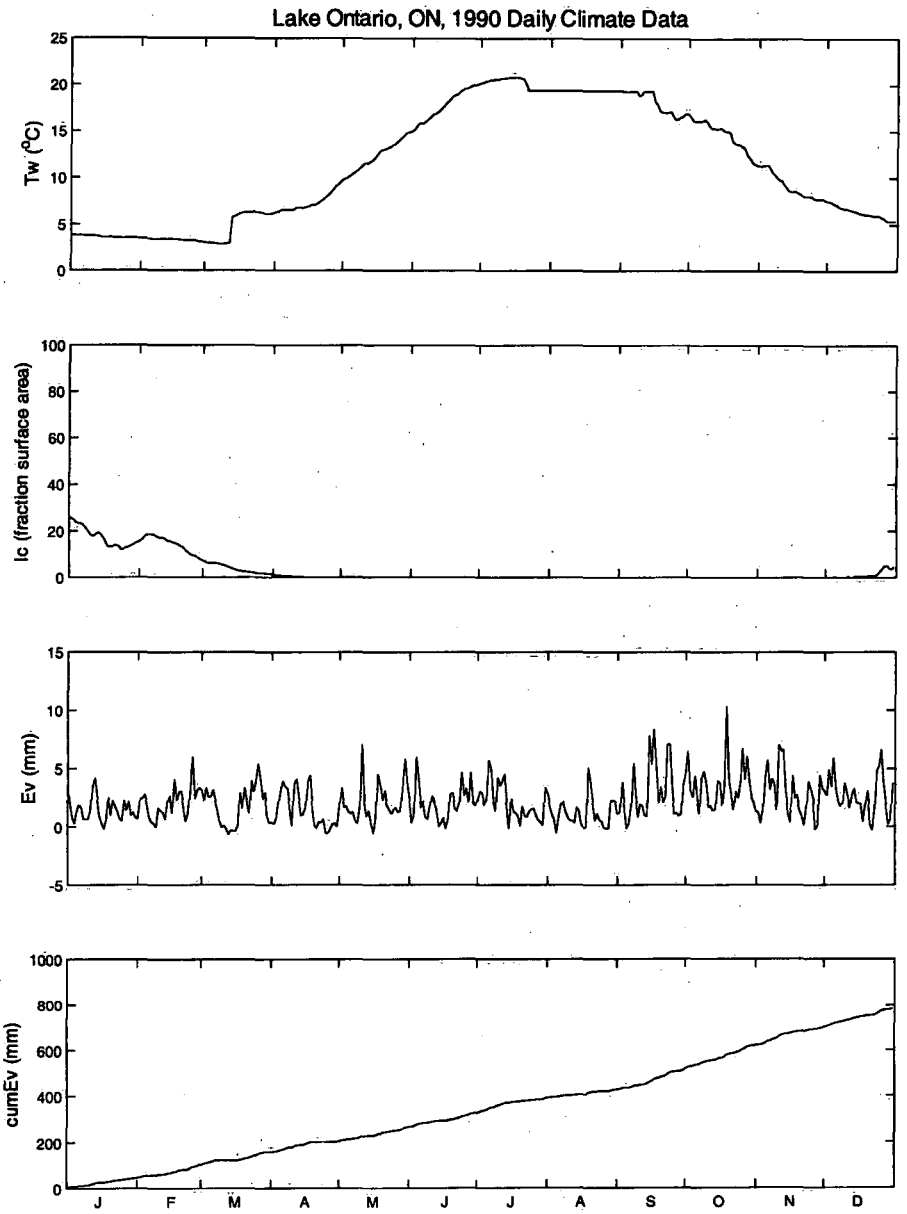
Lake Ontario, ON, 1990 Daily Climate Data
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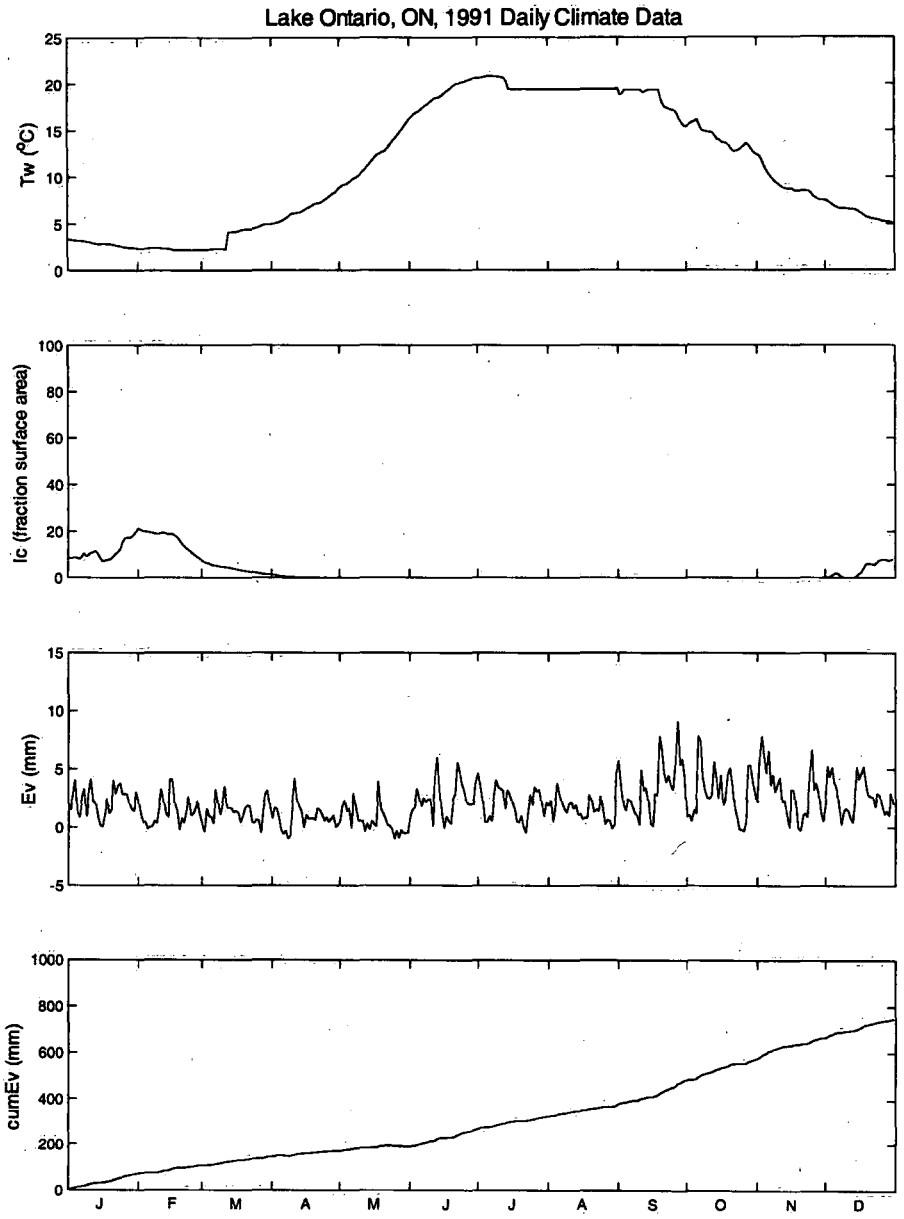
Lake Ontario, ON, 1991 Daily Climate Data
Tw (°C)
Ic (fraction surface area)
Ev (mm)
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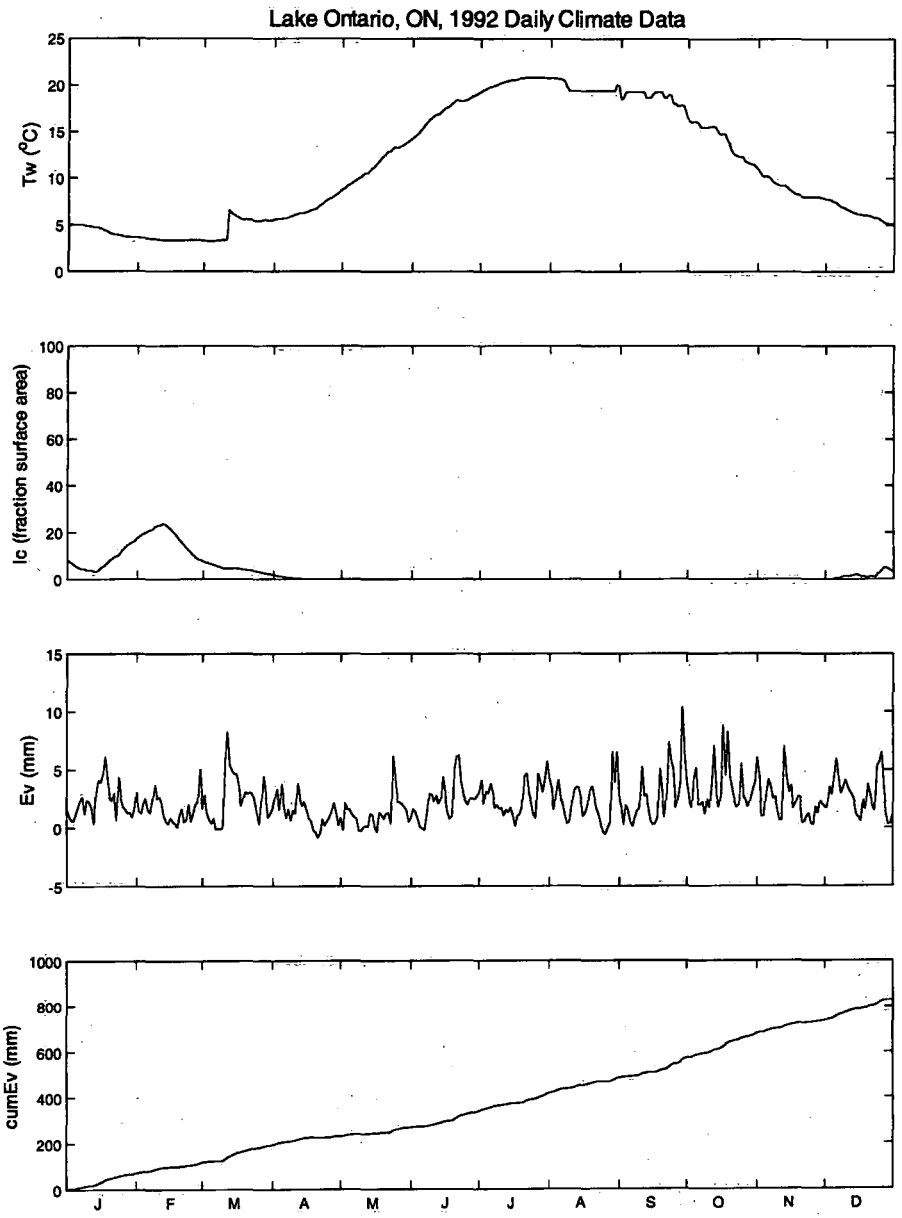
Lake Ontario, ON, 1992 Daily Climate Data
Tw (°C)
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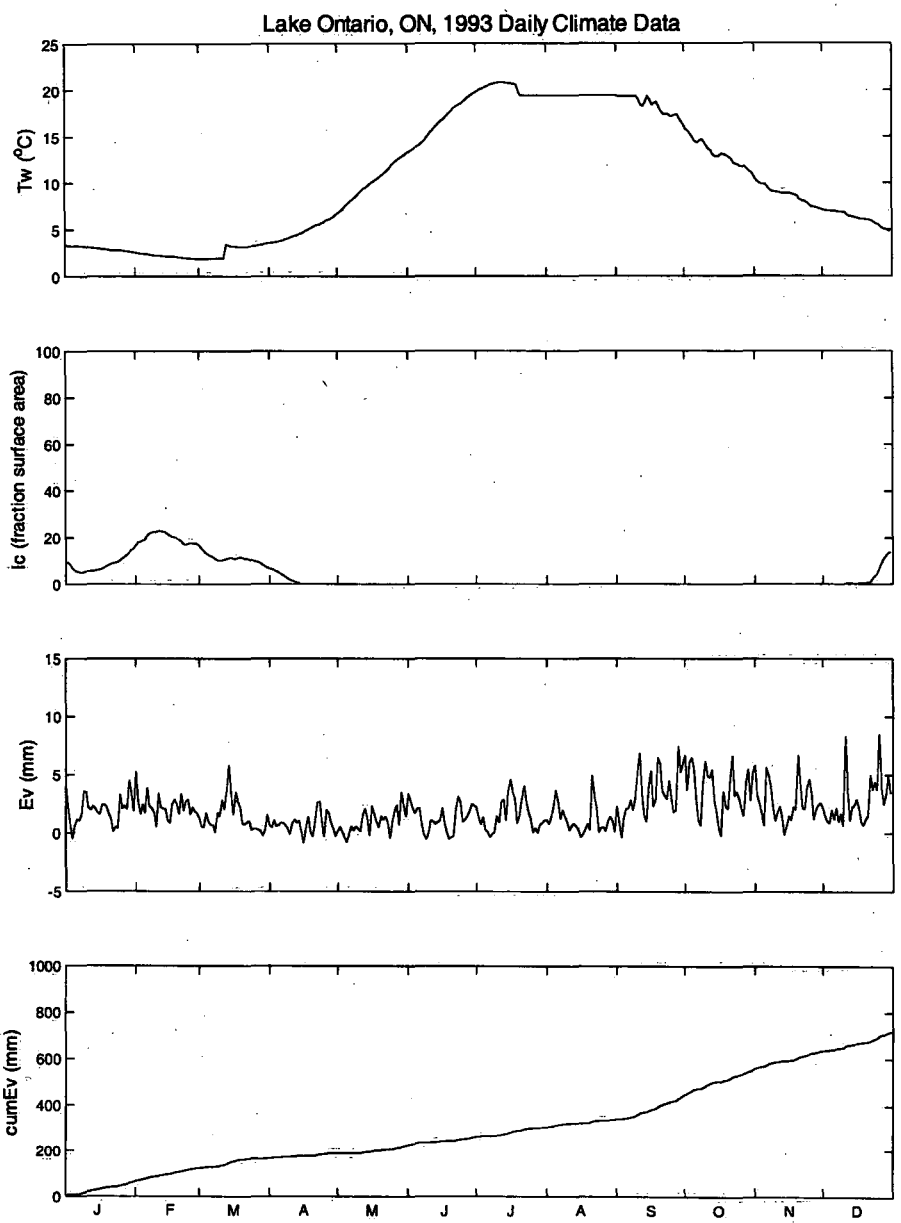
