**DEVELOPMENT OF CLIMATIC INDICE TOOL**

**USING DAILY CLIMATE DATA FOR INPUT**

**FINAL REPORT FOR**

**AGRICULTURE AND AGRI-FOOD CANADA**

**CONTRACT # 3000561703**

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**1. Background:**

The Climate Indice Tool (CIT) is a tool for calculating various climate indices or variables, including those that are used in the Land Suitability Rating System (LSRS) for Canada (Agronomic Interpretations Working Group, 1995). Initially, indices were computed that were required for rating the suitability of small grain but at a later date more indices were added that were required for suitability ratings for crops other than small grain cereals (Pettapiece Pedology, 2007). Additional modifications were proposed to some indices to make them more robust for evaluating impacts of climate change (Bootsma, 2007; Bootsma, 2007b). All of the indices calculated by the CIT are in some way related to temperate or moisture, which are the two factors required for the climatic component of the LSRS.

The original CIT was designed to compute climate indices using 30-year monthly climatic normalsas input data. There is a need, however, to be able to compute many of the indices from daily climate data in each year so that yearly variability and extreme values can be evaluated. To accomplish this, changes are required in the procedures used to calculate the indices, in particular the ways that starting and ending dates for accumulating indices are determined. The original CIT program was developed using the Java programming language. The revised climate indice tool that allows using daily climate data (CITD) is being developed using Ruby on Rails software platform (<http://rubyonrails.org/>).

The purposes of this contract were to:

i) develop procedures for determining relevant climate indices from daily climate data.

ii) assist a programmer to trouble shoot computer code and problems that develop in programming the CITD.

iii) prepare input test data on which to test the new software.

iv) test the new program module to validate the calculations.

iv) document the results.

This final report documents the methods used to compute the indices in both the CIT and the CITD. Results of tests used to validate the new program module are presented.

**2. Input data requirements using daily climate data**

The CITD requires a file in standard tab delimited ASCII text format as input. Following a header record with a label for each entry, each record on the input file must contain the following data:

i) Longitude (decimal degrees) (a negative value in the western hemisphere)

ii) Latitude (decimal degrees)

iii) Elevation (m)

iv) Station or grid point number

v) Year

vi) Month

vii) Day

viii) Daily maximum air temperature (°C) to at least 1 decimal place.

ix) Daily minimum air temperature (°C) to at least 1 decimal place.

x) Daily total precipitation (mm) to at least 1 decimal place.

**3. Variables and methods of calculation**

Climate indices computed by the original CIT and by the revised CITD are shown in Appendix 1, along with the procedures used. Only those indices relevant to the existing LSRS were included in the new CITD (highlighted in blue). Additional variables as well as some new variables that deal with climate extremes may need to be incorporated at a later time. Computing Aridity Indices using daily climate data would require major re-programming using soil moisture budgeting methods, as the procedures used with normals data will not work for daily data. Indices cannot be computed for latitudes above 65.7º N, as the routines which generate daylength based on latitude and time of year do not function properly at higher latitudes.

Following is a listing of indices computed by the original CIT based on normals climate data that are presently used in LSRS:

i) For wheat and barley, as in the original LSRS criteria for small grain cereals(Agronomic Interpretations Working Group, 1995 ):EGDD2 (Temperature factor); Deficit4 (Moisture factor).

ii) For canola(Pettapiece Pedology, 2007): EGDD2 (Temperature factor); Deficit4 (Moisture factor); Days>30 (Heat Index modifier).

iii) For corn and soybeans(Pettapiece Pedology, 2007): CHUAve (Temperature factor); Deficit4 (Moisture factor).

iv) For alfalfa, bromegrass and timothy(Pettapiece Pedology, 2007):GDDSUM1 (Temperature factor); GDD1Stop – GDD1Start (Growing Season Length factor);Deficit4 (Moisture factor).

v) Soil Water Regime Classification: Aridity Indices (AI), namely Arid150-50, Arid150-10, Arid250-50 and Arid250-10

Development of procedures for use in the CITD was relatively straight forward for most of the indices. However, determining criteria for the starting and ending dates for accumulation CHU was considerably more challenging, as the traditional procedures used for this were not well adapted to the daily CITD. Default criteria were developed for starting and ending yearly CHU accumulations. The default criteria use in an earlier phase to the contract were modified to conform closely to existing criteria for Ontario and Quebec. Additional criteria were included which allow the user the option of modifying threshold temperatures, moving averaging periods and earliest/latest start/end dates (see Appendix 4).

**4. Methods of computing Potential Evapotranspiration (PE)**

The original CIT allowed the user to select from several different methods of calculating PE. The selection of available methods was limited by the input data. Only methods which required at the most maximum and minimum air temperature and solar radiation at the top of the atmosphere (and any variables that can be estimated from these) can be used. For the purpose of this contract, only the Baier and Robertson ([Baier and Robertson, 1965](http://pubs.aic.ca/doi/pdf/10.4141/cjps65-051); [Baier, 1971](http://pubs.aic.ca/doi/pdf/10.4141/cjps71-053)) method to compute PE was incorporated into the CITD software and tested. This method must be used by CIT with normals data when deriving LSRS crop ratings, since the P-PE deduction curves contained within the LSRS calculator have been calibrated for Baier Robertson P-PE values. However, other methods of calculating PE are also documented in Appendix 2 for reference purposes, and could be added at some future time if required.

**5. Testing CITD and validating results**

**5.1 Input test data**

Daily climate data for several location/years (either climate station data or grid point data) in Canada were randomly selected for final testing. The data chosen also included some leap years. Tests were conducted by comparing CITD program results with calculations performed using Excel spreadsheet files with the same input data. These tests were repeated each time program changes were made to correct any discrepancies that were identified in the results.

The grid point data used in this evaluation were daily averages for the 1971-2000 period available through NLWIS (2007) by the National Agro-Climate Information Service.

Station data were extracted from the AAFC daily climate archive which utilizes the data from Environment Canada with missing values estimated using data from surrounding stations. Use of grid point data allowed some comparisons to be made of PPE or Deficit4 values with the original CIT which was also tested using the grid point data.

Following is a list of data (stations or grid points and years) which were used in testing the final version of the new CITD program:

Saanichton BC - grid point #43538 for 1971

Osoyoos BC - Station # 1125865 for 1978

Fort Nelson BC - grid point #2846 for 1971

Harrow ON - Station # 6133360 for 1984

Sudbury ON - Station # 6068150 for 1982

Quebec QC - Stations # 7010160 for 1952

Kentville NS - Grid point # 53091 for 1971

Input test data for the above location/years are provided in the attached file "Input\_Test\_Data.zip"

**5.2 Output results from test**

During the testing phase, a number of versions of the new CITD program were tested and corrections to the programs were applied as required. Only the test output of the final version of the program are presented here. The results of tests for the above locations/years are summarized in Appendix 6. The spreadsheet calculations used in these comparisons are presented in an attached file (Final\_tests.xlsx). For the GDD, EGDD, CHU and DAYS>30, the CITD values agree with those calculated using the Excel spreadsheet.

