A NEW APPROACH TO AIR TEMPERATURE ANALYSIS

32ND CONFERENCE ON CLIMATE VARIABILITY AND CHANGE

AMERICAN METEOROLOGICAL SOCIETY

Phoenix, USA

January 7th, 2019

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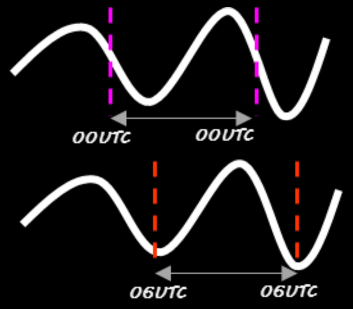
MOTIVATION & RESEARCH QUESTIONS



JULY 1ST 1961: CLIMATOLOGICAL DAY REDEFINED IN CANADA

OLD OBSERVING WINDOW (00UTC)
MISCHARACTERIZATION OF MINIMA

NEW OBSERVING WINDOW (06UTC)
INTRODUCTION OF COLD BIAS & MINIMA DOUBLECOUNTING

HOMOGENIZATION OF DATA AT 120 SYNOPTIC STATIONS
0.5 – 12.5 °C TEMPERATURE ADJUSTMENT ON INDIVIDUAL DAYS

OBSERVING WINDOW AFFECTS THE ACCURACY OF DETERMINATION OF DIURNAL AIR TEMPERATURE EXTREMA

1. Vincent et al. (2009). Bias in minimum temperature introduced by a redefinition of the climatological day at the Canadian stations. *J Appl Meteorol Climatol* 48:2160-2168.

2. Vincent et al. (2012). A second generation of homogenized Canadian monthly surface air temperature for climate trend analysis. *J Geo Research* 117: D18110.

3. Žaknić-Ćatović A. and W.A. Gough (2018). A comparison of climatological observing windows and their impact on detecting daily temperature extrema. *Theor Appl Climatol* 132(1-2):41-54

Q1. SUCCESS RATE OF THE OBSERVING WINDOW IN IDENTIFICATION OF TRUE DIURNAL EXTREMA POINTS?

Q2. EFFECT OF THE OBSERVING WINDOW SELECTION ON LONG-TERM TEMPERATURE AVERAGING?

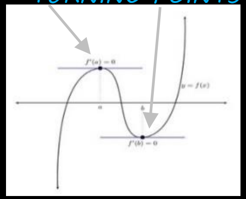
Q3. DIURNAL EXTREMA TIMING: A NEW CLIMATOLOGICAL PARAMETER?

PROBLEM STATEMENT

MATHEMATICAL EXTREMA

POINTS ON A T(t) CURVE IN WHICH DAILY TEMPERATURE TREND CHANGES SIGN

“TURNING POINTS”

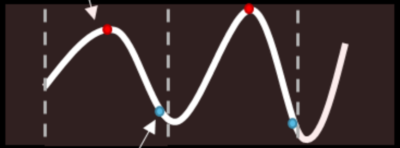


(T(t)DERIVATIVE = 0)

DISCRETE SEARCH METHODS

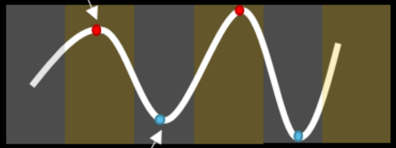
BEGINNING & LENGTH OF SEARCH INTERVAL

$$T_{max} = \max_{0 \le i \le 24} (T_i)$$



$$T_{min} = \min_{0 \le i \le 24} (T_i)$$

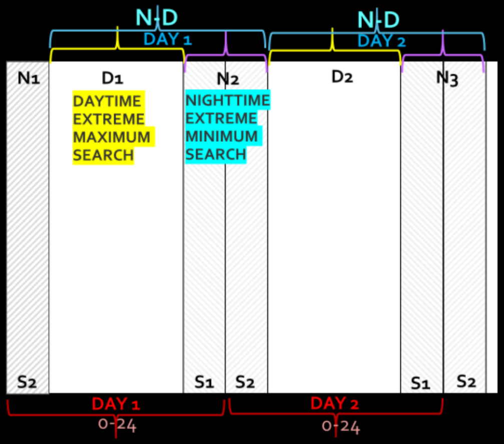
$$T_{max} = \max_{RISE \le i \le SET} (T_i)$$

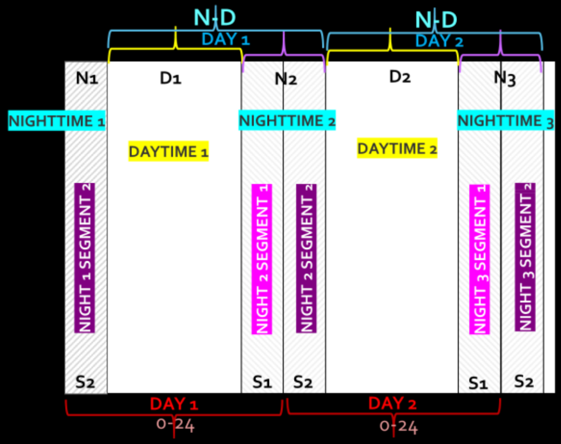


$$T_{min} = \min_{SET \le i \le RISE} (T_i)$$

NIGHTTIME FRAGMENTATION

SEGMENTS OF TWO CONSECUTIVE NIGHTS





NIGHTTIME / DAYTIME: UNIQUE CLIMATOLOGICAL EVENTS

SEPARATION OF DIURNAL EXTREMA SEARCH PERIOD

NIGHTTIME AND DAYTIME

CLIMATOLOGICAL OBSERVING WINDOW (COW)

COW_{0-24} EXTREMA IDENTIFICATION METHOD

MINIMUM & MAXIMUM: D + N_1S_2 + N_2S_1 SEGMENTS

CORRECT IDENTIFICATION OF N_1S_2 MINIMA

T_{min} (N_1S_2) < T_{min} (N_2S_1)