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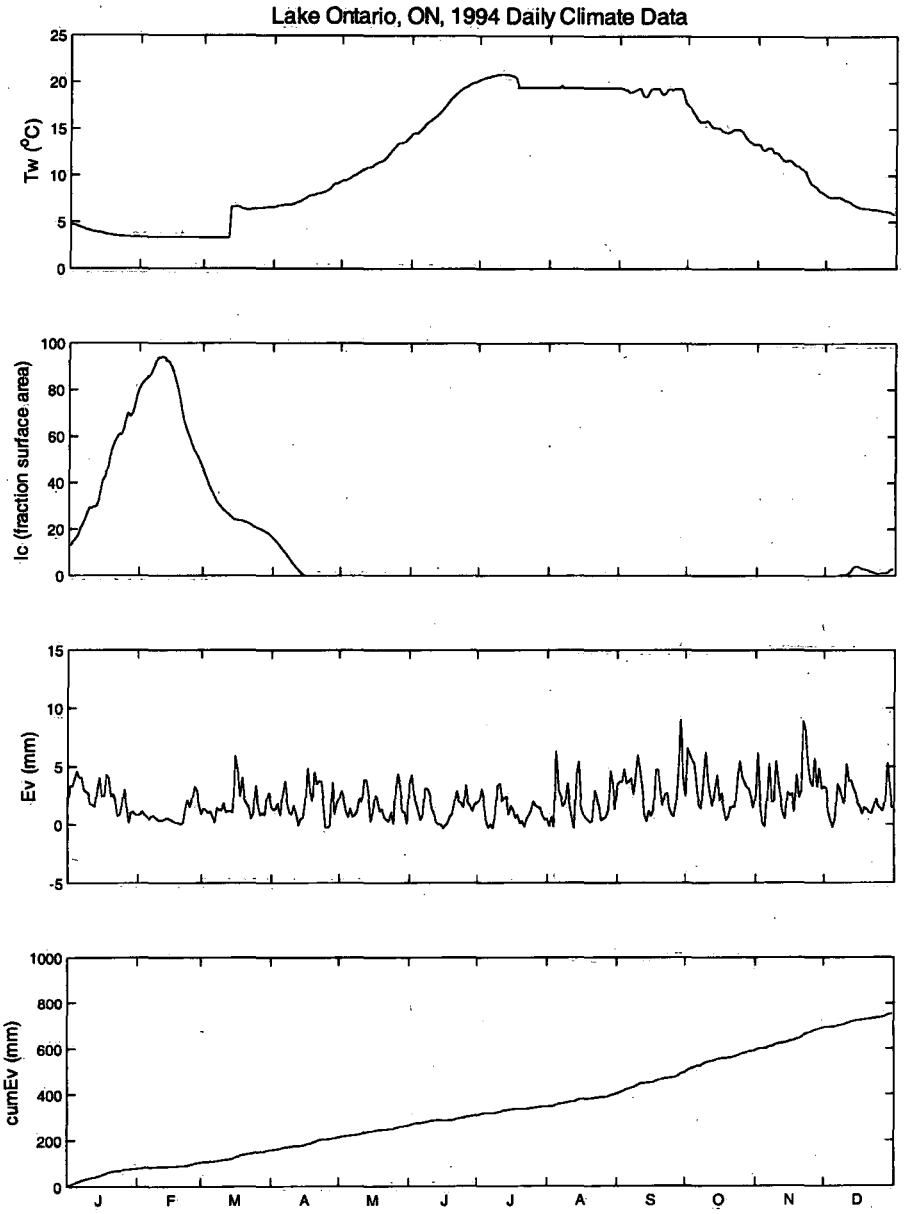
Lake Ontario, ON, 1994 Daily Climate Data
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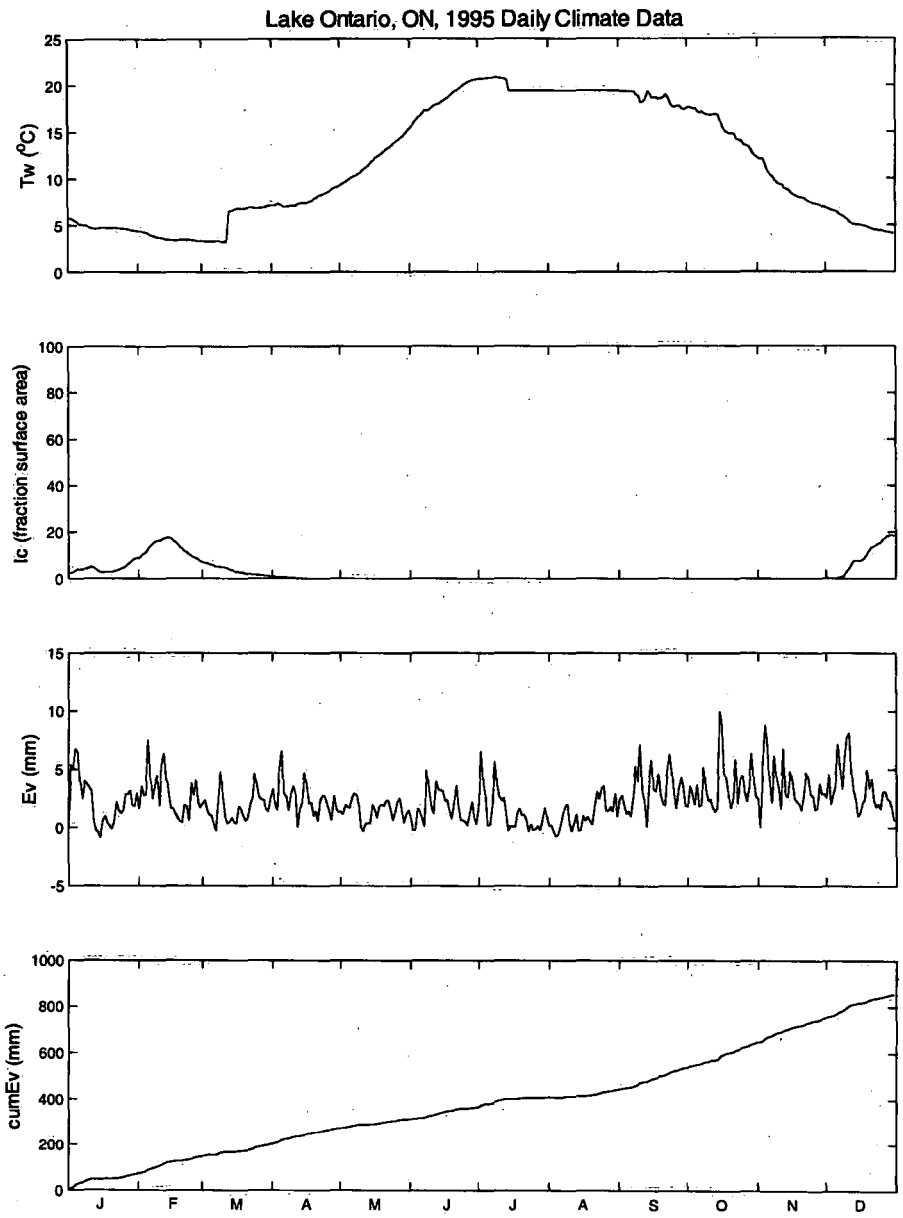
Lake Ontario, ON, 1995 Daily Climate Data
Tw (°C)
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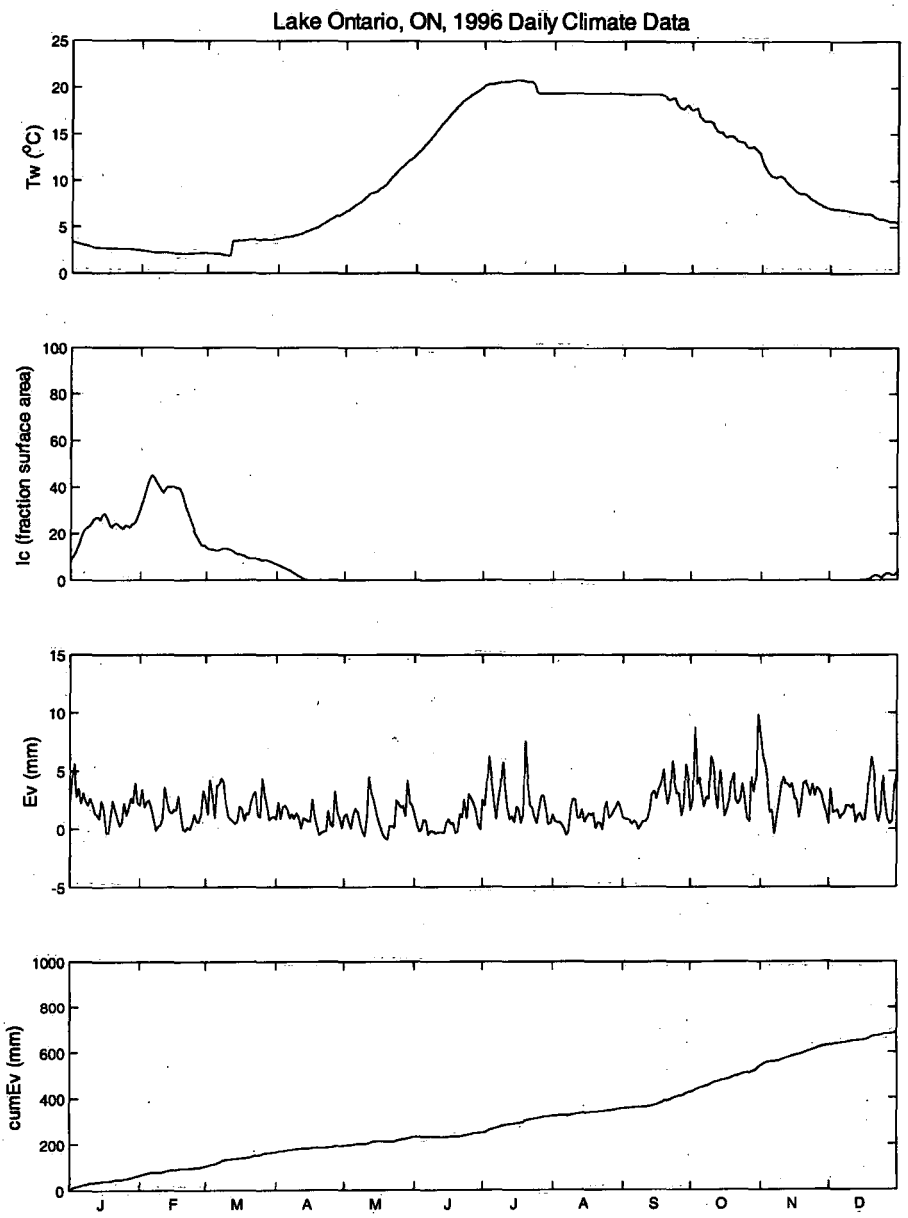
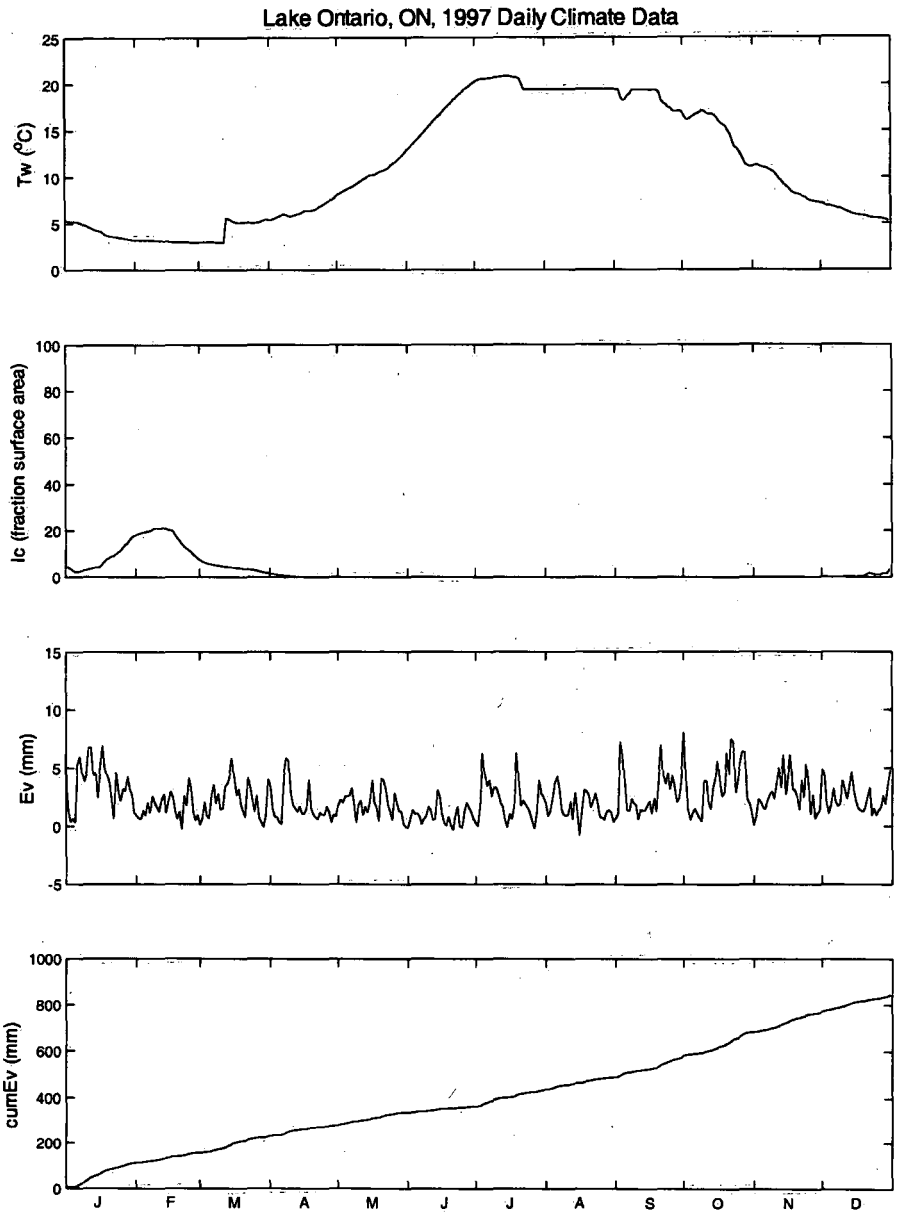
D


Lake Ontario, ON, 1996 Daily Climate Data
Tw (°C)
Ic (fraction surface area)
Ev (mm)
cumEv (mm)
J
F
M
A
M
J
J
A
S
O
N
D


Lake Ontario, ON, 1997 Daily Climate Data
Tw (°C)
Ic (fraction surface area)
Ev (mm)
cumEv (mm)
J
F
M
A
M
J
J
A
S
O
N
D

Appendix 7
MATLAB Scripts

ConvertOntario.m

Reads data form the original data files and generates a MATLAB compatible data files (one per year). These files are formatted to be compatible the "textread" function (comma delimited ASCII files). This script also generates a Cumulative Evaporation value. This conversion is done to simplify the process of reading in information and to greatly speed up the plotting of the data.