Tests under Phase 1 of this contract showed that the CITD program was calculating solar radiation at the top of the atmosphere correctly. This variable is used in the PE calculations. Results for two locations (Abbotsford, BC and Fort Nelson BC) are shown in the file "Rstop\_comparison.xlsx". PE values are often slightly different when compared with values obtained from the AAFC archive which are also based on the Baier-Robertson formula. These differences are likely due to rounding off errors and slight variations in the latitude used in the calculations and are therefore not of concern. When PE values were compared to values calculated for grid point data using the Java version of CIT, the results were always identical (Appendix 6).

Results for EGDD from Osoyoos and Fort Nelson indicate that the daylength factor used to adjust the GDD to compute EGDD is calculated correctly, as these locations are far enough north to require an adjustment factor.

Initial, there were some problems with how the new CITD handled leap years. These problems were resolved by having the program collapse the last two days of the year and deleting day 366. The results for Harrow (1984) and Quebec (1952) in Appendix 6 are based on leap years.

Comparisons of start and end dates and accumulated CHU are presented for CHU1 (default values) and for CHU2 and CHU3 (which allow the user to modify the criteria). Start and stop criteria used for CHU2 and CHU3 are presented in a worksheet in the file "Final\_tests.xlsx" and in Appendix 4. All values were in agreement (appendix 6), indicating that the program was calculating CHU correctly for both the default criteria and the user-selected criteria. Further modifications may be required in the CHU criteria in the future to improve their application to some regions of Canada.

Overall, it is concluded that the new CITD software for calculating climate indices from daily climate data is functioning accurately for the variables that have been selected and following the procedures as documented. Thus the goals outlined for this contract have been met. Additional variables may need to be added to the daily CITD program in the future.

**6. References**

Agronomic Interpretations Working Group. 1995. Land suitability rating for agricultural crops: 1. Spring-seeded small grains. Edited by W.W. Pettapiece. Tech. Bull. No. 1995-6E. Centre for Land and Biological Resources Research, Research Branch, Agriculture and Agri-Food Canada, Ottawa. 90 pp., 2 maps. Available On-line: <http://sis.agr.gc.ca/cansis/publications/manuals/1995-lsrs/index.html> [1013]

Allen, R.G., Pereiro, L.S., Raes, D. and Smith, M. 1998. Crop evapotranspiration: Guidelines for computing crop requirements. Irrigation and Drainage paper No. 56. FAO, Rome. [Online]Available: <http://www.fao.org/docrep/X0490E/x0490e00.htm#Contents> [1998].

Baier, 1971. Evaluation of latent evaporation estimates and their conversion to potential evaporation. *Can. J. Plant Sci*. 51: 255-266.

Baier, W. and Robertson, G.W. 1965. Estimation of latent evaporation from simple weather observations. *Can. J. Plant Sci*. 45: 276-284.

Bootsma, A. 2007. Revised moisture factor for land suitability rating system (LSRS) for use in climate change studies. Final Report for AAFC Contract #3000291328 prepared Jan. 30, 2007, revised Feb. 12, 2007, 6 pp. Available On-line: <https://sites.google.com/site/andybootsma/home/climate-change-studies>

Bootsma, A. 2007b. A revised Heat Index (HI) modifier for Canola for climate change studies. Final Report for AAFC Contract #3000321992 prepared Dec. 10, 2007, revised Dec. 18, 2007.

Available On-line: <https://sites.google.com/site/andybootsma/home/climate-change-studies>

Bootsma, A. 2011. Re-evaluation of Corn Heat Units (CHU) for Quebec. Final Report for Agriculture and Agri-Food Canada Contract # 01B46-2010-0297. 181 pp. Available On-line: <https://sites.google.com/site/andybootsma/home/crop-heat-unit-reports>

Bootsma, A. and Brown, D.M. 1995. Risk analyses of Crop Heat Units available for Corn and other warm-season crops in Ontario. Tech. Bull. 1995-1E. Centre for Land and Biological Resources Research, Research Branch, Agriculture and Agri-Food Canada, Ottawa. 83 pp. Available On-line: <https://sites.google.com/site/andybootsma/home/crop-heat-unit-reports>

Bootsma, A., Tremblay, G. and Filion, P. 1999. Risk analyses of heat units available for corn and soybean production in Quebec. Agriculture and Agri-Food Canada, Research Branch, Eastern Cereal and Oilseed Research Centre, Ottawa, Technical Bulletin, ECORC Contrib. No. 991396. 127 pp. Available On-line: <https://sites.google.com/site/andybootsma/home/crop-heat-unit-reports>

Brown, D.M. and Bootsma, A. 1993. Crop heat units for corn and other warm-season crops in Ontario. Ontario Ministry of Agriculture and Food Factsheet No. 93-119, Agdex 111/31, 4pp. Available On-line: <https://sites.google.com/site/andybootsma/home/crop-heat-unit-reports>

Hargreaves, G.H. and Samani, Z.A. 1985. Reference crop evapotranspiration from temperature. Applied Engineering in Agriculture 1(2): 96-99.

Hubbard, K.G., Mahmood, R. and Carlson, C. 2003. Estimating daily dew point temperature for the northern Great Plains using maximum and minimum temperature. *Agron. J*. 95: 323-328.

[Maulé, C., Helgason, W., McGinn, S. and Cutforth, H. 2006](http://www.engr.usask.ca/societies/csae/protectedpapers/c0533.pdf). Estimation of standardized reference evapotranspiration on the Canadian Prairies using simple models with limited weather data. Canadian Biosystems Engineering 48: 1.1-1.11.

NLWIS, 2007. Daily 10 Km Gridded Climate Dataset: 1961-2003. [computer file]. Version 1.0, [Ottawa]: Agriculture and Agri-Food Canada. National Land and Water Information Service, [2007]

Pettapiece Pedology 2007. Land Suitability Rating System Development (LSRS modifications to accommodate additional crops). Final Consolidated Report, Agriculture and Agri-Food Canada Contract # 3000283404, in conjunction with Spatial Data Systems Consulting and A. Bootsma. 178 pp. Available On-line: <http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/All/sag15025>

Robertson, G.W. 1968. A biometeorological time scale for a cereal crop involving day and night temperature and photoperiod. *Int. J. Biometeor*. 12 (3): 191-223.

Williams, G.D.V. 1974. Deriving a biophotothermal time scale for barley. *Int. J. Biometeor.* 18 (1): 57-69.

Shields, J.A. and Sly, W.K. 1984. Aridity indices derived from soil and climatic parameters. Agriculture Canada, Research Branch, Technical Bulletin 1984-14E, 18 pp.