OMISSIONS OF WARMER MINIMA (N_1S_2)

IDENTIFICATION OF ENDPOINT MINIMA (N_2S_1)

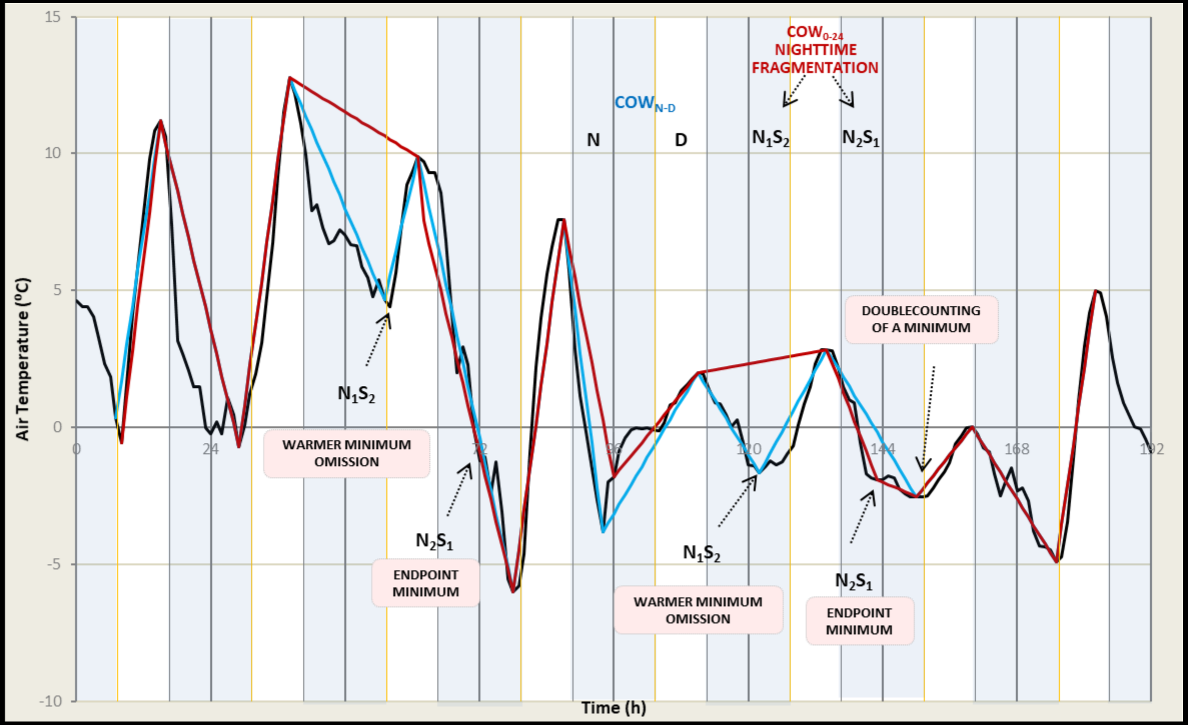
DOUBLECOUNTING OF COLD MINIMA (N_1S_2 & N_2S_1)

COW_{N-D} EXTREMA IDENTIFICATION METHOD

MINIMUM: SUNSET TO SUNRISE

MAXIMUM: SUNRISE TO SUNSET

CORRECT IDENTIFICATIONS OF SOLARLY-DRIVEN TEMPERATURE EXTREMA



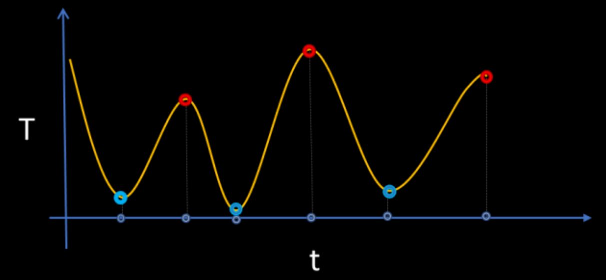
COMPARISON OF COW_{0-24} and COW_{N-D} OBSERVING WINDOWS

DIURNAL EXTREMA TIMING (DET)

A NEW CLIMATOLOGICAL PARAMETER?

KEY ELEMENT TO ACCURACY OF ANALYTICAL TEMPERATURE APPROXIMATIONS

CONNECTION POINTS ON A T(t) CURVE



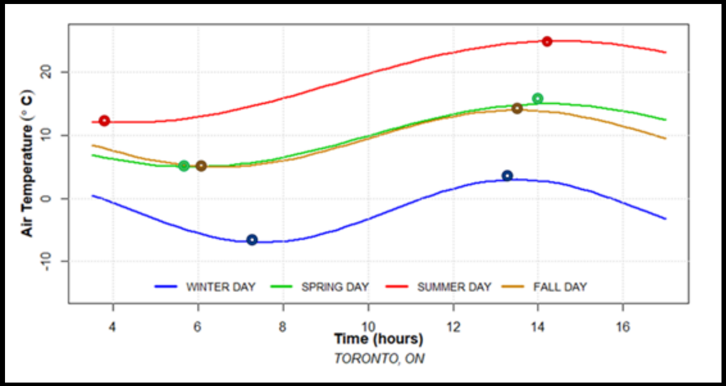
BASIS FOR DEGREE-DAY FORMULA MODIFICATION

IMPROVEMENT OF ESTIMATION OF TEMPERATURE-RELATED QUANTITIES

4. Žaknić-Ćatović A. et al (2018). Modification of the degree-day formula for diurnal meltwater generation and refreezing. *Theor Appl Climatol* 131(3):1157-1171. DOI 10.1007/s00704-017-2068-y