```
%For plotting Lake Ontario Data
%   Years 1953 - 1997

close all
clear all

year=0;
for  PlotYear = 1953: 1: 1997
close all

%Internal parameters
%PlotYear = 1965;

switch PlotYear
    case {1953, 1954, 1955}
        InFile = 'ontf5355.flx';
    case {1956, 1957}
        InFile = 'ontf5657.flx';
    case {1958, 1959, 1960}
        InFile = 'ontf5860.flx';
    case {1961, 1962}
        InFile = 'ontf6162.flx';
    case {1963, 1964, 1965}
        InFile = 'ontf6365.flx';
    case {1966, 1967}
        InFile = 'ontf6667.flx';
    case {1968, 1969, 1970}
        InFile = 'ontf6870.flx';
    case {1971, 1972}
        InFile = 'ontf7172.flx';
    case {1973, 1974, 1975}
        InFile = 'ontf7375.flx';
    case {1976, 1977}
        InFile = 'ontf7677.flx';
```

```
    case {1978, 1979, 1980}
        InFile = 'ontf7880.flx';
    case {1981, 1982, 1983}
        InFile = 'ontf8183.flx';
    case {1984, 1985, 1986}
        InFile = 'ontf8486.flx';
    case {1987, 1988}
        InFile = 'ontf8788.flx';
    case {1989, 1990}
        InFile = 'ontf8990.flx';
    case {1991, 1992}
        InFile = 'ontf9192.flx';
    case {1993, 1994, 1995}
        InFile = 'ontf9396.flx';
    case {1996, 1997}
        InFile = 'ontf9697.flx';
    otherwise
        InFile = '';
end

OutFile = sprintf('L_Ontario_%d.txt', PlotYear);
PrintFile = sprintf('L_Ontario_%d', PlotYear)

%Read the file; reformat it; save it in its new textread friendly format.
fid=fopen(InFile,'r');
fid_out=fopen(OutFile,'w');
%Print a header row
fprintf(fid_out,'year, ordinal, Kd, Ku, Ld, Lu, Q*, Uk, Ta, Td, Rh, Tw, As, Qh, Qe, Ev, Qi,
Ic, Qm, Qt, Qc, cumEv\r\n');
count=0;
linecount=0;
SkipLine=0;
clear cumEv;
cumEv=0;
while (~feof(fid) & year <= PlotYear)
    line=fgetl(fid);

    clear matches;
    matches=findstr(line,'****');
    MatchCount=length(matches);
    if (MatchCount > 0)
        SkipLine=1;
    end
```

```
count=count+1;
if (count>3)
    clear c1 c2 c3 c4 c5 c6 c7 c8
    linecount=linecount+1;
    switch linecount
        case 1
            [year,month,day,ordinal,id]=strread(line,' %d %d %d %d %d');
        case 2
            if ((MatchCount == 0) & (year == PlotYear))
                [Kd,Ku,Ld,Lu,Q,Uk,Ta,Td]=strread(line,' %f %f %f %f %f %f %f %f');
            end
        case 3
            if ((MatchCount == 0) & (year == PlotYear))
                [Rh,Tw,As,Qh,Qe,Ev,Qi,Ic]=strread(line, ' %f %f %f %f %f %f %f %f');
                if (Ev ~= -999.99)
                    if (count == 6)
                        cumEv = Ev;
                    else
                        cumEv = cumEv + Ev;
                    end
                else
                    Ev = NaN;
                end
            end
        otherwise
            if ((MatchCount == 0) & (year == PlotYear))
                [Qm,Qt,Qc]=strread(line,' %f %f %f');
            end

            linecount=0;
            if (SkipLine==0)
                if (year==PlotYear)
                    fprintf(fid_out,'%d, %d, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f,
%f, %f, %f, %f, %f, %f, %f, %f, %f\r\n',...

year,ordinal,Kd,Ku,Ld,Lu,Q,Uk,Ta,Td,Rh,Tw,As,Qh,Qe,Ev,Qi,Ic,Qm,Qt,Qc,cumEv);
                end
            end
            SkipLine=0;
    end
else
    linecount=0;
end
```

```
end
fclose(fid);
fclose(fid_out);

end
```

OntarioMonthly.m

This script reads data from the converted yearly files and generates three comma delimited (.csv) files containing monthly Max, Min and Mean values (1953 through 1997).

```
% Script To generate Monthly summaries.

StartYear = 1953;
EndYear = 1997;
OutFile_Mean = 'L_Ontario_Monthly_Mean.csv';
OutFile_Max = 'L_Ontario_Monthly_Max.csv';
OutFile_Min = 'L_Ontario_Monthly_Min.csv';

% Define a data structure.
ds = struct('Year',{},'Data',{});

% Read in the data,
for  PlotYear = StartYear: 1: EndYear
    close all

    InFile = sprintf('L_Ontario_%d.txt', PlotYear);


[year,ordinal,Kd,Ku,Ld,Lu,Q,Uk,Ta,Td,Rh,Tw,As,Qh,Qe,Ev,Qi,Ic,Qm,Qt,Qc,cumEv]=textread(InFile
,...
        ' %d %d %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f',...
        'headerlines',1,'delimiter',',');
    data=[year,ordinal,Kd,Ku,Ld,Lu,Q,Uk,Ta,Td,Rh,Tw,As,Qh,Qe,Ev,Qi,Ic,Qm,Qt,Qc,cumEv];

    ds(PlotYear).Year=PlotYear;
    ds(PlotYear).Data=data;

    clear year ordinal Kd Ku Ld Lu Q Uk Ta Td Rh Tw As Qh Qe Ev Qi Ic Qm Qt Qc cumEv;
end

%Initialize the results file.
fid_mean=fopen(OutFile_Mean,'w');
fid_max=fopen(OutFile_Max,'w');
fid_min=fopen(OutFile_Min,'w');
```

```
%Print a header row
fprintf(fid_mean,'year, month, Kd, Ku, Ld, Lu, Q*, Uk, Ta, Td, Rh, Tw, As, Qh, Qe, Ev, Qi,
Ic, Qm, Qt, Qc, cumEv\r\n');
fprintf(fid_max,'year, month, Kd, Ku, Ld, Lu, Q*, Uk, Ta, Td, Rh, Tw, As, Qh, Qe, Ev, Qi,
Ic, Qm, Qt, Qc, cumEv\r\n');
fprintf(fid_min,'year, month, Kd, Ku, Ld, Lu, Q*, Uk, Ta, Td, Rh, Tw, As, Qh, Qe, Ev, Qi,
Ic, Qm, Qt, Qc, cumEv\r\n');


%Calculate the Monthly means.
for  PlotYear = StartYear: 1: EndYear   %Loop through the years.
    clear MMean MMax MMin;

    %Determine the start and ends ordinal date for each month.