Sly, W.K. and Coligado, M.C. 1974. Agroclimatic maps for Canada - derived data: moisture and critical temperatures near freezing. Tech. Bull. 81, Agrometeorol. Research and Service, Chemistry and Biology Research Institute, Canada Department of Agriculture, Ottawa, Ont., 31 pp. + maps.

Sly, W., Robertson, G.W. and Coligado, M.C. 1971. Estimation of probable dates of temperatures near freezing from monthly temperature normals, station elevation, and astronomical data. Canada Department of Agriculture, Research Branch, Plant Research Institute, Agrometeorology Section, Ottawa, Tech. Bull. 79, 21 pp.

**Appendix 1: Definition of output variables of the Climatic Indice Tool (CIT and CITD).**

**Blue highlights: variables incorporated into CITD in this phase (name used in CIT is in brackets).**

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable name** | **Definition** | **CITD Method of calculation using daily climate** | **CIT Method using climate normals** |
| Latitude | Latitude of grid point or climate station in decimal degrees N | Read as input data | Read as input data |
| Longitude | Longitude of grid point or climate station in decimal degrees W (negative value) in the western hemisphere | Read as input data | Read as input data |
| Elevation | Elevation of grid point or climate station, in metres | Read as input data | Read as input data |
| GDD (GDDSUM1) | Growing degree-days (GDD) above 5°C accumulated between GDD1Start and GDD1Stop | Sum of Daily GDD for the defined period.  Daily GDD = Tmean -5.0 where Tmean is the mean daily air temperature (°C); if Tmean is < 5.0, Daily GDD=0.0 | Sum of average Daily GDD for the defined period.  Daily GDD = Tmean -5.0 where Tmean is the average mean daily air temperature (°C); if Tmean is < 5.0, Daily GDD=0.0 |
| GDD First (GDD1Start) | Starting date for accumulating GDDSUM1 (calendar day) (Generally considered as start of growing period for perennial crops) | 5-day running mean air temperature reaches and stays above 5°C in spring (after Shields and Sly, 1984). | Date when the average mean daily air temperature (Tmean) first exceeds 5°C in spring. |
| GDD Last (GDD1Stop) | Stopping date for accumulating GDDSUM1 (calendar day) (Generally considered as the end of growing period for perennial forage crops) | 5-day running mean air temperature first drops below 5°C in autumn (after Shields and Sly, 1984). | Day before date when the average mean daily air temperature (Tmean) drops and stays below 5°C in fall. |
| **Variable name** | **Definition** | **CITD Method of calculation using daily climate** | **CIT Method using climate normals** |
| GDDSUM2 | Growing degree-days (GDD) above 5°C accumulated between GDD2Start and GDD2Stop. | Sum of Daily GDD for the defined period.  Daily GDD = Tmean -5.0 , where Tmean is the mean daily air temperature (°C); if Tmean is < 5.0, Daily GDD=0.0 | Sum of Daily GDD for the defined period.  Daily GDD = Tmean -5.0 , where Tmean is the average mean daily air temperature (°C); if Tmean is < 5.0, Daily GDD=0.0 |
| GDD2Start | Starting date for accumulating GDDSUM2 (calendar day). (Starting dates used for wheat and barley). | 10 days after GDD1Start. | 10 days after the average mean daily air temperature (Tmean) first exceeds 5°C in spring (calendar day). |
| GDD2Stop | Stopping date for accumulating GDDSUM2 (calendar day). | Date of first fall frost ( 0°C)  . | Day before the average date of the first fall frost (≤ 0°C) (FF). Since FF is not an input variable, it is estimated by using the procedure developed by Sly et al. (1971) (see Appendix 3) |
| EGDD | Growing degree days (GDDSUM2) adjusted for longer daylengths at higher latitudes. | Same procedure as EGDD2, except accumulated from GDD2 Start to GDD2Stop | Same procedure as EGDD2, except accumulated from GDD2 Start to GDD2Stop |
| EGDD  (EGDD2) | Growing degree days (GDDSUM2) adjusted for longer daylengths at higher latitudes which promotes earlier maturity in small grain cereals (used in the LSRS for small grain cereals (Agronomic Interpretations Working Group, 1995). EGDD2 are accumulated from EGDD2Start to EGDD2Stop. | EGDD2 = GDDSUM2 X DLF  where DLF (daylength factor) is estimated as follows: i). if Latitude (LAT) ≤49° N, then DLF = 1.0  ii). if 49.0 < Latitude < 61.0 then  DLF = -19.3257 + 1.158643(LAT) –  0.022107689(LAT)2 + 0.0001413685(LAT)3  iii). if 61.0°N ≤ LAT ≤65.7°N then DLF = 1.180 | EGDD2 = GDDSUM2 X DLF  where DLF (daylength factor) is estimated as follows: i). if Latitude (LAT) ≤49° N, then DLF = 1.0  ii). if 49.0 < Latitude < 61.0 then  DLF = -19.3257 + 1.158643(LAT) –  0.022107689(LAT)2 + 0.0001413685(LAT)3  iii). if 61.0°N ≤ LAT ≤65.7°N then DLF = 1.180 |
| EGDD First  (EGDD2Start) | Starting date for accumulating EGDD2 (calendar day) | 10 days after GDD1Start or April 1, whichever, is later. | Same as GDD2Start, except that April 1 is set as the earliest limit to the start date. |
| EGDD Last  (EGDD2Stop) | Stopping date for accumulating EGDD2 (calendar day) | Date of first fall frost ( 0°C) or Oct. 31, whichever is earlier. | Same as GDD2Stop, except that October 31 is set as the latest limit to the stop date. |
| **Variable name** | **Definition** | **CITD Method of calculation using daily climate** | **CIT Method using climate normals** |
| Deficit1 | Potential evapotranspiration minus precipitation (PE-P) for period as defined for GDDSUM1 (mm) | Sum of daily PE-P for defined period. | Sum of average daily PE-P for defined period. |
| PE1 | Potential evapotranspiration (PE) for period as defined for GDDSUM1 (mm) | Sum of daily PE for defined period | Sum of average daily PE for defined period. |
| Deficit2 | Potential evapotranspiration minus precipitation (PE-P) for period as defined for GDDSUM2 (mm) | Sum of daily PE-P for defined period. | Sum of average daily PE-P for defined period. |
| PE2 | Potential evapotranspiration (PE) for period as defined for GDDSUM2 (mm) | Sum of daily PE for defined period. | Sum of average daily PE for defined period. |
| Deficit3 | Potential evapotranspiration minus precipitation (PE-P) for period from May 1 to September 30 (mm) | Sum of daily PE-P for defined period. | Sum of average daily PE-P for defined period. |
| PE3 | Average Potential evapotranspiration (PE) for period May 1 to September 30 (mm) | Sum of daily PE for defined period. | Sum of average daily PE for defined period. |