NOT A PART OF CLIMATE RECORDS

ANNUAL & SEASONAL t_{min}, t_{max} SHIFTS



SEASONALLY AVERAGED DIURNAL TEMPERATURE-TIME CHANGE

ANNUAL AVERAGES OF DIURNAL t_{min} AND t_{max} SYSTEMATICALLY CHANGING THROUGH TIME

TEMPERATURE-TIMING ANALYSIS ALGORITHM

DIURNAL AIR TEMPERATURE MEASUREMENTS

DIURNAL TEMPERATURE EXTREMA

HIGH-FREQUENCY TEMPERATURE

$COW_{0\text{-}24}$

$COW_{N\text{-}D}$

NOCTURNAL MINIMA

DAYTIME MAXIMA

TEMPERATURE AVERAGING

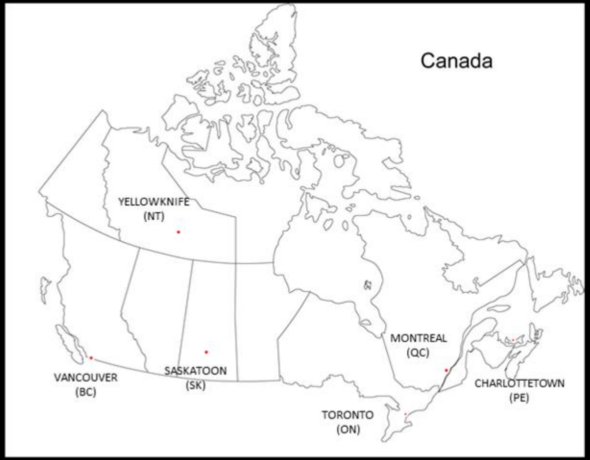
NT_{min}

DT_{max}

DIURNAL EXTREMA TIMING (DET) t_{min} & t_{max}

BMM	AMM	BNM	ANM
BEFORE MIDNIGHT MINIMA	AFTER MIDNIGHT MINIMA	BEFORE NOON MAXIMA	AFTER NOON MAXIMA
BMM DET BMM t_{min}	AMM DET AMM t_{min}	BNM DET BNM t_{max}	ANM DET ANM t_{max}

MIDNIGHT SUNRISE NOON SUNSET

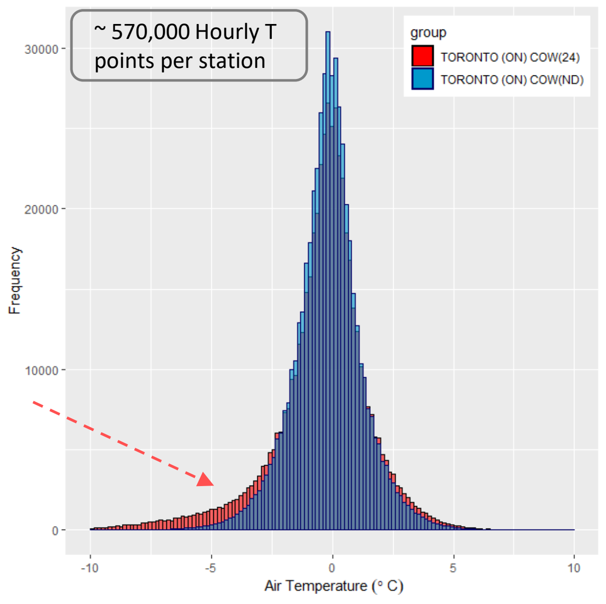


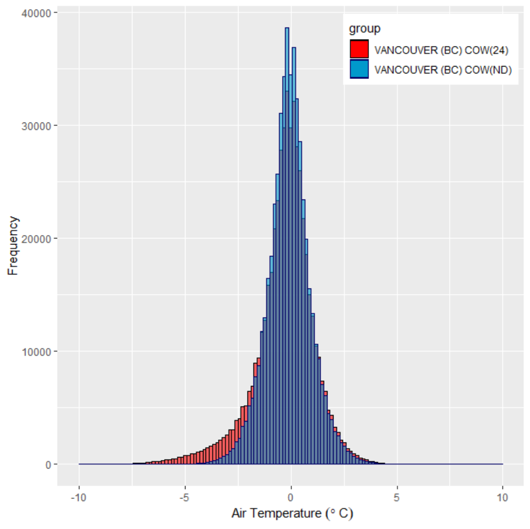
Stations:

VANCOUVER INT' A (BC)
YELLOWKNIFE (NT)
SASKATOON INT'L A (SK)
TORONTO PEARSON INT'L A (ON)
MONTREAL PET INT'L A (QC)
CHARLOTTETOWN (PE)

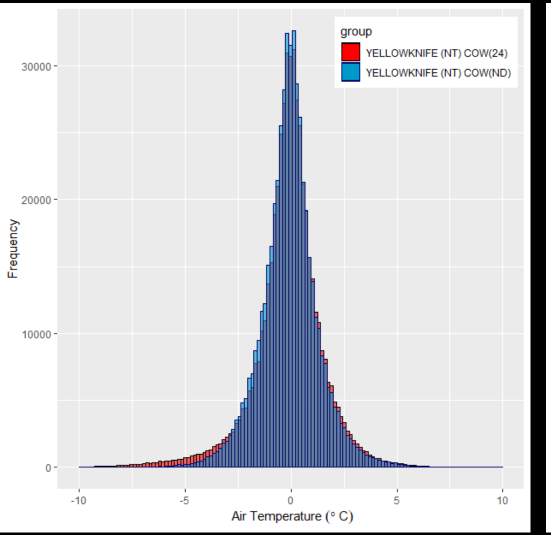
Historical Climate Data
Environment of Canada
Government of Canada

