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Preliminary intercomparison results for NARCCAP, other RCMs, and statistical downscaling over southern Quebec

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September 10-11, 2009 - NCAR Foothills Lab, EOL Atrium

NSERC-SRO project (Canada), Oct. 2007-2010

"Probabilistic assessment of regional changes in climate variability and extremes"

Natural Sciences and Engineering Research Council of Canada | Conseil de recherches en sciences naturelles et en génie du Canada | Canada

Team members (Canada):

1. Universities
- **McGill** (PI): Van TV Nguyen
- **UQÀM**: René Laprise
- **INRS-ETE**: Taha Ouarda & André St-Hilaire
- **University of British Columbia**: William Hsieh

2. Research Lab.
- **Environment Canada (EC)**: Xuebin Zhang (INRS) & Philippe Gachon (UQÀM/McGill, co-PI)

Contact Persons & Collaborators (International-National):

- **ENSEMBLES**: Clare Goodess (CRU, UK), Jens Christensen (DMI, Denmark) & Colin Jones (SMHI, Sweden)
- **NARCCAP**: Linda Mearns (NCAR, US)
- **Canadian Climate Centre for modeling & analysis**: Greg Flato (EC, Canada)
- **Canadian Climate Change Scenarios Network (CCCSN)**: Neil Comer (EC)

Project Objectives

Three main objectives:

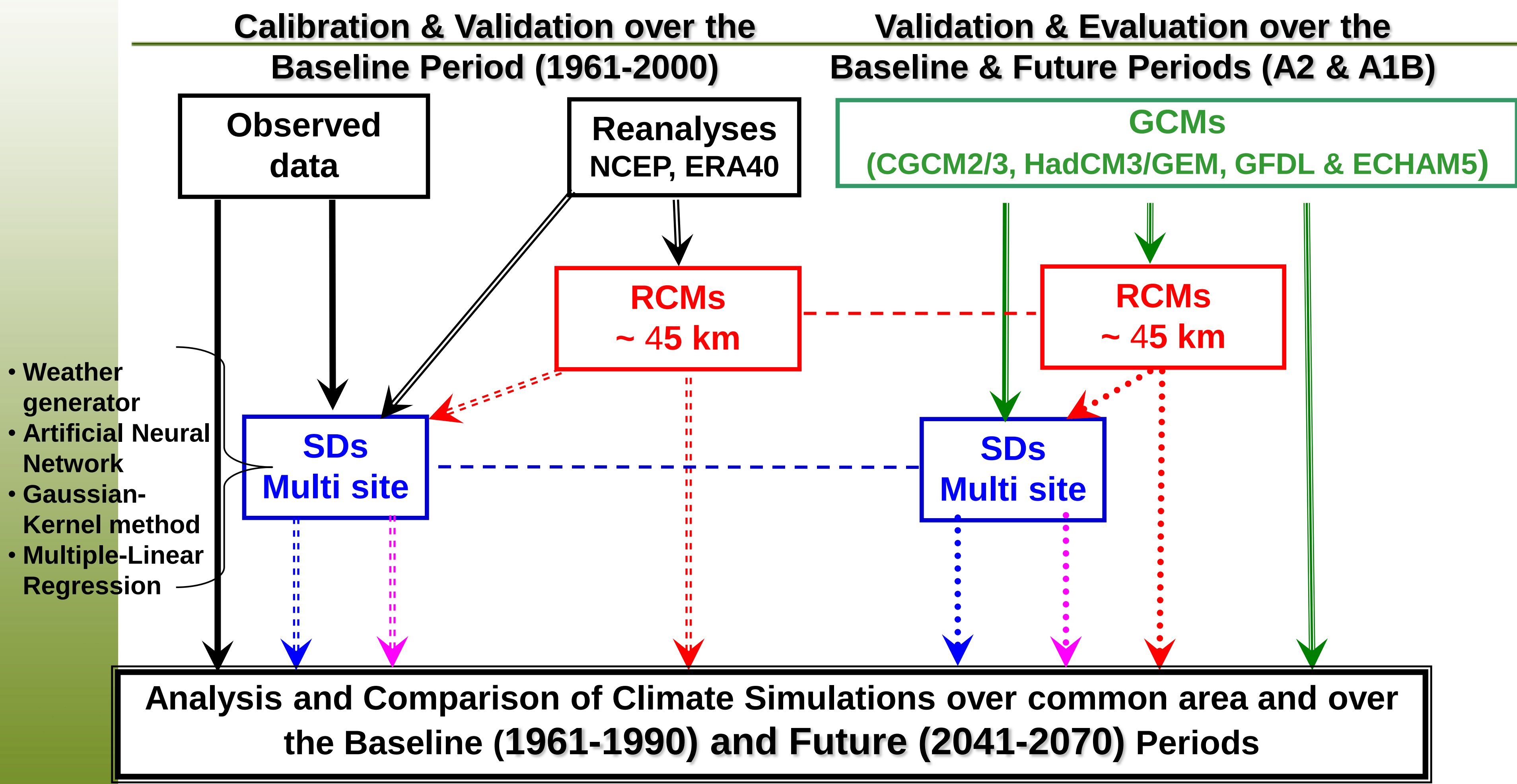
I) Development and application of statistical downscaling methods in order to generate (multi-site & multivariate) climate information