| PPE  (Deficit4) | Potential evapotranspiration minus precipitation (PE-P) for period from May 1 to August 31 | Sum of daily P-PE for defined period (as used in LSRS - usually a negative value. | Sum of average daily PE-P for defined period. |
| PE4 | Potential evapotranspiration (PE) for period May 1 to August 31 (mm) | Sum of daily PE for defined period. | Sum of average daily PE for defined period. |
| **Variable name** | **Definition** | **CITD Method of calculation using daily climate** | **CIT Method using climate normals** |
| Deficit5 | Potential evapotranspiration minus precipitation (PE-P) summed for positive values of PE-P only. This is used to estimate Aridiy indices (see below) | Sum of daily positive PE-P values for same period as in GDDSUM1 (mm). | Sum of average daily positive PE-P values for same period as in GDDSUM1 (mm). |
| PE5 | Potential evapotranspiration (PE) (mm) summed for positive values of PE-P only for same period as in GDDSUM1 (mm) | Sum of daily PE values for defined period. | Sum of average daily PE values for defined period. |
| AridXX-YY | Seasonal Aridity index (cm) for soil with XX mm water-holding capacity, YY% probability level | This index **cannot be computed** using the methods for normals climate data. It requires a daily soil moisture budgeting procedure when daily climate data are used (Shields and Sly, 1984). Major programming would be necessary. | The index is computed from the water deficit (PE-P) in a manner similar to Sly and Coligado (1974). Note that Aridity is in cm, water deficits are in mm. A regression equation is used to compute Arid150-50 as follows:  Arid150\_50 = -6.63 + 0.09071\*(Deficit5) –  0.00002983\*(Deficit5)\*\*2  Note: Regression estimates should not be used for Deficit5 values that exceed 900mm. |
| STOPBarley | Maturity date estimated for barley using the Biophotothemal Time Scale (BPTS) (calendar day) | The stop date for barley is estimated using the Biophotothemal Time Scale (BPTS), which uses relationships between the rate of development in barley and temperature and photoperiod ([Williams, 1974](http://www.springerlink.com/content/x363850694569t07/fulltext.pdf)). If the stop date is later than GDD2Stop (indicating that maturity is not reached before frost), then ‘STOPBarley’ is set to ‘-99’ | The stop date for barley is estimated using the Biophotothemal Time Scale (BPTS), which uses relationships between the rate of development in barley and temperature and photoperiod ([Williams, 1974](http://www.springerlink.com/content/x363850694569t07/fulltext.pdf)). If the stop date is later than GDD2Stop (indicating that maturity is not reached before frost), then ‘STOPBarley’ is set to ‘-99’ |
| **Variable name** | **Definition** | **CITD Method of calculation using daily climate** | **CIT Method using climate normals** |
| STOPWheat | Maturity date estimated for wheat (calendar day) | The stop date for wheat is estimated using the Biometeorological Time Scale (BMTS), which uses relationships between the rate of development in wheat and temperature and photoperiod. ([Robertson, 1968](http://www.springerlink.com/content/k81374l430q2vx66/fulltext.pdf)). If the stop date is later than GDD2Stop (indicating that maturity is not reached before frost), then ‘STOPWheat’ is set to ‘-99’ | The stop date for wheat is estimated using the Biometeorological Time Scale (BMTS), which uses relationships between the rate of development in wheat and temperature and photoperiod. ([Robertson, 1968](http://www.springerlink.com/content/k81374l430q2vx66/fulltext.pdf)). If the stop date is later than GDD2Stop (indicating that maturity is not reached before frost), then ‘STOPWheat’ is set to ‘-99’ |
| GDDWheat | Growing degree-days above 5°C for wheat | Sum of daily GDD from GDD2Start to STOPWheat.  Daily GDD = Tmean -5.0 where Tmean is the mean daily air temperature (°C); if Tmean is < 5.0, Daily GDD=0.0. If STOPWheat ‘-99’, i.e.later than GDD2Stop then accumulation is stopped on GDD2Stop. | Sum of average daily GDD from GDD2Start to STOPWheat.  Daily GDD = Tmean -5.0 where Tmean is the average mean daily air temperature (°C); if Tmean is < 5.0, Daily GDD=0.0. If STOPWheat ‘-99’, i.e.later than GDD2Stop (estimated average date of first fall frost), then accumulation is stopped on GDD2Stop. |
| GDDBarley | Growing degree-days above 5°C for barley | Sum of daily GDD from GDD2Start and STOPBarley.  Daily GDD = Tmean -5.0 where Tmean is the average mean daily air temperature (°C); if Tmean is < 5.0, Daily GDD=0.0 | Sum of average daily GDD from GDD2Start and STOPBarley.  Daily GDD = Tmean -5.0 where Tmean is the average mean daily air temperature (°C); if Tmean is < 5.0, Daily GDD=0.0 |
| **Variable name** | **Definition** | **CITD Method of calculation using daily climate** | **CIT Method using climate normals** |
| DEFWheat | Seasonal water deficit (PE-P) for wheat (mm). | Sum of daily values of Potential evapotranspiration minus Precipitation (PE-P) from GDD2Start to STOPWheat. If STOPWheat is later than GDD2Stop then accumulation is stopped on GDD2Stop.  NOTE: The scaling of DEFWheat used for normals data will not be required. | Sum of average daily values of Potential evapotranspiration minus Precipitation (PE-P) from GDD2Start to STOPWheat. If STOPWheat is later than GDD2Stop (estimated average date of first fall frost), then accumulation is stopped on GDD2Stop.  The scaling of DEFWheat is determined as follows:  Scaled Deficit = 1.2306 (DEFwheat) – 17.566  For a complete explanation of the Scaled Deficit, see Bootsma, 2007. |
| DEFBarley | Seasonal water deficit (PE-P) for barley (mm). | Sum of daily values of Potential evapotranspiration minus Precipitation (PE-P) from GDD2Start to STOPBarley. If STOPBarley is later than GDD2Stop, then accumulation is stopped on GDD2Stop. | Sum of average daily values of Potential evapotranspiration minus Precipitation (PE-P) from GDD2Start to STOPBarley. If STOPBarley is later than GDD2Stop (estimated average date of first fall frost), then accumulation is stopped on GDD2Stop. |