CONFORMITY OF LINEARLY TRACKED TEMPERATURES WITH HOURLY OBSERVATIONS

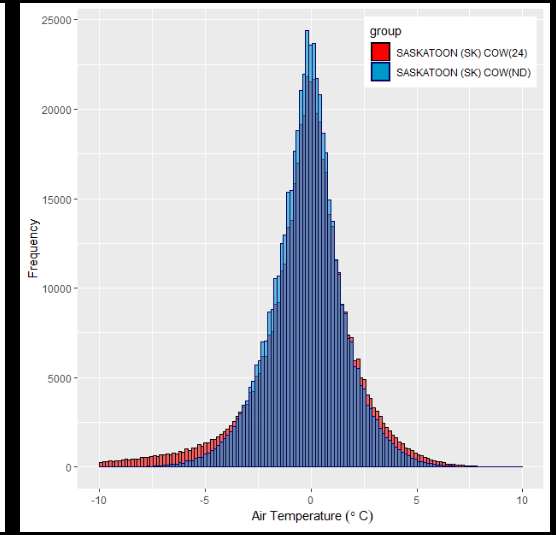




VANCOUVER (BC)

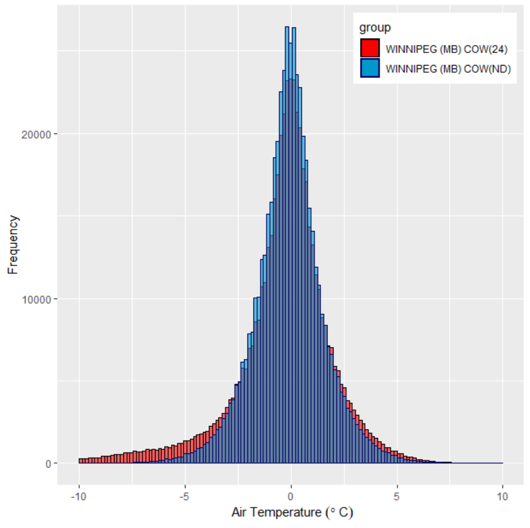


YELLOWKNIFE (NT)

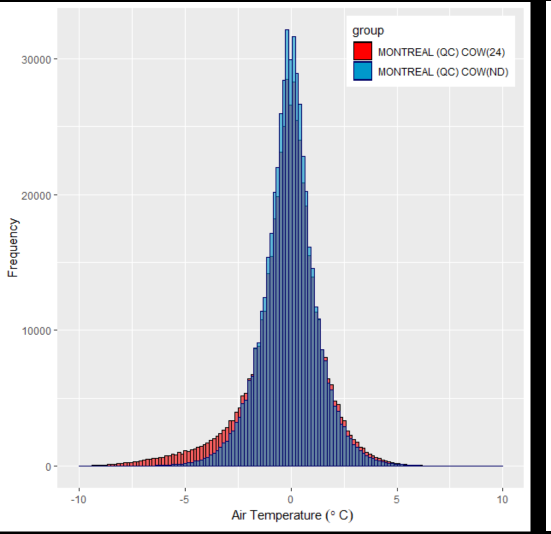


SASKATOON (SK)

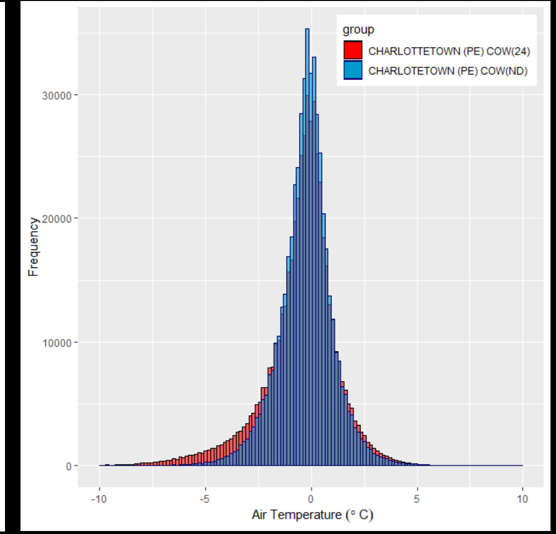
MAIN STATISTICS	μ_{0-24} (°C)	σ_{0-24} (°C)	μ_{N-D} (°C)	σ_{N-D} (°C)
TORONTO	-0.44	2.06	-0.18	1.45
VANCOUVER	-0.32	1.44	-0.09	1.04
YELLOWKNIFE	-0.13	1.70	-0.05	1.40
SASKATOON	-0.36	2.47	-0.17	1.77
WINNIPEG	-0.36	2.41	-0.09	1.66
MONTREAL	-0.29	1.84	-0.06	1.36
CHARLOTTETOWN	-0.49	1.77	-0.24	1.31



WINNIPEG (MB)