    IsLeap = mod(PlotYear,4);
    if (IsLeap == 0)    %0 represents a leap year.
        Month_Start = [1 32 61 92 122 153 183 214 245 275 306 336];
        Month_End = [31 60 91 121 152 182 213 244 274 305 335 366];
    else
        Month_Start = [1 32 60 91 121 152 182 213 244 274 305 335];
        Month_End = [31 59 90 120 151 181 212 243 273 304 334 365];
    end

    for i = 1: 1: 12    %Loop through the months.
        %Kd
        clear FD Filtered ii
        FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),3);
        [ii] = find(FD ~= -999.99);
        Filtered = FD(ii);
        if (size(Filtered) > 0)
            MMean(i,3) = mean(Filtered);
            MMax(i,3) = max(Filtered);
            MMin(i,3) = min(Filtered);
        else
            MMean(i,3) = -999.99;
            MMax(i,3) = -999.99;
            MMin(i,3) = -999.99;
        end
        %Ku
        clear FD Filtered ii
        FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),4);
        [ii] = find(FD ~= -999.99);
        Filtered = FD(ii);
        if (size(Filtered) > 0)
            MMean(i,4) = mean(Filtered);
```

```
    MMax(i,4) = max(Filtered);
    MMin(i,4) = min(Filtered);
else
    MMean(i,4) = -999.99;
    MMax(i,4) = -999.99;
    MMin(i,4) = -999.99;
end
%Ld
clear FD Filtered ii
FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),5);
[ii] = find(FD ~= -999.99);
Filtered = FD(ii);
if (size(Filtered) > 0)
    MMean(i,5) = mean(Filtered);
    MMax(i,5) = max(Filtered);
    MMin(i,5) = min(Filtered);
else
    MMean(i,5) = -999.99;
    MMax(i,5) = -999.99;
    MMin(i,5) = -999.99;
end
%Lu
clear FD Filtered ii
FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),6);
[ii] = find(FD ~= -999.99);
Filtered = FD(ii);
if (size(Filtered) > 0)
    MMean(i,6) = mean(Filtered);
    MMax(i,6) = max(Filtered);
    MMin(i,6) = min(Filtered);
else
    MMean(i,6) = -999.99;
    MMax(i,6) = -999.99;
    MMin(i,6) = -999.99;
end
%Q
clear FD Filtered ii
FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),7);
[ii] = find(FD ~= -999.99);
Filtered = FD(ii);
if (size(Filtered) > 0)
    MMean(i,7) = mean(Filtered);
    MMax(i,7) = max(Filtered);
```

```
    MMin(i,7) = min(Filtered);
else
    MMean(i,7) = -999.99;
    MMax(i,7) = -999.99;
    MMin(i,7) = -999.99;
end
%Uk
clear FD Filtered ii
FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),8);
[ii] = find(FD ~= -999.99);
Filtered = FD(ii);
if (size(Filtered) > 0)
    MMean(i,8) = mean(Filtered);
    MMax(i,8) = max(Filtered);
    MMin(i,8) = min(Filtered);
else
    MMean(i,8) = -999.99;
    MMax(i,8) = -999.99;
    MMin(i,8) = -999.99;
end
%Ta
clear FD Filtered ii
FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),9);
[ii] = find(FD ~= -999.99);
Filtered = FD(ii);
if (size(Filtered) > 0)
    MMean(i,9) = mean(Filtered);
    MMax(i,9) = max(Filtered);
    MMin(i,9) = min(Filtered);
else
    MMean(i,9) = -999.99;
    MMax(i,9) = -999.99;
    MMin(i,9) = -999.99;
end
%Td
clear FD Filtered ii
FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),10);
[ii] = find(FD ~= -999.99);
Filtered = FD(ii);
if (size(Filtered) > 0)
    MMean(i,10) = mean(Filtered);
    MMax(i,10) = max(Filtered);
    MMin(i,10) = min(Filtered);
```

```
else
    MMean(i,10) = -999.99;
    MMax(i,10) = -999.99;
    MMin(i,10) = -999.99;
end
%Rh
clear FD Filtered ii
FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),11);
[ii] = find(FD ~= -999.99);
Filtered = FD(ii);
if (size(Filtered) > 0)
    MMean(i,11) = mean(Filtered);
    MMax(i,11) = max(Filtered);
    MMin(i,11) = min(Filtered);
else
    MMean(i,11) = -999.99;
    MMax(i,11) = -999.99;
    MMin(i,11) = -999.99;
end
%Tw
clear FD Filtered ii
FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),12);
[ii] = find(FD ~= -999.99);
Filtered = FD(ii);
if (size(Filtered) > 0)
    MMean(i,12) = mean(Filtered);
    MMax(i,12) = max(Filtered);
    MMin(i,12) = min(Filtered);
else
    MMean(i,12) = -999.99;
    MMax(i,12) = -999.99;
    MMin(i,12) = -999.99;
end
%As
clear FD Filtered ii
FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),13);
[ii] = find(FD ~= -999.99);
Filtered = FD(ii);
if (size(Filtered) > 0)
    MMean(i,13) = mean(Filtered);
    MMax(i,13) = max(Filtered);
    MMin(i,13) = min(Filtered);
else
```

```
    MMean(i,13) = -999.99;
    MMax(i,13) = -999.99;
    MMin(i,13) = -999.99;
end
%Qh
clear FD Filtered ii
FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),14);
[ii] = find(FD ~= -999.99);
Filtered = FD(ii);
if (size(Filtered) > 0)
    MMean(i,14) = mean(Filtered);
    MMax(i,14) = max(Filtered);
    MMin(i,14) = min(Filtered);
else
    MMean(i,14) = -999.99;
    MMax(i,14) = -999.99;
    MMin(i,14) = -999.99;
end
%Qe
clear FD Filtered ii
FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),15);
[ii] = find(FD ~= -999.99);
Filtered = FD(ii);
if (size(Filtered) > 0)
    MMean(i,15) = mean(Filtered);
    MMax(i,15) = max(Filtered);
    MMin(i,15) = min(Filtered);
else
    MMean(i,15) = -999.99;
    MMax(i,15) = -999.99;
    MMin(i,15) = -999.99;
end
%Ev
clear FD Filtered ii
FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),16);
[ii] = find(FD ~= -999.99);
Filtered = FD(ii);
if (size(Filtered) > 0)
    MMean(i,16) = mean(Filtered);
    MMax(i,16) = max(Filtered);
    MMin(i,16) = min(Filtered);
else
    MMean(i,16) = -999.99;
```

```
    MMax(i,16) = -999.99;
    MMin(i,16) = -999.99;
end
%Qi
clear FD Filtered ii
FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),17);
[ii] = find(FD ~= -999.99);
Filtered = FD(ii);
if (size(Filtered) > 0)
    MMean(i,17) = mean(Filtered);
    MMax(i,17) = max(Filtered);
    MMin(i,17) = min(Filtered);
else
    MMean(i,17) = -999.99;
    MMax(i,17) = -999.99;
    MMin(i,17) = -999.99;
end
%Ic
clear FD Filtered ii
FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),18);
[ii] = find(FD ~= -999.99);
Filtered = FD(ii);
if (size(Filtered) > 0)
    MMean(i,18) = mean(Filtered);
    MMax(i,18) = max(Filtered);
    MMin(i,18) = min(Filtered);
else
    MMean(i,18) = -999.99;
    MMax(i,18) = -999.99;
    MMin(i,18) = -999.99;
end
%Qm
clear FD Filtered ii
FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),19);
[ii] = find(FD ~= -999.99);
Filtered = FD(ii);
if (size(Filtered) > 0)
    MMean(i,19) = mean(Filtered);
    MMax(i,19) = max(Filtered);
    MMin(i,19) = min(Filtered);
else
    MMean(i,19) = -999.99;
    MMax(i,19) = -999.99;
```

```
    MMin(i,19) = -999.99;
end
%Qt
clear FD Filtered ii
FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),20);
[ii] = find(FD ~= -999.99);
Filtered = FD(ii);
if (size(Filtered) > 0)
    MMean(i,20) = mean(Filtered);
    MMax(i,20) = max(Filtered);
    MMin(i,20) = min(Filtered);
else
    MMean(i,20) = -999.99;
    MMax(i,20) = -999.99;
    MMin(i,20) = -999.99;
end
%Qc
clear FD Filtered ii
FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),21);
[ii] = find(FD ~= -999.99);
Filtered = FD(ii);
if (size(Filtered) > 0)
    MMean(i,21) = mean(Filtered);
    MMax(i,21) = max(Filtered);
    MMin(i,21) = min(Filtered);
else
    MMean(i,21) = -999.99;
    MMax(i,21) = -999.99;
    MMin(i,21) = -999.99;
end
%cumEv
clear FD Filtered ii
FD = ds(PlotYear).Data(Month_Start(i):Month_End(i),22);
[ii] = find(FD ~= -999.99);
Filtered = FD(ii);
if (size(Filtered) > 0)
    MMean(i,22) = mean(Filtered);
    MMax(i,22) = max(Filtered);
    MMin(i,22) = min(Filtered);
else
    MMean(i,22) = -999.99;
    MMax(i,22) = -999.99;
    MMin(i,22) = -999.99;
```

```
        end

        %Save the results to the output file.
        fprintf(fid_mean,' %d, %d, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f,
%f, %f, %f, %f, %f, %f\r\n',...