| PEWheat | Seasonal potential evapotranspiration (PE) for wheat (mm). | Sum of daily values of Potential evapotranspiration (PE) from GDD2Start to STOPWheat. If STOPWheat is later than GDD2Stop, then accumulation is stopped on GDD2Stop. | Sum of average daily values of Potential evapotranspiration (PE) from GDD2Start to STOPWheat. If STOPWheat is later than GDD2Stop (estimated average date of first fall frost), then accumulation is stopped on GDD2Stop. |
| PEBarley | Seasonal potential evapotranspiration (PE) for barley (mm). | Sum of daily values of Potential evapotranspiration (PE) from GDD2Start to STOPBarley . If STOPBarley is later than GDD2Stop, then accumulation is stopped on GDD2Stop. | Sum of average daily values of Potential evapotranspiration (PE) from GDD2Start to STOPBarley . If STOPBarley is later than GDD2Stop (estimated average date of first fall frost), then accumulation is stopped on GDD2Stop. |
| **Variable name** | **Definition** | **CITD Method of calculation using daily climate** | **CIT Method using climate normals** |
| EGDD600 | Date when 600 EGDD are accumulated (estimated start of flowering period for canola). | Daily EGDD are accumulated from the start date (GDD2Start) until 600 EGDD are reached. | Average daily EGDD are accumulated from the start date (GDD2Start) until 600 EGDD are reached. |
| EGDD1100 | Date when 1100 EGDD are accumulated (estimate end of flowering period for canola). | Daily EGDD are accumulated from the start date (GDD2Start) until 1100 EGDD are reached. | Average daily EGDD are accumulated from the start date (GDD2Start) until 1100 EGDD are reached. |
| TmaxEGDD | Average daily maximum air temperature between EGDD600 and EGDD1100. | NOT REQUIRED WHEN USING DAILY CLIMATE DATA | The mean of average daily maximum air temperatures between EGDD600 and EGDD1100 (ºC). |
| Days>30 | Canola heat index (HI) | Number of days when Tmax exceeds 30°C between EGDD600 and EGDD1100 (the flowering period of canola). | Days>30 = 0.11551 (TmaxEGDD)2 – 4.37124 (TmaxEGDD) + 41.54  The following conditions are applied when using this equation (1): If TmaxEGDD is < 19ºC, then Days>30 = 0.0; if TmaxEGDD is > 32ºC, then Days>30 = -99 (the relationship may not be valid outside this range)  Other conditions that apply:  i) if EGDD600 was not reached, then TmaxEGDD = -99 and Days>30 = 0.0; ii) if EGDD1100 was not reached then EGDD1100 = -99 and TmaxEGDD = -99 and DAYS>30 = -99. (However, it can be safely assumed that DAYS>30 = 0.0 if EGDD1100 date is not reached). For a complete explanation of the heat index modifier, see Bootsma, 2007b. |
| **Variable name** | **Definition** | **CITD Method of calculation using daily climate** | **CIT Method using climate normals** |
| CHU1  (CHU) | Seasonal Crop (Corn) Heat Units (CHU) for corn and soybeans. | CHU values are calculated from daily maximum and minimum air temperatures and accumulated from CHU1 First to CHU1 Last (see Appendix 4 for details). | CHUnormal values are calculated from average daily maximum and minimum air temperatures and accumulated from Start\_CHU to Stop\_CHU |
| CHU2normal | Seasonal Crop (Corn) Heat Units (CHU). | NOT REQUIRED WHEN USING DAILY CLIMATE DATA | CHUnormal values are calculated from average daily maximum and minimum air temperatures and accumulated from Start\_CHU to GDD2Stop (the average date of first fall frost (0ºC) as estimated by the program as described in Appendix 4). The GDD2Stop date corresponds closely to the date determined by ‘Stop\_CHU’, and eliminates the need for determining accurate threshold temperatures for ending CHU accumulations for each region since it is calculated from the normals data. |
| CHU1 First  (Start\_CHU) | Starting date of CHU1 accumulations (calendar day) | Three consecutive days when mean daily air temperature >12.8 C have occurred after April 15. The third day is the starting date (see Appendix 4). | Starting date is based on a threshold value of the mean daily air temperature (Tmean) that must be exceeded as defined by the user. Threshold temperatures estimate the average planting date of corn and presently vary from 8.8 to 12.7 ºC for different regions across Canada (see Appendix 5). |
| CHU1 Last  (Stop\_CHU) | Ending date of CHU1 accumulations (calendar day) | The first occurrence of minimum air temperature of ≤ -2°C or Oct. 15, whichever occurs first (see Appendix 4). | Stopping date is based on the date when the mean daily minimum air temperature (Tmin) drops below a threshold value as defined by the user. Threshold temperatures estimate the 10% probability date of first fall freeze (-2ºC) and presently vary from 3.7 to 6.5 ºC for different  regions across Canada (see Appendix 5). |
| **Variable name** | **Definition** | **CITD Method of calculation using daily climate** | **CIT Method using climate normals** |
| CHUAve | Adjusted seasonally accumulated values of CHU2normal | NOT REQUIRED FOR DAILY DATA | CHU2normal is adjusted using a regression equation that is specific for each region of Canada. The equation is of the form:  CHUAve = a0 + a1\*CHU2normal  The constant (a0) and coefficient (a1) values must be entered in the input “threshold file” as input into the program. Appropriate values have been developed for most regions as shown in Appendix 5. However, these could be further refined in future. The adjustment is needed so that the CHU values calculated from normals data corresponds closely to CHU values determined on an annual basis using daily data. |
| CHU80% | Value of seasonally accumulated CHU equaled or exceeded 80% of the time (i.e. 8 years out of 10) | REQUIRES A SUBROUTINE TO DO PROBABILITY ANALYSES OF YEARLY VALUES. | CHU2normal is adjusted using a regression equation that is specific for each region of Canada. The equation is of the form:  CHU80% = b0 + b1\*CHU2normal  The constant (b0) and coefficient (b1) values must be entered in the “threshold file” as input into the program. Appropriate values have been developed for most regions (see Appendix 5). |
| CHU2 | Seasonal Crop (Corn) Heat Units (CHU) for corn and soybeans | CHU values are calculated from daily maximum and minimum air temperatures and accumulated from CHU2 First to CHU2 Last (see Appendix 4 for details). | N/A |
| CHU2 First | Starting date of CHU2 accumulations (calendar day) | As specified by the user (see Appendix 4 for details). | N/A |
| CHU2 Last | Ending date of CHU2 accumulations (calendar day) | As specified by the user (see Appendix 4 for details). | N/A |