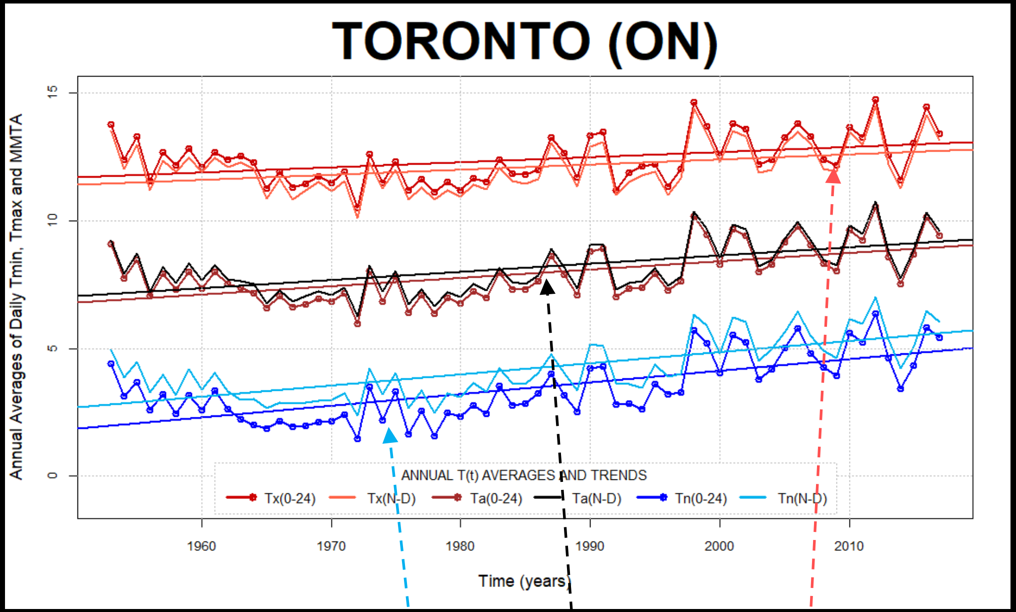


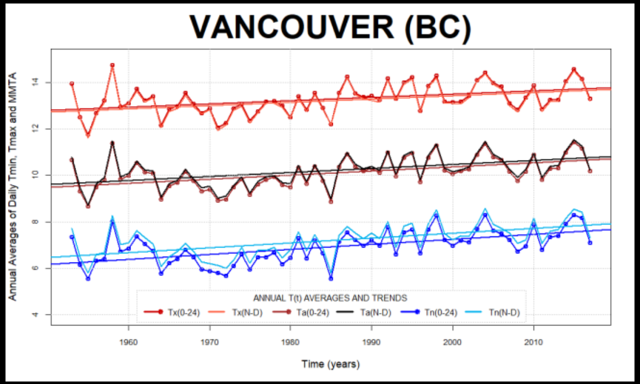
MONTREAL (QC)

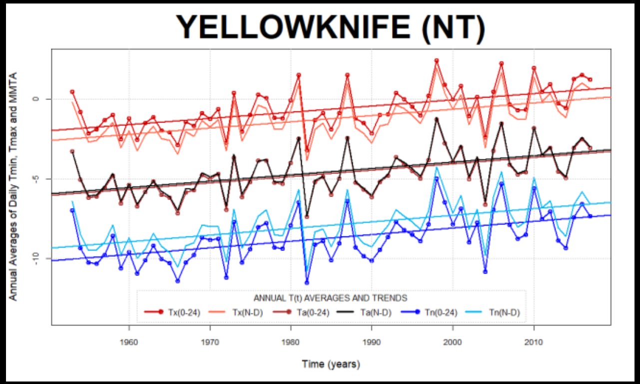


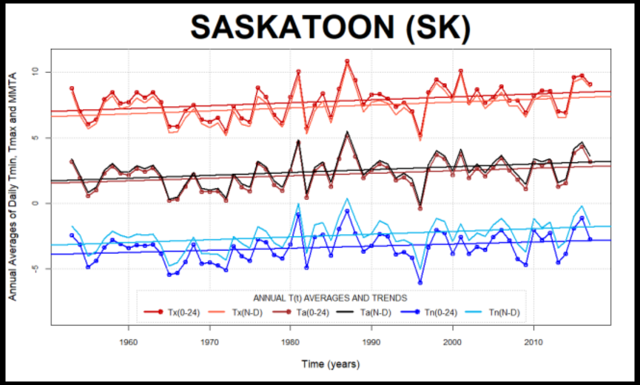
CHARLOTTETOWN (PE)

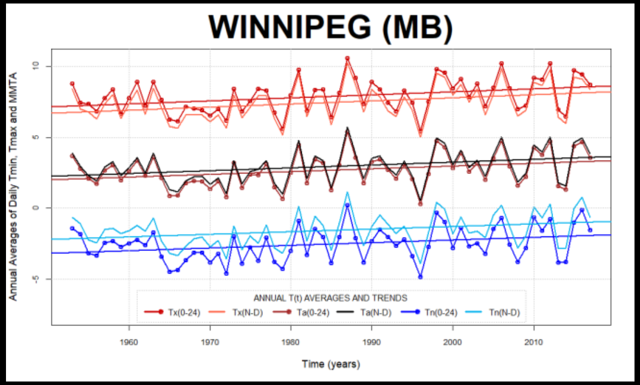
ANNUALLY AVERAGED DIURNAL AIR TEMPERATURE EXTREMA