II) Development and evaluation of future high-resolution RCMs. Applying statistical downscaling (SD) methods from GCM to RCM resolutions and intercompare RCMs & SDs

III) Generate high resolution probabilistic climate change scenarios including extremes and variability with assessments of their associated uncertainties (from various downscaling approaches)

Metric of the Downscaling Scheme & simulations

Uncertainties related to GCM/RCM boundary forcings, Downscaling Methods (2 families) & Emission Scenarios (2 SRES)



GCM = Global Climate Model; SD = Statistical Downscaling; RCM = Dynamical Downscaling

Research objectives from RCMs runs from NARCCAP (and others)

1. Inter-compare different RCMs (NCEP driven) to further reconstruct observed extremes (precipitation, temperature) for the Quebec/Ontario/BC region;
   - Evaluate errors or added values due to RCM (NCEP vs GCMs driven conditions): low & high frequency variability;
   - Test and choice the appropriate methodology of interpolation to validate the RCM outputs with gridded observed data (e.g., Cubic Spline method or other methods);
2. Frequency analysis (occurrence & intensity) of the extremes as simulated by the RCMs;
3. Develop and validate preditors from selected RCM runs to be used in Statistical Downscaling models;
4. Inter-compare different RCMs vs Statistical Downscaling models and construct probabilistic scenarios (uncertainties with confidence interval information).

(13 series) RCMs runs available from Ouranos, CRCMD & NARCCAP

Run	Model Version	Domain & Resolution[1]	Driving atmospheric & oceanic data	GHG+A evolution	Time window
abf	Canadian RCM.3.7.1	AMNO 45 km & 29L	NCEP & AMIP02	-	1960-dec - 1990-dec
abg			ERA40 & AMIP02		1960-dec - 1990-dec
abi			CGCM2 3rd member (6h)	Observed	1960-dec - 1990-dec
abj			CGCM2 3rd member (6h)	SRES A2	2040-dec - 2070-dec
acu	Canadian RCM.4.1.1	QC 45 km & 29L	CGCM3 4th member (6h)	Obs + SRES A2	1960-dec - 2100-nov
acy			ERA40 & AMIP02	-	1960-dec - 2002-jul
acw		AMNO 45 km & 29L	ERA40 (6h) & AMIP03		1960-dec - 2002-jul
ade			NCEP & AMIP05 (6h)		1960-dec - 2005-may
adj	Canadian RCM.4.2.0	AMNO 45 km & 29L	CGCM3 4th member (6h)	SRES A2	1960-dec - 1990-dec
adk			CGCM3 4th member (6h)		2040-dec - 2070-dec
abx	ARPÈGE 4.4	WINI 160x32 OGG & 31L	ERA40 (6-hrs)	-	1961-jan - 2001-dec
acb			ERA40 (6-hrs) & [ARPEGE.3 coupled OPA A2]	[illegible]	[illegible]

Run	Model Version	Domain & Resolution & No of grid Points	Drivi[illegible] atmosph[illegible] & ocea[illegible] data
LAM_NA_ERA40_0.5deg	GEMCLIM CRCM5	North America & 0.5deg & 150lon x 138lat pts	ERA-4[illegible] 0.5de[illegible]
LAM_NA_ERA40_0.25deg		North America & 0.25deg & 300lon x 276lat pts	ERA-4[illegible] 0.25d[illegible]

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	Phase I		Phase II			
	NCEP		GFDL	CGCM3	HADCM3	CCSM
CRCM	finished		--	finished	--	planned
ECPC	finished		running	--	planned	--
HRM3	finished		planned	--	finished	--
MM5I	finished		--	--	planned	finished
RCM3	finished		finished	planned	--	--
WRFP	finished		--	planned	--	finished
Timeslices			finished	--	--	running

(1) Assessment of RCMs simulations (daily surface variables) based on extreme indices (vs gridded observed & reanalysis information)