**Appendix 2.** Procedures for calculating Potential Evapotranspiration (PE) using methods which only require temperature and solar radiation at the top of the atmosphere (extra terrestrial) as input data.

**2.1 Baier and Robertson Method for calculating PE** ([Baier and Robertson, 1965](http://pubs.aic.ca/doi/pdf/10.4141/cjps65-051); [Baier, 1971](http://pubs.aic.ca/doi/pdf/10.4141/cjps71-053)).

(This method must be used by CIT with normals data when deriving LSRS crop ratings, since the P-PE deduction curves contained within the LSRS calculator have been calibrated for “Baier Robertson P-PE” values.)

PEBR1 = 0.086 \* (0.928 \* Tmaxf + 0.933 \* Trangef + 0.0486 \* RStop - 87.03);

if PE <0 then PE=0.0;

where Tmaxf = Tmax \* 9 / 5 + 32

Tminf = Tmin \* 9 / 5 + 32

Trangef = Tmaxf – Tminf

RStop = 23.89\* Ra

Tmax and Tmin are the mean daily maximum and minimum temperatures in °C; Tmaxf and Tminf are the mean daily maximum and minimum temperatures in °F.

Ra is the extra terrestrial radiation in MJ/m2/day.

RStop is extra terrestrial radiation in cal/cm2/day.

(1 cal/cm2/day = 0.041868 MJ/m2/day; 1 MJ/m2/day = 23.89 cal/cm2/day)

**2.2 HG: Hargreaves and Samani** (Hargreaves and Samani, 1985)

PEHG = 0.0023 \* (Tmax - Tmin)^0.5 \* (Tmean + 17.8) \* (Ra / Lv)

Tmean = mean air temperature (°C)

Tmax = maximum air temperature (°C)

Tmin = minimum air temperature (°C)

Ra = extra terrestrial radiation (MJ/m2/day)

(1 cal/cm2/day = 0.041868 MJ/m2/day; 1 MJ/m2/day = 23.89 cal/cm2/day)

Lv = latent heat of vaporization (MJ/kg)

= 2.45 MJ/kg (Allen et al., 1998**)**

**2.3 MHG: Modified Hargreaves temperature model by** [Maulé et al., 2006](http://www.engr.usask.ca/societies/csae/protectedpapers/c0533.pdf)

PEHG = 0.0023 \* (Tmax - Tmin)^0.5 \* (Tmean + 17.8) \* (Ra / Lv)

if PEMH ≤0 then PEMH =0.0;

Tmean = mean air temperature (°C)

Tmax = maximum air temperature (°C)

Tmin = minimum air temperature (°C)

Ra = extra terrestrial radiation (MJ/m2/day)

(1 cal/cm2/day = 0.041868 MJ/m2/day; 1 MJ/m2/day = 23.89 cal/cm2/day)

Lv = latent heat of vaporization (MJ/kg)

= 2.45 MJ/kg (Allen et al., 1998**)**

**2.4 Mt : Temperature model by** [Maulé et al., 2006](http://www.engr.usask.ca/societies/csae/protectedpapers/c0533.pdf)

PEt = 0.0109 \* Tmean + 0.134 \* (Tmax - Tmin) + 0.708 \* ∆ \* Ra - 0.669

If (PEt < 0.0), then PEt = 0

Tmean = mean air temperature (°C)

Tmax = maximum air temperature (°C)

Tmin = minimum air temperature (°C)

∆ = slope of the saturation temperature pressure curve (kPa/°C)

=  where *T* = Tmean (Allen et al. 1998)

Ra = extra terrestrial radiation (MJ/m2/day)

(1 cal/cm2/day = 0.041868 MJ/m2/day; 1 MJ/m2/day = 23.89 cal/cm2/day)

**2.5 Mtr : Temperature and humidity model by** [Maulé et al., 2006](http://www.engr.usask.ca/societies/csae/protectedpapers/c0533.pdf)

PEtr = 0.131 \* Tmean + 0.0515 \* (Tmax - Tmin) - 3.18 \* ea + 0.846 \* ∆ \* Ra + 1.28

If (PEtr < 0.0), then PEtr = 0

Tmean = mean air temperature (°C)

Tmax = maximum air temperature (°C)

Tmin = minimum air temperature (°C)

ea = actual vapour pressure (kPa)

∆ = slope of the saturation temperature pressure curve (kPa/°C)

=  where *T* = Tmean (Allen et al. 1998)

Ra = extra terrestrial radiation (MJ/m2/day)

(1 cal/cm2/day = 0.041868 MJ/m2/day; 1 MJ/m2/day = 23.89 cal/cm2/day)

Actual vapour pressure (ea) can be estimated from dew point temperature (Tdew) as follows:

x0490e0j

where eo is the saturation vapour pressure at the dewpoint temperature (Tdew) [°C]

(Allen et al., 1998)

Dew point temperature can be estimated from air temperature ([Hubbard et al., 2003](https://www.agronomy.org/publications/select-items)) as follows:

Tdew = -0.036 \* Tmean + 0.9679 \* Tmin + 0.0072 \* (Tmax – Tmin) + 1.0119

where Tdew = dew point temperature (°C)

**Appendix 3:** **Calculation of average date of first fall frost (≤ 0°C) (FF), using procedure by Sly et al. (1971)**

**(not required for CITD when used with daily climate data)**

FF = DF42 - LAG

where DF42 = the first date in fall when the mean minimum air temperature (Tmin)

≤ 5.56°C.

LAG = -32.7 + 0.769(X1) + 0.341(X2) - 0.00484(X3) + 0.00928(X4) (days)

X1 is the cooling in fall during the 30 days previous to the date of occurrence of

Tmin ≤ 5.56°C.

X1 = [Tmin on day DF42 - Tmin on day (DF42-30)] X 1.8 where Tmin is in °C.

X2 is the difference between July (Tminjul) and January (Tminjan) mean minimum temperature:

X2 = [Tminjul - Tminjan] X 1.8, where Tminjul and Tminjan are in °C.

X3 is the elevation (ELEV) of the location.

X3 = ELEV X 3.2808 where ELEV is in metres.

X4 is the product of the square of the night length and the temperature range on day DF42.

X4 = [(24 - N)2 X (Tmax - Tmin)] X 1.8

where N is the daylength and Tmax and Tmin are the mean maximum minimum

temperatures on day DF42 in °C .

**Appendix 4. Calculation of Crop (Corn) Heat Units (CHU) from daily climate data.**

Daily values of CHU are computed after [Brown and Bootsma (1993)](http://www.uoguelph.ca/plant/research/homepages/ttollena/research/assets/Crop%20Heat%20Units%20for%20Corn%20and%20Other%20Warm-Season%20Crops%20in%20Ontario.pdf), using the following formula:

Ymax = 3.33 (Tmax - 10.0) - 0.084 (Tmax - 10.0)2

Ymin = 1.8 (Tmin - 4.44)

If Tmax < 10.0, Ymax = 0.0; if Tmin < 4.44, Ymin = 0.0

Where Ymax and Ymin are the contributions to CHU from daily maximum (Tmax) and minimum (Tmin) air temperature respectively.

Then, Daily CHU = (Ymax + Ymin) / 2.0

Daily CHU are accumulated from starting and stopping dates determined by the dates when certain temperature threshold values are reached.

For evaluating CHU in Ontario, the starting and ending dates for accumulation were defined by Brown and Bootsma as follows:

**Start date**: Date when the average mean daily air temperature, based on 30-year normal, exceeded 10°C AND three consecutive days with mean daily air temperature >12.8 C had occurred after this date was met. The third day is the starting date.

**Stop date**: When the minimum air temperature dropped to ≤ -2°C or when the 30-year average daily mean air temperature dropped to 12°C (or lower), whichever occurred first. These criteria were also used in risk analyses of CHU for Ontario (Bootsma and Brown, 1995)

For Quebec, starting and ending date criteria have been used as follows (Bootsma et al., 1999):

**Start date**: Date when the average mean daily air temperature, based on 30-year normal, exceeded 10°C. Yearly variations from this average date were then determined based on the extent to which May temperature and precipitation deviated from the 30-yr normal.