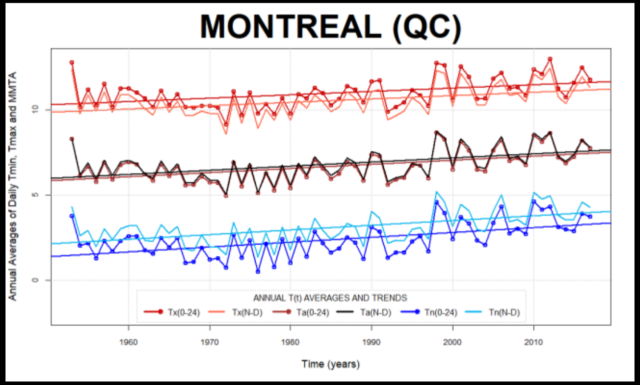


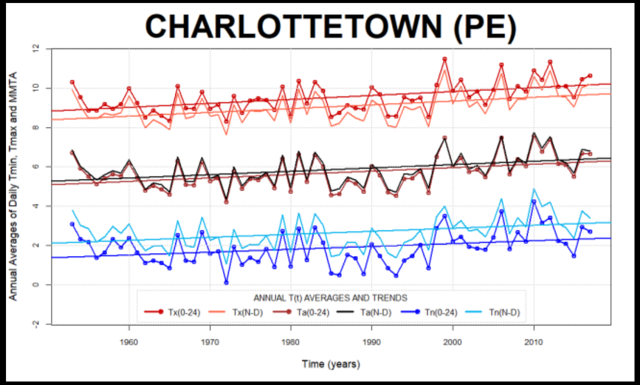












TEMPERATURE DIFFERENCES BETWEEN COWs

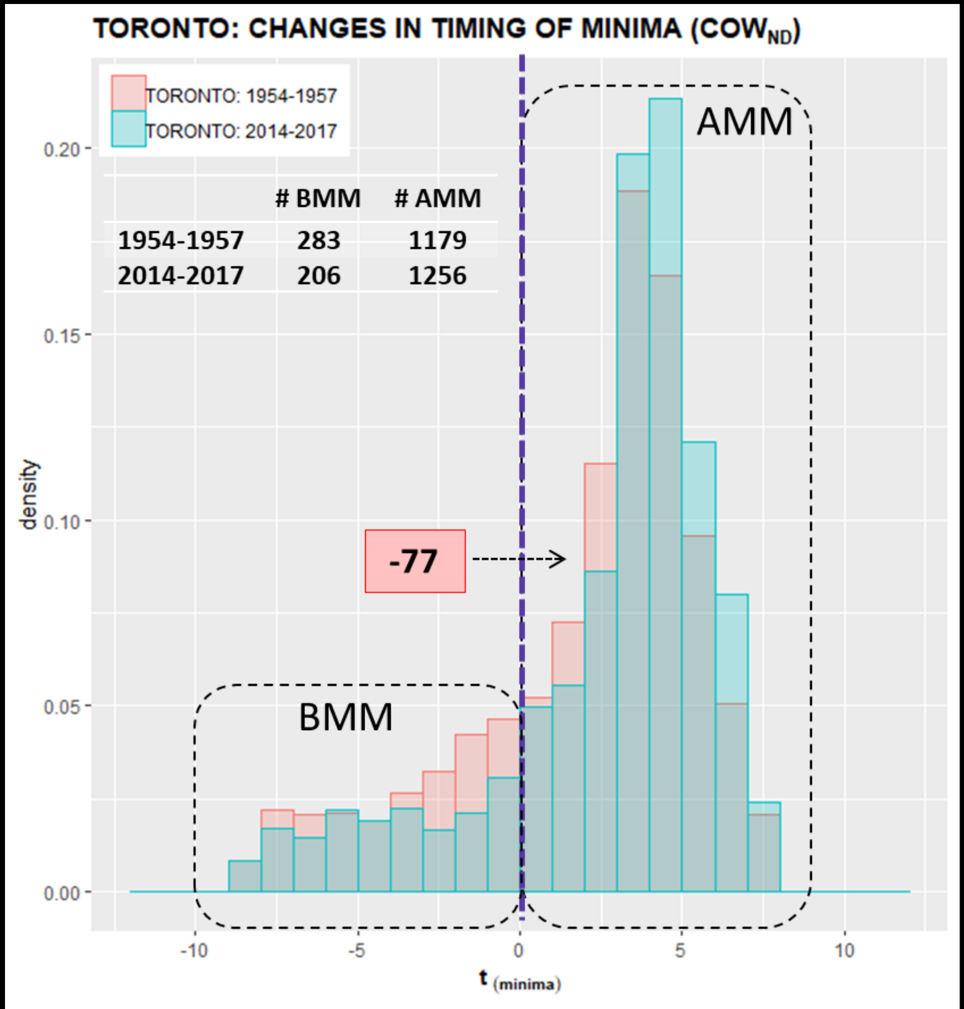
$\text{COW}_{0\text{-}24} - \text{COW}_{N\text{-}D}$	ΔT_{min} (°C)	ΔMMA (°C)	ΔT_{max} (°C)	ΔDTR (°C)
TORONTO	-0.77	-0.23	0.31	1.08
VANCOUVER	-0.28	-0.10	0.08	0.35
YELLOWKNIFE	-0.80	-0.10	0.60	1.40
SASKATOON	-0.89	-0.25	0.39	1.28
WINNIPEG	-0.96	-0.26	0.45	1.40
MONTREAL	-0.70	-0.13	0.44	1.14
CHARLOTTETOWN	-0.77	-0.15	0.47	1.25
CANADIAN AVERAGES	**-0.74**	**-0.17**	**0.39**	**1.13**

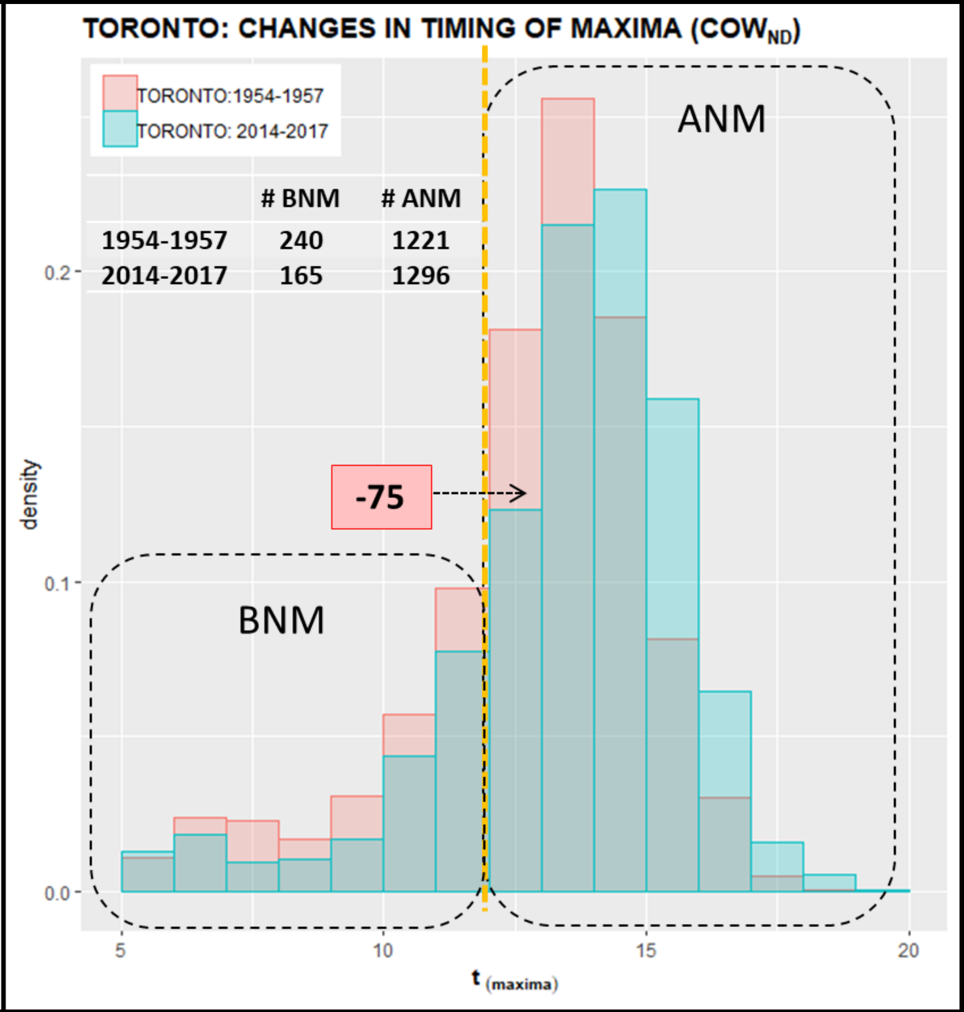
TIME EVOLUTION OF DIURNAL EXTREMA TIMING