            PlotYear, i, MMean(i,3:22));
        fprintf(fid_max,' %d, %d, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f,
%f, %f, %f, %f, %f, %f\r\n',...
            PlotYear, i, MMax(i,3:22));
        fprintf(fid_min,' %d, %d, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f,
%f, %f, %f, %f, %f, %f\r\n',...
            PlotYear, i, MMin(i,3:22));
    end
end

fclose all;
```

OntarioSummary.m

This script generate a comma delimited (.csv) file containing daily Max, Min, Mean and Median values for the 1953 through 1997 years (i.e., maximum temperature for ordinal day 1, over the 45 year span).

```
% Script for stats gathering of daily met data.

StartYear = 1953;
EndYear = 1997;
OutFile = 'L_Ontario_Summary.csv';

% Define a data structure.
ds = struct('Year',{},'Data',{});

% Read in the data,
for  PlotYear = StartYear: 1: EndYear
    close all

    InFile = sprintf('L_Ontario_%d.txt', PlotYear);

[year,ordinal,Kd,Ku,Ld,Lu,Q,Uk,Ta,Td,Rh,Tw,As,Qh,Qe,Ev,Qi,Ic,Qm,Qt,Qc,cumEv]=textread(InFile
,...
        ' %d %d %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f',...
        'headerlines',1,'delimiter',',');
    data=[year,ordinal,Kd,Ku,Ld,Lu,Q,Uk,Ta,Td,Rh,Tw,As,Qh,Qe,Ev,Qi,Ic,Qm,Qt,Qc,cumEv];

    ds(PlotYear).Year=PlotYear;
    ds(PlotYear).Data=data;
```

```
    clear year ordinal Kd Ku Ld Lu Q Uk Ta Td Rh Tw As Qh Qe Ev Qi Ic Qm Qt Qc cumEv;
end


% Produce some statistics.
for Day = 1: 1: 365
    YearCount=1;
    for PlotYear = StartYear: 1: EndYear
        Kd(1,YearCount) = ds(PlotYear).Data(Day,3);
        Ku(1,YearCount) = ds(PlotYear).Data(Day,4);
        Ld(1,YearCount) = ds(PlotYear).Data(Day,5);
        Lu(1,YearCount) = ds(PlotYear).Data(Day,6);
        Q(1,YearCount) = ds(PlotYear).Data(Day,7);
        Uk(1,YearCount) = ds(PlotYear).Data(Day,8);
        Ta(1,YearCount) = ds(PlotYear).Data(Day,9);
        Td(1,YearCount) = ds(PlotYear).Data(Day,10);
        Rh(1,YearCount) = ds(PlotYear).Data(Day,11);
        Tw(1,YearCount) = ds(PlotYear).Data(Day,12);
        As(1,YearCount) = ds(PlotYear).Data(Day,13);
        Qh(1,YearCount) = ds(PlotYear).Data(Day,14);
        Qe(1,YearCount) = ds(PlotYear).Data(Day,15);
        Ev(1,YearCount) = ds(PlotYear).Data(Day,16);
        Qi(1,YearCount) = ds(PlotYear).Data(Day,17);
        Ic(1,YearCount) = ds(PlotYear).Data(Day,18);
        Qm(1,YearCount) = ds(PlotYear).Data(Day,19);
        Qt(1,YearCount) = ds(PlotYear).Data(Day,20);
        Qc(1,YearCount) = ds(PlotYear).Data(Day,21);
        cumEv(1,YearCount) = ds(PlotYear).Data(Day,22);
        YearCount=YearCount+1;
    end
    %Only look at non "missing number" numbers
    clear Filtered;
    [ii] = find(Kd(1,:) ~= -999.99);
    Filtered = Kd(ii);
    DataMax(Day,3) = max(Filtered);
    DataMin(Day,3) = min(Filtered);
    DataMean(Day,3) = mean(Filtered);
    DataMedian(Day,3) = median(Filtered);

    %Only look at non "missing number" numbers
    clear Filtered;
    [ii] = find(Ku(1,:) ~= -999.99);
```

```
Filtered = Ku(ii);
DataMax(Day,4) = max(Filtered);
DataMin(Day,4) = min(Filtered);
DataMean(Day,4) = mean(Filtered);
DataMedian(Day,4) = median(Filtered);

%Only look at non "missing number" numbers
clear Filtered;
[ii] = find(Ld(1,:) ~= -999.99);
Filtered = Ld(ii);
DataMax(Day,5) = max(Filtered);
DataMin(Day,5) = min(Filtered);
DataMean(Day,5) = mean(Filtered);
DataMedian(Day,5) = median(Filtered);
%Only look at non "missing number" numbers
clear Filtered;
[ii] = find(Lu(1,:) ~= -999.99);
Filtered = Lu(ii);
DataMax(Day,6) = max(Filtered);
DataMin(Day,6) = min(Filtered);
DataMean(Day,6) = mean(Filtered);
DataMedian(Day,6) = median(Filtered);
%Only look at non "missing number" numbers
clear Filtered;
[ii] = find(Q(1,:) ~= -999.99);
Filtered = Q(ii);
DataMax(Day,7) = max(Filtered);
DataMin(Day,7) = min(Filtered);
DataMean(Day,7) = mean(Filtered);
DataMedian(Day,7) = median(Filtered);
%Only look at non "missing number" numbers
clear Filtered;
[ii] = find(Uk(1,:) ~= -999.99);
Filtered = Uk(ii);
DataMax(Day,8) = max(Filtered);
DataMin(Day,8) = min(Filtered);
DataMean(Day,8) = mean(Filtered);
DataMedian(Day,8) = median(Filtered);
%Only look at non "missing number" numbers
clear Filtered;
[ii] = find(Ta(1,:) ~= -999.99);
Filtered = Ta(ii);
DataMax(Day,9) = max(Filtered);
```

```
DataMin(Day,9) = min(Filtered);
DataMean(Day,9) = mean(Filtered);
DataMedian(Day,9) = median(Filtered);
%Only look at non "missing number" numbers
clear Filtered;
[ii] = find(Td(1,:) ~= -999.99);
Filtered = Td(ii);
DataMax(Day,10) = max(Filtered);
DataMin(Day,10) = min(Filtered);
DataMean(Day,10) = mean(Filtered);
DataMedian(Day,10) = median(Filtered);
%Only look at non "missing number" numbers
clear Filtered;
[ii] = find(Rh(1,:) ~= -999.99);
Filtered = Rh(ii);
DataMax(Day,11) = max(Filtered);
DataMin(Day,11) = min(Filtered);
DataMean(Day,11) = mean(Filtered);
DataMedian(Day,11) = median(Filtered);
%Only look at non "missing number" numbers
clear Filtered;
[ii] = find(Tw(1,:) ~= -999.99);
Filtered = Tw(ii);
DataMax(Day,12) = max(Filtered);
DataMin(Day,12) = min(Filtered);
DataMean(Day,12) = mean(Filtered);
DataMedian(Day,12) = median(Filtered);
%Only look at non "missing number" numbers
clear Filtered;
[ii] = find(As(1,:) ~= -999.99);
Filtered = As(ii);
DataMax(Day,13) = max(Filtered);
DataMin(Day,13) = min(Filtered);
DataMean(Day,13) = mean(Filtered);
DataMedian(Day,13) = median(Filtered);
%Only look at non "missing number" numbers
clear Filtered;
[ii] = find(Qh(1,:) ~= -999.99);
Filtered = Qh(ii);
DataMax(Day,14) = max(Filtered);
DataMin(Day,14) = min(Filtered);
DataMean(Day,14) = mean(Filtered);
DataMedian(Day,14) = median(Filtered);
```

```
%Only look at non "missing number" numbers
clear Filtered;
[ii] = find(Qe(1,:) ~= -999.99);
Filtered = Qe(ii);
DataMax(Day,15) = max(Filtered);
DataMin(Day,15) = min(Filtered);
DataMean(Day,15) = mean(Filtered);
DataMedian(Day,15) = median(Filtered);
%Only look at non "missing number" numbers
clear Filtered;
[ii] = find(Ev(1,:) ~= -999.99);
Filtered = Ev(ii);
DataMax(Day,16) = max(Filtered);
DataMin(Day,16) = min(Filtered);
DataMean(Day,16) = mean(Filtered);
DataMedian(Day,16) = median(Filtered);
%Only look at non "missing number" numbers
clear Filtered;
[ii] = find(Qi(1,:) ~= -999.99);
Filtered = Qi(ii);
DataMax(Day,17) = max(Filtered);
DataMin(Day,17) = min(Filtered);
DataMean(Day,17) = mean(Filtered);
DataMedian(Day,17) = median(Filtered);
%Only look at non "missing number" numbers
clear Filtered;
[ii] = find(Ic(1,:) ~= -999.99);
Filtered = Ic(ii);
DataMax(Day,18) = max(Filtered);
DataMin(Day,18) = min(Filtered);
DataMean(Day,18) = mean(Filtered);
DataMedian(Day,18) = median(Filtered);
%Only look at non "missing number" numbers
clear Filtered;
[ii] = find(Qm(1,:) ~= -999.99);
Filtered = Qm(ii);
DataMax(Day,19) = max(Filtered);
DataMin(Day,19) = min(Filtered);
DataMean(Day,19) = mean(Filtered);
DataMedian(Day,19) = median(Filtered);
%Only look at non "missing number" numbers
clear Filtered;
[ii] = find(Qt(1,:) ~= -999.99);
```

```
    Filtered = Qt(ii);
    DataMax(Day,20) = max(Filtered);
    DataMin(Day,20) = min(Filtered);
    DataMean(Day,20) = mean(Filtered);
    DataMedian(Day,20) = median(Filtered);
    %Only look at non "missing number" numbers
    clear Filtered;
    [ii] = find(Qc(1,:) ~= -999.99);
    Filtered = Qc(ii);
    DataMax(Day,21) = max(Filtered);
    DataMin(Day,21) = min(Filtered);
    DataMean(Day,21) = mean(Filtered);
    DataMedian(Day,21) = median(Filtered);
    %Only look at non "missing number" numbers
    clear Filtered;
    [ii] = find(cumEv(1,:) ~= -999.99);
    Filtered = cumEv(ii);
    DataMax(Day,22) = max(Filtered);
    DataMin(Day,22) = min(Filtered);
    DataMean(Day,22) = mean(Filtered);
    DataMedian(Day,22) = median(Filtered);

    clear Kd Ku Ld Lu Q Uk Ta Td Rh Tw As Qh Qe Ev Qi Ic Qm Qt Qc cumEv;
end


%Save the results to a text file


fid_out=fopen(OutFile,'w');
%Print a header row
fprintf(fid_out,'ordinal, Kd, Ku, Ld, Lu, Q*, Uk, Ta, Td, Rh, Tw, As, Qh, Qe, Ev, Qi, Ic,
Qm, Qt, Qc, cumEv\r\n');
fprintf(fid_out,'Max (%d-%d)\r\n',StartYear,EndYear)
for Day = 1: 1: 365
    fprintf(fid_out,'%d, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f,
%f, %f, %f\r\n',...