Precipitation indices				
Frequency	**Prcp1**	Wet days (precipitation>1 mm), [%]	Season	N/a
Intensity	**SDII**	Precipitation intensity (rain/rainday), [mm/day]	Season	SDII
Duration and Extremes	**CDD**	Max no of consecutive dry days (precipitation<1 mm), [day]	Season	CDD
	R3d	Greatest 3 days total rainfall [mm]	Season	R5d
	Prec90pc	90^{th} percentile of rainday amounts [mm/day]	Season	R95t and N° of days with prec. >95^{th} perc.
	R90p	%days with precipitation > 90^{th} percentile calculated for wet days on the basis of 61-90 period, [%]	Season	
Temperature indices				
Daily variability	**Fr/Th**	Days with freeze and thaw cycle (Tmax > 0°C and Tmin < 0°C), [day]	Month	N/a
	Fd	Total number of frost days (days with absolute minimum temperature < 0 deg C), [day]	Month	Fd
Cold Extremes	**Tmin10pb**	10^{th} percentile of daily minimum temperature, [°C]	Season	N/a
	Tmax10pb	10^{th} percentile of daily maximum temperature, [°C]	Season	N/a
	TN10p	% days Tmin<10^{th} percentile calculated for each calendar day (61-90 based period) using running 5 day window, [%]	Season	N/a
Warm Extremes	**Tmin90pb**	90^{th} percentile of daily minimum temperature, [°C]	Season	N/a
	Tmax90pb	90^{th} percentile of daily maximum temperature, [°C]	Season	N/a
	TX90p	% days Tmax>90^{th} percentile calculated for each calendar day (61-90 based period) using 5 days window, [%]	Season	N/a

(1) Extreme Analysis

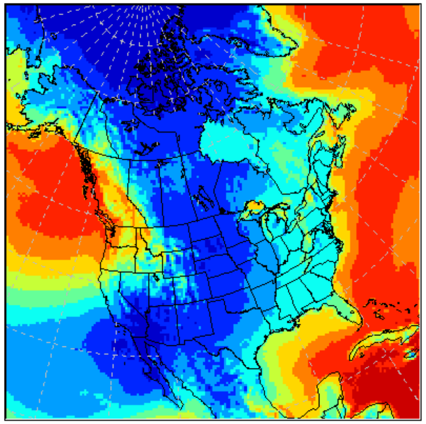
Example: Number of Days with Daily PCP ≥ 1 mm (Prcp1)