BMM
BEFORE
MIDNIGHT
MINIMA

↓

AMM
AFTER
MIDNIGHT
MINIMA





BNM
BEFORE
NOON
MAXIMA

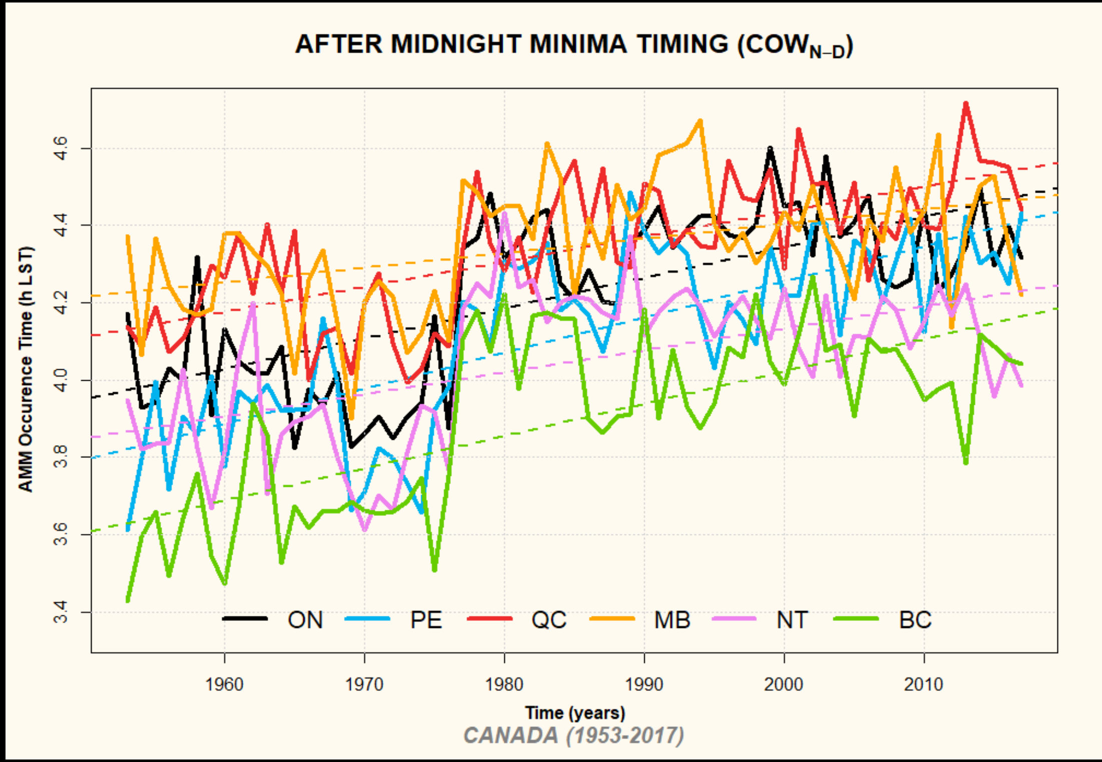
↓

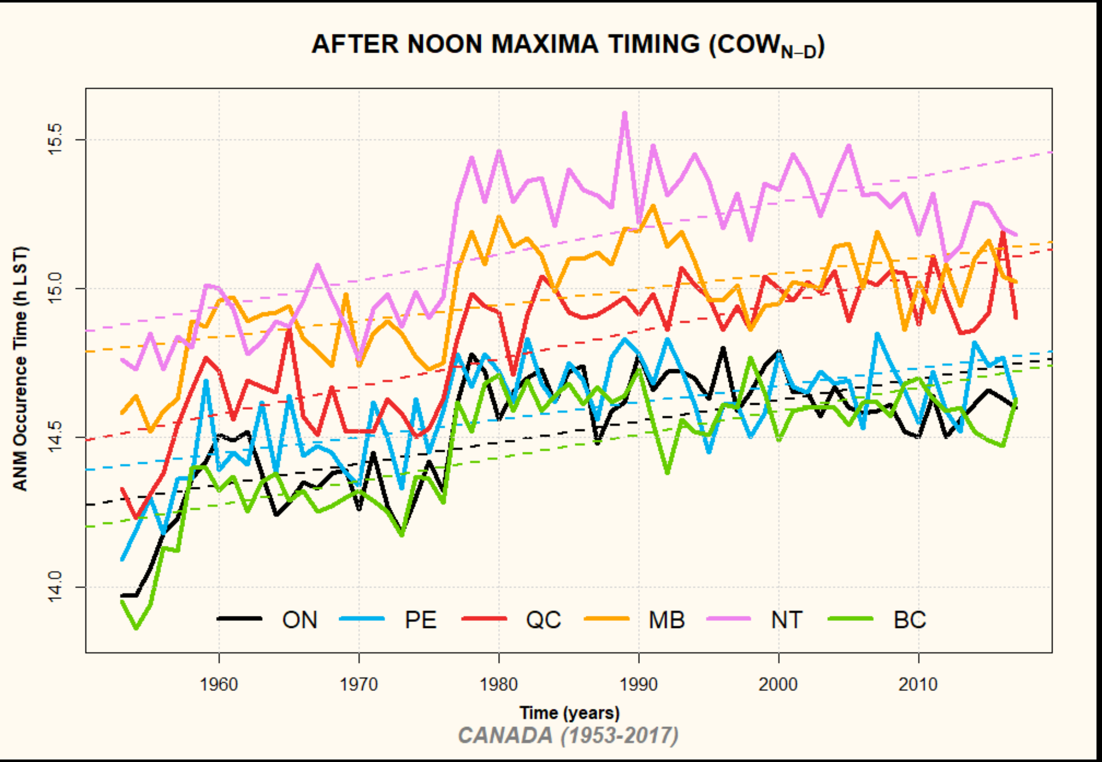
ANM
AFTER
NOON
MAXIMA

MIGRATION COUNT	BMM	BNM
VANCOUVER	-109	-63
YELLOWKNIFE	-36	-54
SASKATOON	-35	-69

MIGRATION COUNT	BMM	BNM
WINNIPEG	-42	-16
MONTREAL	-69	-36
CHARLOTTETOWN	-100	-134

TRENDS OF ANNUALLY AVERAGED TIMING SUBPOPULATIONS





AMM TIME SHIFTS	TIME INCREMENT (h) $m_{lin}(t_{min})$ x (2017-1953)	$m_{lin}(t_{min})$ (h/y)	MK p-value
TORONTO	0.51	7.9e-03	3.58e-07
VANCOUVER	0.54	8.3e-03	1.19e-07
YELLOWKNIFE	0.37	5.7e-03	1.20e-03
SASKATOON	0.45	6.8e-03	2.72e-05
WINNIPEG	0.24	3.7e-03	1.00e-03
MONTREAL	0.42	6.5e-03	2.22e-16
CHARLOTTETOWN	0.59	9.1e-03	2.00e-16

ANM TIME SHIFTS	TIME INCREMENT (h) $m_{lin}(t_{max})$ x (2017-1953)	$m_{lin}(t_{max})$ (h/y)	MK p-value
TORONTO	0.46	7.1e-03	4.53e-06
VANCOUVER	0.51	7.8e-03	5.96e-07
YELLOWKNIFE	0.57	8.7e-03	1.07e-06
SASKATOON	1.39	2.1e-02	3.58e-04
WINNIPEG	0.35	5.3e-03	2.60e-05
MONTREAL	0.61	9.3e-03	2.22e-16
CHARLOTTETOWN	0.38	5.8e-03	2.15e-06

CLIMATE PARAMETER SENSITIVITY INDEX (CPSI)

$$CPSI(NT_{min}) = (\Delta NT_{min}) / (\delta NT_{min})$$

ΔT_{min} = CHANGE IN TEMPERATURE MINIMA DUE TO CLIMATE CHANGE
δT_{min} = NORMAL VARIABILITY RANGE OF TEMPERATURE MINIMA