**Stop date**: the date of 10% probability of occurrence of a killing freeze (Tmin-2C), or the

first occurrence of Tmin\_-2\_C, whichever occurred first. If the 10% probability date was not

available, then it could be estimated by the date when the average Tmin was \_6.5\_C.

In 2011, a re-evaluation of CHU for Quebec was undertaken with newly formulated start and stop date criteria developed in consultation with agronomists as follows (Bootsma, 2011):

**Start date**: The first occurrence of a 5-day moving average temperature equal to or greater than 12.8 °C after the 30 year median date of the last spring frost (0°C). The 5th day of the 5-day moving average was used as the starting date.

**Stop date**: CHU accumulations were ended the day before the first occurrence of a killing frost of ≤2.0°C.

While the CHU formula is the same for all regions of Canada, the criteria for estimating the start and end date for accumulating CHU can vary from region to region.

For the purpose of the CITD, the 30-year normal criteria were not practical since it may be frequently necessary to evaluate data for much shorter time periods, and normals data may often not be available. Therefore, the following default criteria for starting and ending CHU1 were programmed into the CITD and tested:

**Start date for CHU1 (CHU1 First)**: Three consecutive days when mean daily air temperature >12.8 C have occurred after April 15. The third day is the starting date.

**Stop date for CHU1 (CHU1 Last)**: The first occurrence of minimum air temperature of ≤ -2°C or Oct. 15, whichever occurs first.

In addition to the above start/end criteria, a second option was included in the program whereby the user has some flexibility in modifying the start/end criteria as one criteria may not be applicable to all regions of Canada. The start/stop criteria for accumulating CHU2 are based on a user-specified threshold temperature of flexible running mean temperature averages along with earliest and latest possible dates as follows:

Start Date for CHU2: First day that the X-day running tmean is ≥Y° C on or after date Z. X, Y and Z are set by the user.

Stop Date for CHU2: Day before the running X-day running tmean is ≤Y2° C or date Z2 at the latest. X, Y2 and Z2 are set by the user.

Tests of CHU2 and CHU3 shown in Appendix 6 used the following threshold values:

For CHU2, X=5 days, Y= 12.8°C, Z= April 15, Y2 = 10.1°C, Z2 = Oct. 31.

For CHU3, X=8 days, Y= 13.0°C, Z= April 15, Y2 = 11.3°C, Z2 = Oct. 31.

**Appendix 5 (not required for CITD when used with daily climate data)**.

Example of threshold values and regression equation constants and coefficients for specific ranges of latitude and longitude for CHU calculations

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Latitude range | | Longitude range | | Start temp. | Stop temp | CHU ave | | CHU 80% | |  |
| Min | Max | Min | Max | Constant | Coeff. | Constant | Coeff. | Prov. |
| 46.000 | 66.00 | -59.5 | -51.00 | 8.8 | 3.7 | 164.96 | 0.9465 | -207.54 | 1.0342 | NFLD |
| 42.000 | 47.95 | -68.0 | -59.50 | 11.0 | 5.8 | 185.20 | 0.9377 | -11.80 | 0.9538 | Atlantic |
| 44.000 | 47.95 | -74.0 | -68.05 | 12.8 | 6.5 | 157.45 | 0.9194 | 37.55 | 0.9297 | QC |
| 47.951 | 66.00 | -79.0 | -59.55 | 12.8 | 6.5 | 157.45 | 0.9194 | 37.55 | 0.9297 | QC |
| 40.000 | 47.95 | -95.0 | -74.01 | 12.8 | 6.5 | 177.82 | 0.9150 | 68.62 | 0.9020 | ON |
| 47.951 | 66.00 | -95.0 | -79.01 | 12.8 | 6.5 | 177.82 | 0.9150 | 68.62 | 0.9020 | ON |
| 48.000 | 66.00 | -101.5 | -95.01 | 11.2 | 5.8 | 212.93 | 0.9071 | 143.75 | 0.8436 | MB |
| 48.000 | 66.00 | -110.0 | -101.51 | 11.2 | 5.3 | 212.93 | 0.9071 | 143.75 | 0.8436 | SK |
| 48.000 | 52.00 | -115.0 | -110.01 | 11.2 | 4.9 | 212.93 | 0.9071 | 143.75 | 0.8436 | AB |
| 52.001 | 66.00 | -120.0 | -110.01 | 11.2 | 4.9 | 212.93 | 0.9071 | 143.75 | 0.8436 | AB |
| 48.000 | 52.00 | -136.0 | -115.01 | 12.7 | 4.6 | 343.24 | 0.8427 | 121.28 | 0.8545 | BC |
| 52.001 | 66.00 | -140.0 | -120.01 | 12.7 | 4.6 | 343.24 | 0.8427 | 121.28 | 0.8545 | BC |

Appendix 6. Comparison of CITD results with Excel spreadsheet calculations. Values highlighted in greeen are based on the original CIT Java program. Values for which CITD and spreadsheet values differ slightly are highlighted in yellow.

|  |  |  |
| --- | --- | --- |
| LOCATION: | Saanichton | Grid point # 43538 |
| Longitude | Latitude | Elevation (m) |
| -123.44 | 48.58 | 49 |
| VARIABLE | CITD results | Spread sheet |
| GDD First (day #) | 43 | 43 |
| GDD Last (day #) | 328 | 328 |
| GDD Length (days) | 286 | 286 |
| GDD | 1883 | 1883 |
| EGDD First (day #) | 91 | 91 |
| EGDD Last (day #) | 304 | 304 |
| EGDD | 1783 | 1783 |
| CHU1 | 2410 | 2410 |
| CHU1 start (day #) | 150 | 150 |
| CHU1 stop (day #) | 288 | 288 |
| CHU2 | 2446 | 2446 |
| CHU2 start (day #) | 148 | 148 |
| CHU2 stop (day #) | 289 | 289 |
| CHU3 | 2371 | 2371 |
| CHU3 start (day #) | 151 | 151 |
| CHU3 stop (day #) | 285 | 285 |
| PPE (mm) | -293.8 | -293.8 |
| PE4 (mm) | 410.4 | 410.4 |
| P4 (mm) | 116.6 | 116.6 |
| DAYS>30 | 0 | 0 |

|  |  |  |
| --- | --- | --- |
| LOCATION: | Fort Nelson 1971 | Grid point # 2846 |
| Longitude | Latitude | Elevation (m) |
| -122.59 | 58.83 | 309 |
| VARIABLE | CITD results | Spread sheet |
| GDD First (day #) | 111 | 111 |
| GDD Last (day #) | 277 | 277 |
| GDD Length (days) | 167 | 167 |
| GDD | 1287 | 1287 |
| EGDD First (day #) | 121 | 121 |
| EGDD Last (day #) | 272 | 272 |
| EGDD | 1405 | 1405 |
| CHU1 | 1948 | 1948 |
| CHU1 start (day #) | 150 | 150 |
| CHU1 stop (day #) | 286 | 286 |
| CHU2 | 1853 | 1853 |
| CHU2 start (day #) | 150 | 150 |
| CHU2 stop (day #) | 259 | 259 |
| CHU3 | 1702 | 1702 |
| CHU3 start (day #) | 154 | 154 |
| CHU3 stop (day #) | 249 | 249 |
| PPE (mm) | -207.6 | -207.6 |
| PE4 (mm) | 207.6 | 463.1 |
| P4 (mm) | 255.5 | 255.5 |
| DAYS>30 | 0 | 0 |