In %

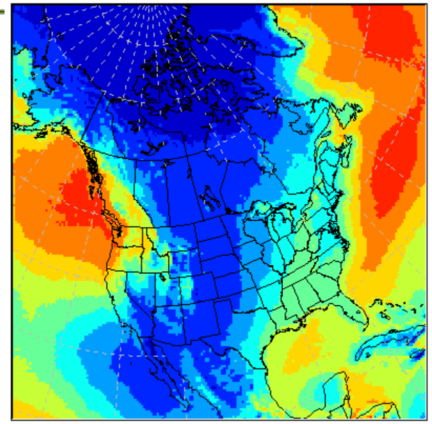
Winter: Dec to Feb

Seasonal Mean over 1961-1990

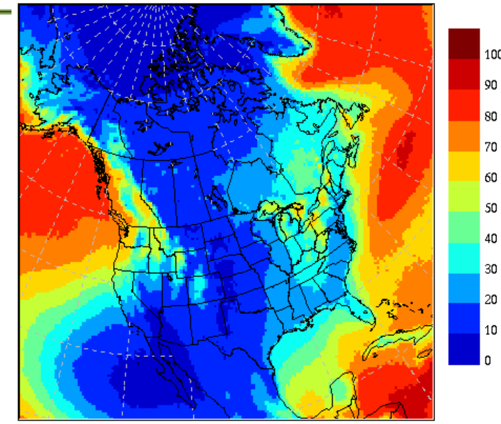
A. CRCM nested with CGCM2 #3



B. CRCM nested with CGCM3 T47 #4

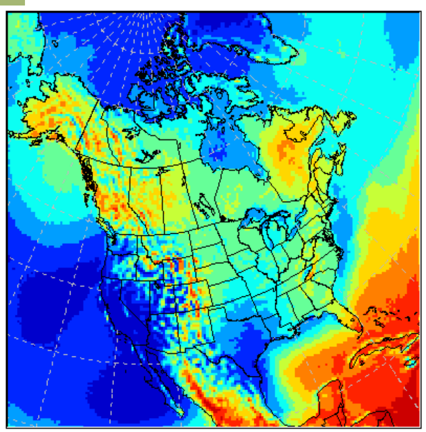


C. ARPEGE nested with ERA40

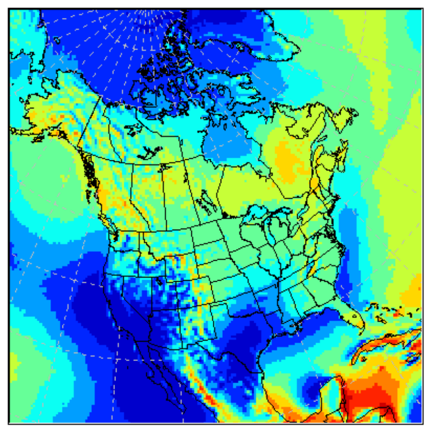


Summer: Jun to Aug

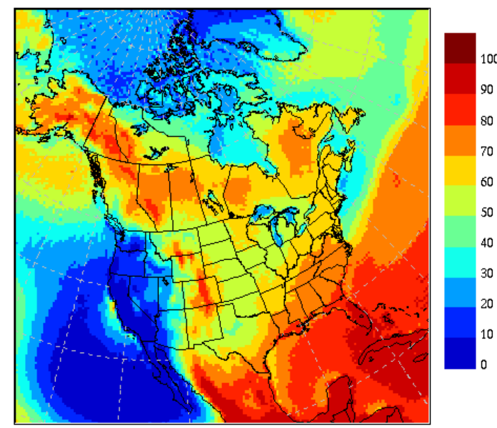
A. CRCM nested with CGCM2 #3



B. CRCM nested with CGCM3 T47 #4



C. ARPEGE nested with ERA40



(1) Extreme Analysis

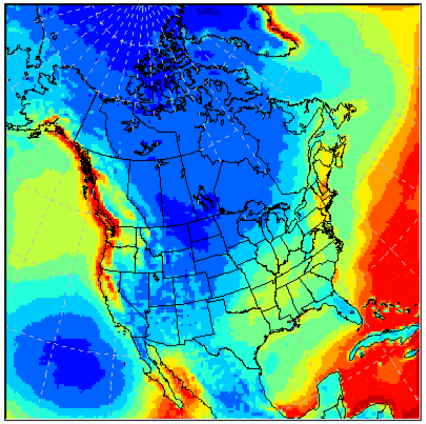
Example: Intensity Index (SDII): Mean intensity per wet day