$$\Delta T_{min} = m_{lin}\,(NT_{min}) \times (2017\text{-}1953)$$

$$\delta T_{min} = \max\,(NT_{min}) - \min\,(NT_{min})$$

$$CPSI(t_{min}) = (\Delta t_{min}) / (\delta t_{min})$$

Δt_{min} = CHANGE IN AMM TIMING DUE TO CLIMATE CHANGE
δt_{min} = NORMAL VARIABILITY RANGE OF AMM TIMING

$$\Delta t_{min} = m_{lin}\,(t_{min}) \times (2017\text{-}1953)$$

$$\delta t_{min} = \max\,(t_{min}) - \min\,(t_{min})$$

CPSI (%)	NT_{min}	DT_{max}	AMM t_{min}	ANM t_{max}
TORONTO (ON)	4.88	2.21	6.40	6.64
VANCOUVER (BC)	3.24	1.95	6.67	6.23
YELLOWKNIFE (NT)	3.70	3.37	3.70	7.09
SASKATOON (SK)	1.92	1.90	5.57	19.89
WINNIPEG (MB)	1.69	1.95	3.03	5.72
MONTREAL (QC)	2.79	1.96	5.26	10.05
CHARLOTTETOWN (PE)	1.89	2.11	7.46	5.33
CANADIAN AVERAGES (%)	2.88	2.21	5.44	8.71

SUMMARY AND CONCLUSIONS

COMPONENTS OF THE NEW APPROACH TO AIR TEMPERATURE ANALYSIS	**$COW_{N\text{-}D}$ NT_{min}, DT_{max}**	**DET AMM t_{min}, ANMt_{max}**	**CPSI (NT_{min}) CPSI (t_{min})**

APPLICATION OF THE NEW APPROACH IN CANADA-WIDE STUDY

$COW_{N\text{-}D}$ NT_{min} > $COW_{0\text{-}24}$ T_{min}	**+0.74°C**
MIGRATION OF BMM TO AMM	**67**
MIGRATION OF BNM TO ANM	**64**
ANM t_{max} TIME INCREMENT	**+37 min**
AMM t_{min} TIME INCREMENT	**+27 min**
CPSI RANKING HIGH INDEX FOR **t_{max}** & **t_{min}** PARAMETERS	**8.71 %** **5.44 %**