|  |  |  |
| --- | --- | --- |
| LOCATION/Year: | Osoyoos 1978 | Stn # 112865 |
| Longitude | Latitude | Elevation (m) |
| -123.44 | 48.58 | 49 |
| VARIABLE | CITD results | Spread sheet |
| GDD First (day #) | 75 | 75 |
| GDD Last (day #) | 301 | 301 |
| GDD Length (days) | 227 | 227 |
| GDD | 2401 | 2401 |
| EGDD First (day #) | 91 | 91 |
| EGDD Last (day #) | 285 | 285 |
| EGDD | 2260 | 2260 |
| CHU1 | 3367 | 3367 |
| CHU1 start (day #) | 117 | 117 |
| CHU1 stop (day #) | 288 | 288 |
| CHU2 | 3346 | 3346 |
| CHU2 start (day #) | 117 | 117 |
| CHU2 stop (day #) | 286 | 286 |
| CHU3 | 3259 | 3259 |
| CHU3 start (day #) | 120 | 120 |
| CHU3 stop (day #) | 286 | 286 |
| PPE (mm) | -537.1 | -523.7 |
| PE4 (mm) | 613.0 | 599.6 |
| P4 (mm) | 75.9 | 75.9 |
| DAYS>30 | 10 | 10 |

|  |  |  |
| --- | --- | --- |
| LOCATION: | Harrow 1984 | Stn # 6133360 |
| Longitude | Latitude | Elevation (m) |
| -82.90 | 42.03 | 191 |
| VARIABLE | CITD results | Spread sheet |
| GDD First (day #) | 101 | 101 |
| GDD Last (day #) | 317 | 317 |
| GDD Length (days) | 217 | 217 |
| GDD | 2430 | 2430 |
| EGDD First (day #) | 111 | 111 |
| EGDD Last (day #) | 305 | 305 |
| EGDD | 2379 | 2379 |
| CHU1 | 3618 | 3618 |
| CHU1 start (day #) | 119 | 119 |
| CHU1 stop (day #) | 289 | 289 |
| CHU2 | 3380 | 3380 |
| CHU2 start (day #) | 119 | 119 |
| CHU2 stop (day #) | 273 | 273 |
| CHU3 | 3143 | 3143 |
| CHU3 start (day #) | 143 | 143 |
| CHU3 stop (day #) | 276 | 276 |
| PPE (mm) | -210.4 | -207.1 |
| PE4 (mm) | 494.5 | 491.2 |
| P4 (mm) | 284.1 | 284.1 |
| DAYS>30 | 2 | 2 |

|  |  |  |
| --- | --- | --- |
| LOCATION: | Sudbury 1982 | Stn # 6068150 |
| Longitude | Latitude | Elevation (m) |
| -80.80 | 46.63 | 348 |
| VARIABLE | CITD results | Spread sheet |
| GDD First (day #) | 115 | 115 |
| GDD Last (day #) | 289 | 289 |
| GDD Length (days) | 175 | 175 |
| GDD | 1612 | 1612 |
| EGDD First (day #) | 125 | 125 |
| EGDD Last (day #) | 287 | 287 |
| EGDD | 1565 | 1565 |
| CHU1 | 2425 | 2425 |
| CHU1 start (day #) | 136 | 136 |
| CHU1 stop (day #) | 288 | 288 |
| CHU2 | 2340 | 2340 |
| CHU2 start (day #) | 126 | 126 |
| CHU2 stop (day #) | 260 | 260 |
| CHU3 | 1994 | 1994 |
| CHU3 start (day #) | 136 | 136 |
| CHU3 stop (day #) | 245 | 245 |
| PPE (mm) | -274.6 | -268.6 |
| PE4 (mm) | 463.0 | 457.0 |
| P4 (mm) | 188.4 | 188.4 |
| DAYS>30 | 1 | 1 |

|  |  |  |
| --- | --- | --- |
| LOCATION: | Kentville 1971 | Grid point # 53091 |
| Longitude | Latitude | Elevation (m) |
| -64.46 | 45.06 | 75 |
| VARIABLE | CITD results | Spread sheet |
| GDD First (day #) | 109 | 109 |
| GDD Last (day #) | 315 | 315 |
| GDD Length (days) | 207 | 207 |
| GDD | 1754 | 1754 |
| EGDD First (day #) | 119 | 119 |
| EGDD Last (day #) | 304 | 304 |
| EGDD | 1735 | 1735 |
| CHU1 | 2583 | 2583 |
| CHU1 start (day #) | 151 | 151 |
| CHU1 stop (day #) | 288 | 288 |
| CHU2 | 2543 | 2543 |
| CHU2 start (day #) | 151 | 151 |
| CHU2 stop (day #) | 281 | 281 |
| CHU3 | 2486 | 2486 |
| CHU3 start (day #) | 153 | 153 |
| CHU3 stop (day #) | 278 | 278 |
| PPE (mm) | -129.1 | -129.1 |
| PE4 (mm) | 469.2 | 469.2 |
| P4 (mm) | 340.1 | 340.1 |
| DAYS>30 | 0 | 0 |

|  |  |  |
| --- | --- | --- |
| LOCATION: | Quebec 1952 | Stn # 7010160 |
| Longitude | Latitude | Elevation (m) |
| -71.38 | 46.80 | 74 |
| VARIABLE | CITD results | Spread sheet |
| GDD First (day #) | 126 | 126 |
| GDD Last (day #) | 283 | 283 |
| GDD Length (days) | 158 | 158 |
| GDD | 1722 | 1722 |
| EGDD First (day #) | 136 | 136 |
| EGDD Last (day #) | 281 | 281 |
| EGDD | 1676 | 1676 |
| CHU1 | 2616 | 2616 |
| CHU1 start (day #) | 146 | 146 |
| CHU1 stop (day #) | 284 | 284 |
| CHU2 | 2565 | 2565 |
| CHU2 start (day #) | 145 | 145 |
| CHU2 stop (day #) | 270 | 270 |
| CHU3 | 2545 | 2545 |
| CHU3 start (day #) | 146 | 146 |
| CHU3 stop (day #) | 270 | 270 |
| PPE (mm) | -104.3 | -106.5 |
| PE4 (mm) | 504.7 | 506.9 |
| P4 (mm) | 400.4 | 400.4 |
| DAYS>30 | 7 | 7 |