In mm/day

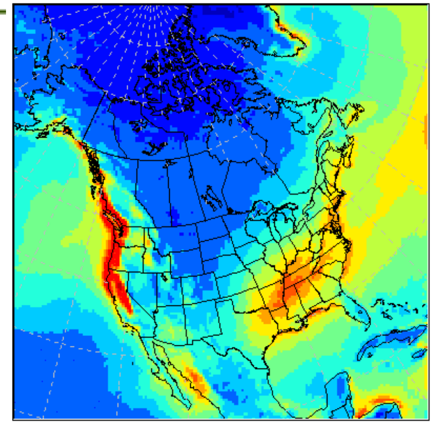
Winter: Dec to Feb

Seasonal Mean over 1961-1990

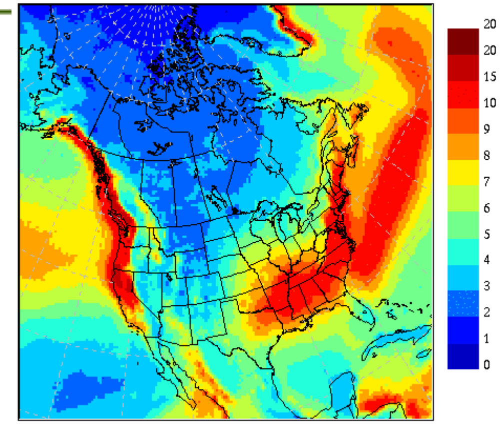
A. CRCM nested with CGCM2 #3



B. CRCM nested with CGCM3 T47 #4

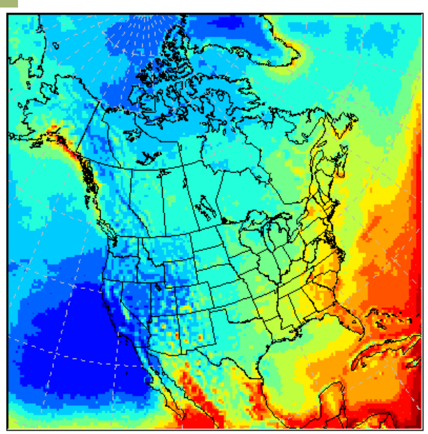


C. ARPEGE nested with ERA40

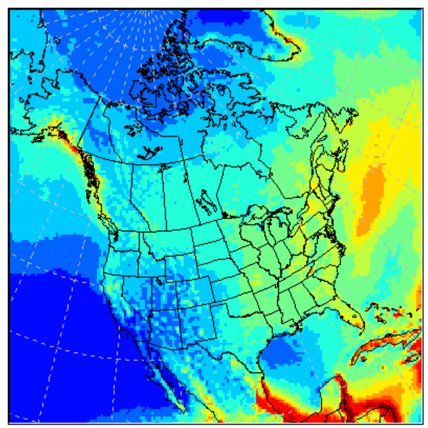


Summer: Jun to Aug

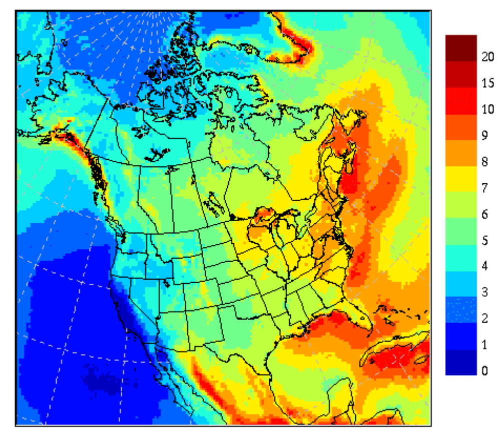
A. CRCM nested with CGCM2 #3



B. CRCM nested with CGCM3 T47 #4



C. ARPEGE nested with ERA40



(1) Extreme Analysis

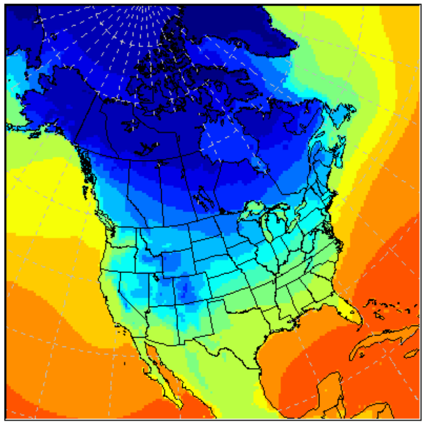
Example: 10th Percentile of Daily Tmin

In °C

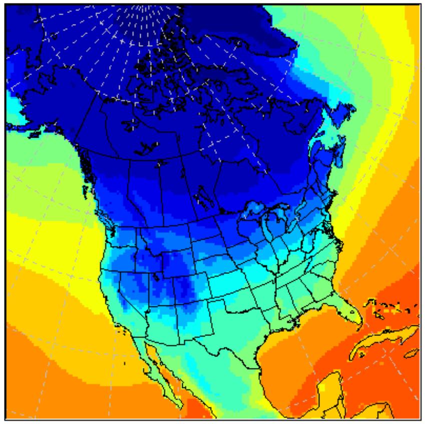
Winter: Dec to Feb

Seasonal Mean over 1961-1990