        Day,...

DataMax(Day,3),DataMax(Day,4),DataMax(Day,5),DataMax(Day,6),DataMax(Day,7),DataMax(Day,8),Da
taMax(Day,9),...

DataMax(Day,10),DataMax(Day,11),DataMax(Day,12),DataMax(Day,13),DataMax(Day,14),DataMax(Day,
15),DataMax(Day,16),...

DataMax(Day,17),DataMax(Day,18),DataMax(Day,19),DataMax(Day,20),DataMax(Day,21),DataMax(Day,
22));
```

```
end
fprintf(fid_out,'Min (%d-%d)\r\n',StartYear,EndYear);
for Day = 1: 1: 365
    fprintf(fid_out,'%d, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f,
%f, %f, %f\r\n',...
        Day,...

DataMin(Day,3),DataMin(Day,4),DataMin(Day,5),DataMin(Day,6),DataMin(Day,7),DataMin(Day,8),Da
taMin(Day,9),...

DataMin(Day,10),DataMin(Day,11),DataMin(Day,12),DataMin(Day,13),DataMin(Day,14),DataMin(Day,
15),DataMin(Day,16),...

DataMin(Day,17),DataMin(Day,18),DataMin(Day,19),DataMin(Day,20),DataMin(Day,21),DataMin(Day,
22));
end
fprintf(fid_out,'Mean (%d-%d)\r\n',StartYear,EndYear);
for Day = 1: 1: 365
    fprintf(fid_out,'%d, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f,
%f, %f, %f\r\n',...
        Day,...

DataMean(Day,3),DataMean(Day,4),DataMean(Day,5),DataMean(Day,6),DataMean(Day,7),DataMean(Day
,8),DataMean(Day,9),...

DataMean(Day,10),DataMean(Day,11),DataMean(Day,12),DataMean(Day,13),DataMean(Day,14),DataMea
n(Day,15),DataMean(Day,16),...

DataMean(Day,17),DataMean(Day,18),DataMean(Day,19),DataMean(Day,20),DataMean(Day,21),DataMea
n(Day,22));
end
fprintf(fid_out,'Median (%d-%d)\r\n',StartYear,EndYear);
for Day = 1: 1: 365
    fprintf(fid_out,'%d, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f, %f,
%f, %f, %f\r\n',...
        Day,...

DataMedian(Day,3),DataMedian(Day,4),DataMedian(Day,5),DataMedian(Day,6),DataMedian(Day,7),Da
taMedian(Day,8),DataMedian(Day,9),...

DataMedian(Day,10),DataMedian(Day,11),DataMedian(Day,12),DataMedian(Day,13),DataMedian(Day,1
4),DataMedian(Day,15),DataMedian(Day,16),...

DataMedian(Day,17),DataMedian(Day,18),DataMedian(Day,19),DataMedian(Day,20),DataMedian(Day,2
1),DataMedian(Day,22));
end
fclose(fid_out);
```

PlotOntario.m

This script generates daily time series plots for all parameters contained within the converted data files. One plot is generated per year.

```
%For plotting Lake Ontario Data
%   Years 1953 - 1997

close all
clear all

for  PlotYear = 1953: 1: 1997
close all

OutFile = sprintf('L_Ontario_%d.txt', PlotYear);
PrintFile = sprintf('L_Ontario_%d', PlotYear);

PlotTitle=sprintf('Lake Ontario, ON, %d Daily Climate Data', PlotYear);


%Read the Data
[year,ordinal,Kd,Ku,Ld,Lu,Q,Uk,Ta,Td,Rh,Tw,As,Qh,Qe,Ev,Qi,Ic,Qm,Qt,Qc,cumEv]=textread(OutFil
e,...
    ' %d %d %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f %f',...
    'headerlines',1,'delimiter',',');
data=[year,ordinal,Kd,Ku,Ld,Lu,Q,Uk,Ta,Td,Rh,Tw,As,Qh,Qe,Ev,Qi,Ic,Qm,Qt,Qc,cumEv];
clear year ordinal Kd Ku Ld Lu Q Uk Ta Td Rh Tw As Qh Qe Ev Qi Ic Qm Qt Qc cumEv


%Remove "Missing Data" values.
for i=1:22 %Number of columns
    [ii]=find(data(:,i) == -999.99);
    data(ii,i) = NaN;
end


%Plot the data
TickLabelFontSize = 8;
AxisLabelFontSize = 10;
TitleSize = 12;

IsLeap = mod(PlotYear,4);
if (IsLeap == 0)    %0 represents a leap year.
    X_Ticks = [1 32 61 92 122 153 183 214 245 275 306 336];
    X_Labels = 'J|F|M|A|M|J|J|A|S|O|N|D';
else
    X_Ticks = [1 32 60 91 121 152 182 213 244 274 305 335];
    X_Labels = 'J|F|M|A|M|J|J|A|S|O|N|D';
```

```
end
X_Label_Ticks = [15 47 75 106 136 168 197 228 259 289 320 350];

%Set the data for the x-axis
x=data(:,2);
XMin=1;
XMax=366;

%================================
% Page 1 Plots
%
%   Radiative Exchanges
%   Kd (MJ m^-2 day^-1)
%   Ku (MJ m^-2 day^-1)
%   Ld (MJ m^-2 day^-1)
%   Lu (MJ m^-2 day^-1)
%--------------------------------

close all
clear Y1 Y2 Y3 Y4

Y1 = data(:,3);
Y2 = data(:,4);
Y3 = data(:,5);
Y4 = data(:,6);

%'-k' = Solid Black Line
subplot(4,1,1),plot(x,Y1,'-k');
orient tall;
title(PlotTitle,'fontsize',TitleSize);
set(gca,'fontsize',TickLabelFontSize);
ylabel('Kd (MJ m^{-2} day^{-1})','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax 0 40]);
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');

subplot(4,1,2),plot(x,Y2,'-k')
set(gca,'fontsize',TickLabelFontSize);
ylabel('Ku (MJ m^{-2} day^{-1})','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
```

```
axis([XMin  XMax 0 8]);
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');

subplot(4,1,3),plot(x,Y3,'-k')
set(gca,'fontsize',TickLabelFontSize);
ylabel('Ld (MJ m^{-2} day^{-1})','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax 0 40]);
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');

subplot(4,1,4),plot(x,Y4,'-k')
set(gca,'fontsize',TickLabelFontSize);
ylabel('Lu (MJ m^{-2} day^{-1})','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax 0 40]);
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');

% Plot a second Axis to place Months between tick marks.
ax1 = gca;
ax2 = axes('Position',get(ax1,'Position'), ...
    'XAxisLocation','bottom', 'YAxisLocation', 'left', ...
    'Color', 'none', ...