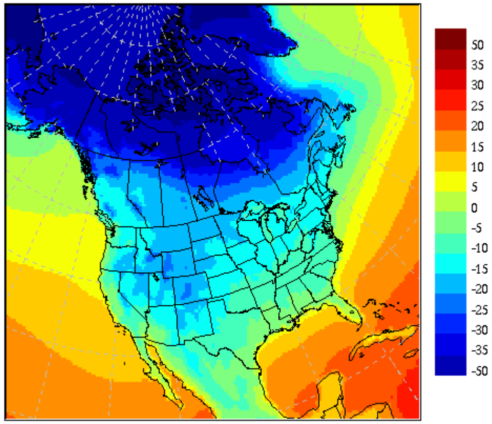
A. CRCM nested with CGCM2 #3



B. CRCM nested with CGCM3 T47 #4

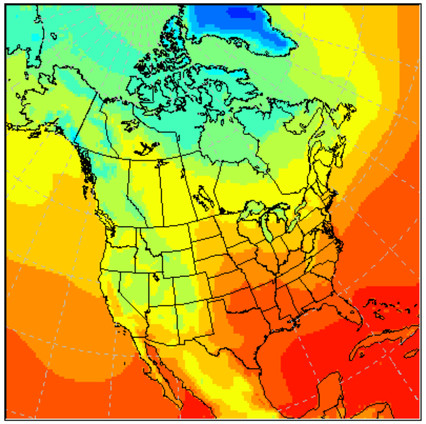


C. ARPEGE nested with ERA40

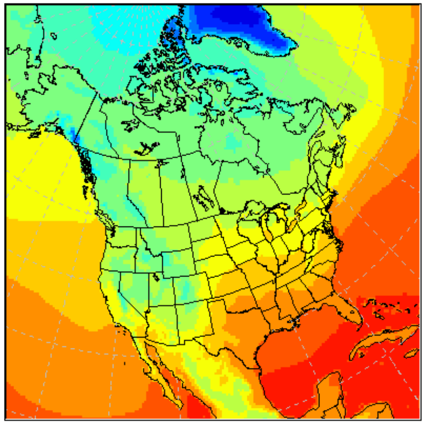


Summer: Jun to Aug

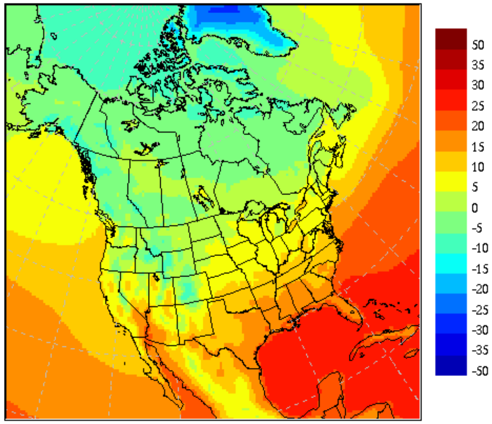
A. CRCM nested with CGCM2 #3



B. CRCM nested with CGCM3 T47 #4



C. ARPEGE nested with ERA40



(1) Extreme Analysis

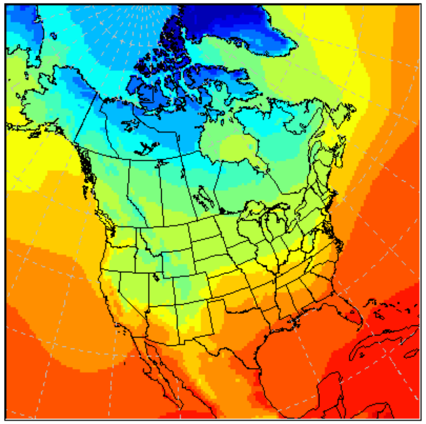
Example: 90th Percentile of Daily Tmax

In °C

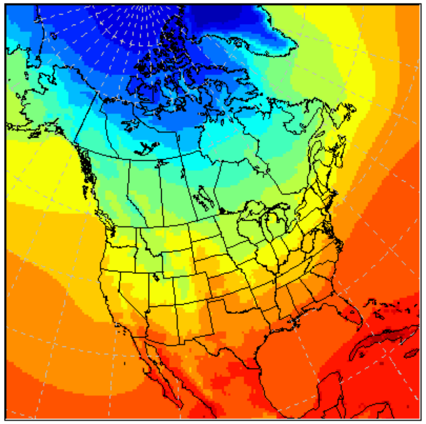
Winter: Dec to Feb

Seasonal Mean over 1961-1990

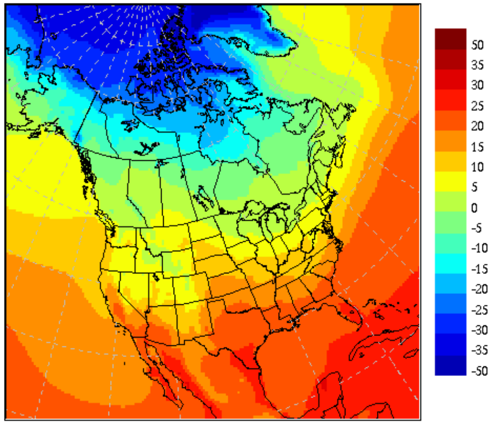
A. CRCM nested with CGCM2 #3