    'XColor', 'k', 'YColor', 'k');
set(ax2,'fontsize',TickLabelFontSize);
set(ax2,'XLim',get(ax1,'XLim'));
set(ax2,'YLim',get(ax1,'YLim'));
set(ax2,'XTick',X_Label_Ticks);
set(ax2,'XTickLabel',X_Labels);
set(ax2,'YTickLabel',[]);
set(ax2,'TickLength',[0 0]);

%Save the plot to a file.
PlotFile = ['Radiative_', PrintFile];
print('-dmeta', '-r600', PlotFile);
```

```
%================================
% Page 2 Plots
%
%   Heat Fluxes
%   Q* (MJ m^-2 day^-1)
%   Qe (MJ m^-2 day^-1)
%   Qh (MJ m^-2 day^-1)
%   Qt (MJ m^-2 day^-1)
%--------------------------------

close all
clear Y1 Y2 Y3 Y4

Y1 = data(:,7);
Y2 = data(:,15);
Y3 = data(:,14);
Y4 = data(:,20);

%'-k' = Solid Black Line
subplot(4,1,1),plot(x,Y1,'-k');
orient tall;
title(PlotTitle,'fontsize',TitleSize);
set(gca,'fontsize',TickLabelFontSize);
ylabel('Q* (MJ m^{-2} day^{-1})','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax -10 25])
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');

subplot(4,1,2),plot(x,Y2,'-k')
set(gca,'fontsize',TickLabelFontSize);
ylabel('Qe (MJ m^{-2} day^{-1})','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax -10 40])
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');
```

```
subplot(4,1,3),plot(x,Y3,'-k')
set(gca,'fontsize',TickLabelFontSize);
ylabel('Qh (MJ m^{-2} day^{-1})','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax -10 40])
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');

subplot(4,1,4),plot(x,Y4,'-k')
set(gca,'fontsize',TickLabelFontSize)
ylabel('Qt (MJ m^{-2} day^{-1})','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax -60 40])
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');

% Plot a second Axis to place Months between tick marks.
ax1 = gca;
ax2 = axes('Position',get(ax1,'Position'), ...
    'XAxisLocation','bottom', 'YAxisLocation', 'left', ...
    'Color', 'none', ...
    'XColor', 'k', 'YColor', 'k')
set(ax2,'fontsize',TickLabelFontSize);
set(ax2,'XLim',get(ax1,'XLim'));
set(ax2,'YLim',get(ax1,'YLim'));
set(ax2,'XTick',X_Label_Ticks);
set(ax2,'XTickLabel',X_Labels);
set(ax2,'YTickLabel',[]);
set(ax2,'TickLength',[0 0]);

%Save the plot to a file.
PlotFile = ['HeatFluxes_', PrintFile];
print('-dmeta', '-r600', PlotFile);


%================================
% Page 3 Plots
%
%   Meteorology
```

```
%   Ta (Deg C)
%   Td (Dec C)
%   Rh (%)
%   Uk (m/s)
%--------------------------------

close all
clear Y1 Y2 Y3 Y4

Y1 = data(:,9);
Y2 = data(:,10);
Y3 = data(:,11);
Y4 = data(:,8);

%'-k' = Solid Black Line
subplot(4,1,1),plot(x,Y1,'-k');
orient tall;
title(PlotTitle,'fontsize',TitleSize);
set(gca,'fontsize',TickLabelFontSize);
ylabel('Ta (^oC)','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax -20 30])
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');

subplot(4,1,2),plot(x,Y2,'-k')
set(gca,'fontsize',TickLabelFontSize);
ylabel('Td (^oC)','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax -30 30])
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');

subplot(4,1,3),plot(x,Y3,'-k')
set(gca,'fontsize',TickLabelFontSize);
ylabel('Rh (%)','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax 0 100])
XLim('Manual');
```

```
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');

subplot(4,1,4),plot(x,Y4,'-k')
set(gca,'fontsize',TickLabelFontSize)
ylabel('Uk (m/s)','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax 0 16])
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');

% Plot a second Axis to place Months between tick marks.
ax1 = gca;
ax2 = axes('Position',get(ax1,'Position'), ...
    'XAxisLocation','bottom', 'YAxisLocation', 'left', ...
    'Color', 'none', ...
    'XColor', 'k', 'YColor', 'k')
set(ax2,'fontsize',TickLabelFontSize);
set(ax2,'XLim',get(ax1,'XLim'));
set(ax2,'YLim',get(ax1,'YLim'));
set(ax2,'XTick',X_Label_Ticks);
set(ax2,'XTickLabel',X_Labels);
set(ax2,'YTickLabel',[]);
set(ax2,'TickLength',[0 0]);

%Save the plot to a file.
PlotFile = ['Meteorology_', PrintFile];
print('-dmeta', '-r600', PlotFile);


%================================
% Page 4 Plots
%
%   Other fluxes
%   As (fraction)
%   Qi (MJ/m^2/day)
%   Qm (MJ/m^2/day)
%   Qc (Exa Joules)
%--------------------------------
```

```
close all
clear Y1 Y2 Y3 Y4

Y1 = data(:,13);
Y2 = data(:,17);
Y3 = data(:,19);
Y4 = data(:,21);

%'-k' = Solid Black Line
subplot(4,1,1),plot(x,Y1,'-k');
orient tall;
title(PlotTitle,'fontsize',TitleSize);
set(gca,'fontsize',TickLabelFontSize);
ylabel('As (fractional value)','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax 0 1])
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');

subplot(4,1,2),plot(x,Y2,'-k')
set(gca,'fontsize',TickLabelFontSize);
ylabel('Qi (MJ m^{-2} day^{-1})','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax -4 4])
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');

subplot(4,1,3),plot(x,Y3,'-k')
set(gca,'fontsize',TickLabelFontSize);
ylabel('Qm (MJ m^{-2} day^{-1})','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax -0.5 0.5])
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');

subplot(4,1,4),plot(x,Y4,'-k')
set(gca,'fontsize',TickLabelFontSize)
```

```
ylabel('Qc (x10^{18} Joules)','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax 0 60])
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');

% Plot a second Axis to place Months between tick marks.
ax1 = gca;
ax2 = axes('Position',get(ax1,'Position'), ...
    'XAxisLocation','bottom', 'YAxisLocation', 'left', ...
    'Color', 'none', ...
    'XColor', 'k', 'YColor', 'k')
set(ax2,'fontsize',TickLabelFontSize);
set(ax2,'XLim',get(ax1,'XLim'));
set(ax2,'YLim',get(ax1,'YLim'));
set(ax2,'XTick',X_Label_Ticks);
set(ax2,'XTickLabel',X_Labels);
set(ax2,'YTickLabel',[]);
set(ax2,'TickLength',[0 0]);

%Save the plot to a file.
PlotFile = ['OtherFluxes_', PrintFile];
print('-dmeta', '-r600', PlotFile);

% ================================
% Page 5 Plots
%
%   Evaporation
%   Tw (Deg C)
%   Ic (fraction surface area)
%   Ev (mm)
%   cumEv (mm)
% --------------------------------

close all
clear Y1 Y2 Y3 Y4

Y1 = data(:,12);
Y2 = data(:,18);
Y3 = data(:,16);
Y4 = data(:,22);
```

```
%'-k' = Solid Black Line
subplot(4,1,1),plot(x,Y1,'-k');
orient tall;
title(PlotTitle,'fontsize',TitleSize);
set(gca,'fontsize',TickLabelFontSize);
ylabel('Tw (^oC)','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax 0 25])
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');

subplot(4,1,2),plot(x,Y2,'-k')
set(gca,'fontsize',TickLabelFontSize);
ylabel('Ic (fraction surface area)','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax 0 100])
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');

subplot(4,1,3),plot(x,Y3,'-k')
set(gca,'fontsize',TickLabelFontSize);
ylabel('Ev (mm)','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax -5 15])
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');

subplot(4,1,4),plot(x,Y4,'-k')
set(gca,'fontsize',TickLabelFontSize)
ylabel('cumEv (mm)','FontSize',AxisLabelFontSize);
%set the X and Y axis limits. Set Y axis to auto scaling.
axis([XMin  XMax 0 1000])
XLim('Manual');
set(gca,'XTick',X_Ticks);
set(gca,'XTickLabel',[]);
%YLim('Auto');
```

```
% Plot a second Axis to place Months between tick marks.
ax1 = gca;
ax2 = axes('Position',get(ax1,'Position'), ...
    'XAxisLocation','bottom', 'YAxisLocation', 'left', ...
    'Color', 'none', ...
    'XColor', 'k', 'YColor', 'k')
set(ax2,'fontsize',TickLabelFontSize);
set(ax2,'XLim',get(ax1,'XLim'));
set(ax2,'YLim',get(ax1,'YLim'));
set(ax2,'XTick',X_Label_Ticks);
set(ax2,'XTickLabel',X_Labels);
set(ax2,'YTickLabel',[]);
set(ax2,'TickLength',[0 0]);

%Save the plot to a file.
PlotFile = ['Evaporation_', PrintFile];
print('-dmeta', '-r600', PlotFile);

end
```

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