B. CRCM nested with CGCM3 T47 #4

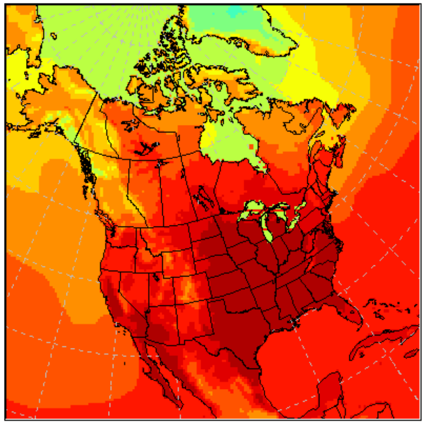


C. ARPEGE nested with ERA40

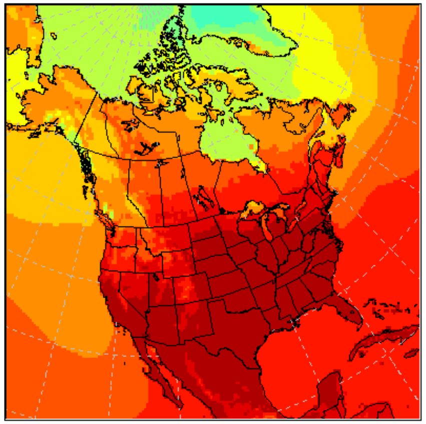


Summer: Jun to Aug

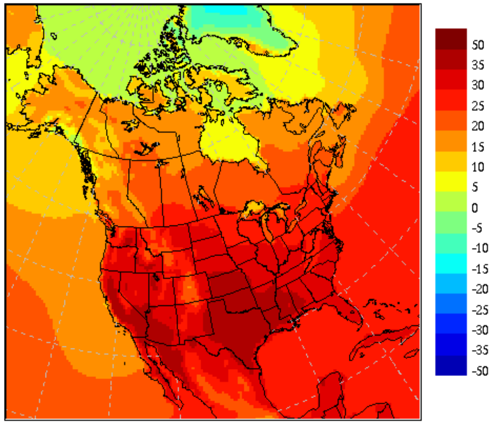
A. CRCM nested with CGCM2 #3



B. CRCM nested with CGCM3 T47 #4

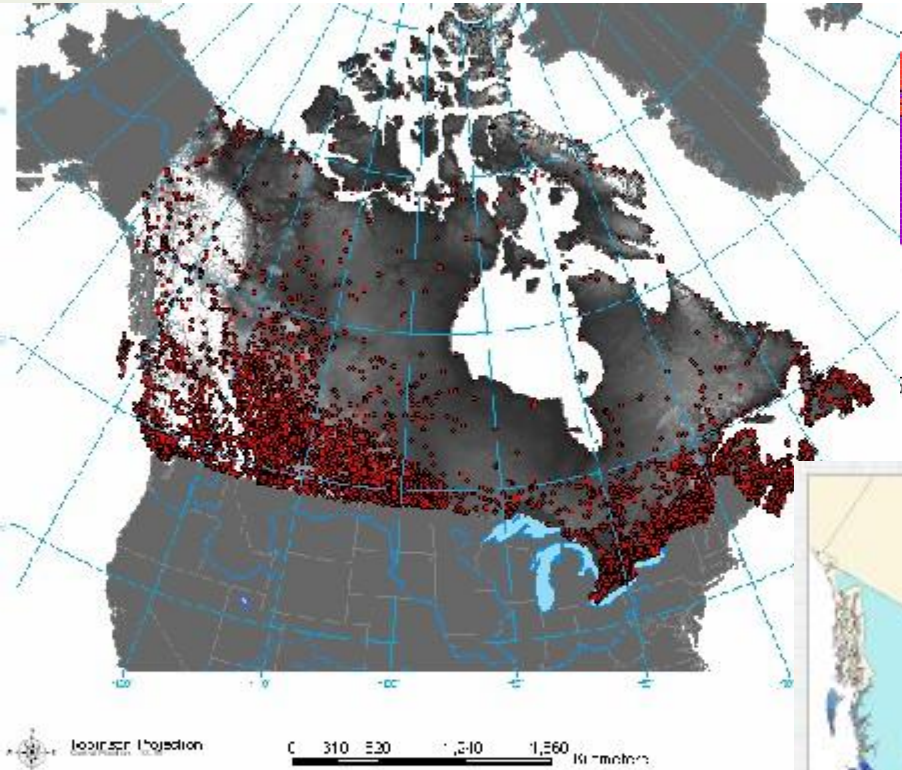


C. ARPEGE nested with ERA40

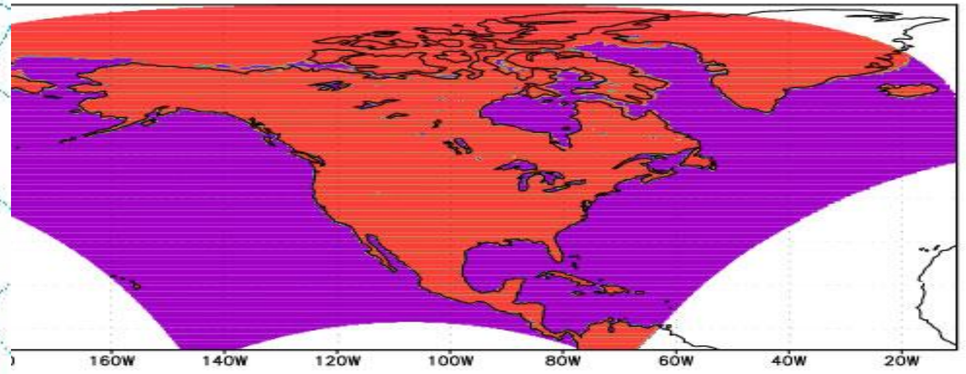


(1) Select the appropriate method of interpolation to validate the RCM outputs with gridded data

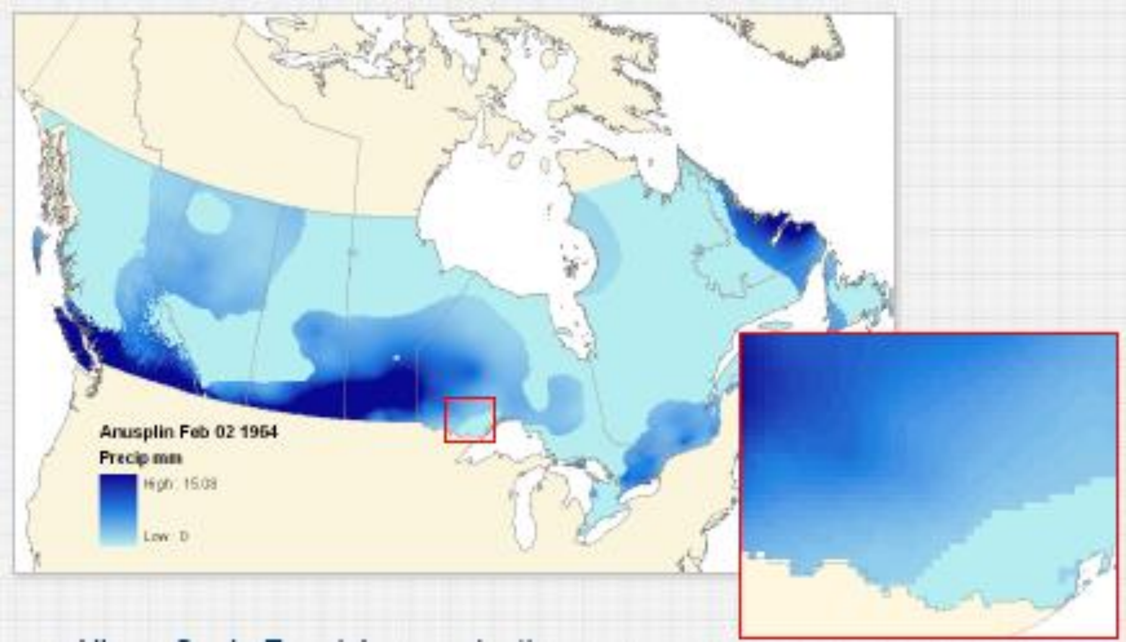
e.g., Cubic Spline method or others & compare with other products: ex.10-km gridded dataset from Hutchinson et al. (2009) & regional reanalysis (NARR)



Gridded dataset from Hutchinson et al. (2009) using Anusplin, 10-km daily values of Tmin, Tmax & Prec.



NARR



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(3) ATMOSPHERIC INPUT VARIABLES: Predictors development for SDs

Main Variables used from GCMs (Sfc & Atm. Levels):

- Temperatures
- Pressure or Geopotential Height
- Specific/Relative Humidity
- Wind components (U & V)

PREDICTOR VARIABLES
Mean sea level pressure
1000hPa Wind Speed
1000hPa U-component
1000hPa V-component
1000hPa Vorticity
1000hPa Wind Direction
1000hPa Divergence
500hPa Wind Speed
500hPa U-component
500hPa V-component
500hPa Vorticity
500hPa Geopotential
500hPa Wind Direction
500hPa Divergence
850hPa Wind Speed
850hPa U-component
850hPa V-component
850hPa Vorticity
850hPa Geopotential
850hPa Wind Direction
850hPa Divergence
500hPa Specific Humidity
850hPa Specific Humidity
1000hPa Specific Humidity
Temperature at 2m

(3) ATMOSPHERIC INPUT VARIABLES: Predictors development for SDs

Main Variables used from RCMs (Sfc & Atm. Levels):

Variable Name (Predictor)	Unit	Level(s)	Frequency
Ground Cover	[0 or 1]	at/near surface	
Orography Height	m		
Mean Sea Level Pressure	Pa		
Ground Temperature	°C		
Accumulated Precipitations	mm		
Minimum Screen Temperature	°C		
Maximum Screen Temperature	°C		
Sensible Heat Flux	W/m^2		
Minimum of Sensible Heat Flux	W/m^2		
Maximum Sensible Heat Flux	W/m^2		
Air Temperature	°C	Standard Pressure Levels: 1000, 925, 850, 700, 600 and 500 hPa	daily
Geopotential	m^2/s^2		
Specific Humidity	kg/kg		
Eastward Wind	m/s		
Northward Wind	m/s		
Vertical Velocity	m/s		
Wind Speed	m/s		
Wind Direction	deg North		
Divergence	s^{-1}		
Relative Vorticity	s^{-1}		
Absolute Vorticity	s^{-1}		
Minimum of Temperature Advection	K/s		
Maximum of Temperature Advection	K/s		
Minimum of Humidity Advection	kg/(s*kg)		
Maximum of Humidity Advection	kg/(s*kg)		
Minimum of Abs. Vorticity Advection	$1/s^2$		
Maximum of Abs. Vorticity Advection	$1/s^2$		
Geopotential Thickness	m^2/s^2	Between: 925-1000 hPa 850-925 hPa 700-850 hPa 600-700 hPa 500-600 hPa	

(3) ATMOSPHERIC INPUT VARIABLES issues from NARCCAP runs (Available information ?)

Table 5: Atmospheric fields (3-D, 3-hourly)			
Var.	**Long Name**	**Units**	**Notes**
cli	Cloud Ice Fraction of Layer	1	instantaneous
clw	Cloud Liquid Water Fraction of Layer	1	instantaneous
hus	Specific Humidity	kg kg-1	instantaneous
ta	Temperature	K	instantaneous
ua	Zonal Wind Component	m s-1	instantaneous
va	Meridional Wind Component	m s-1	instantaneous
wa	Vertical Wind Component	m s-1	instantaneous

3-D fields have not been yet provided every 25 hPa from 1050 hPa to 25 hPa, i.e. hence predictors from NARCCAP runs cannot be developed

	Table 1	Table 2	Table 3	Table 4	Table 5
CRCM	done	done	qc	qc	post
ECPC	done	done	post	post	post
HRM3	done	done	qc	post	post
MM5I	post	done	post	post	post
RCM3	post	done	done	post	post
WRFP	post	done	post	post	post

(3) ATMOSPHERIC INPUT VARIABLES: Predictors development for SDs

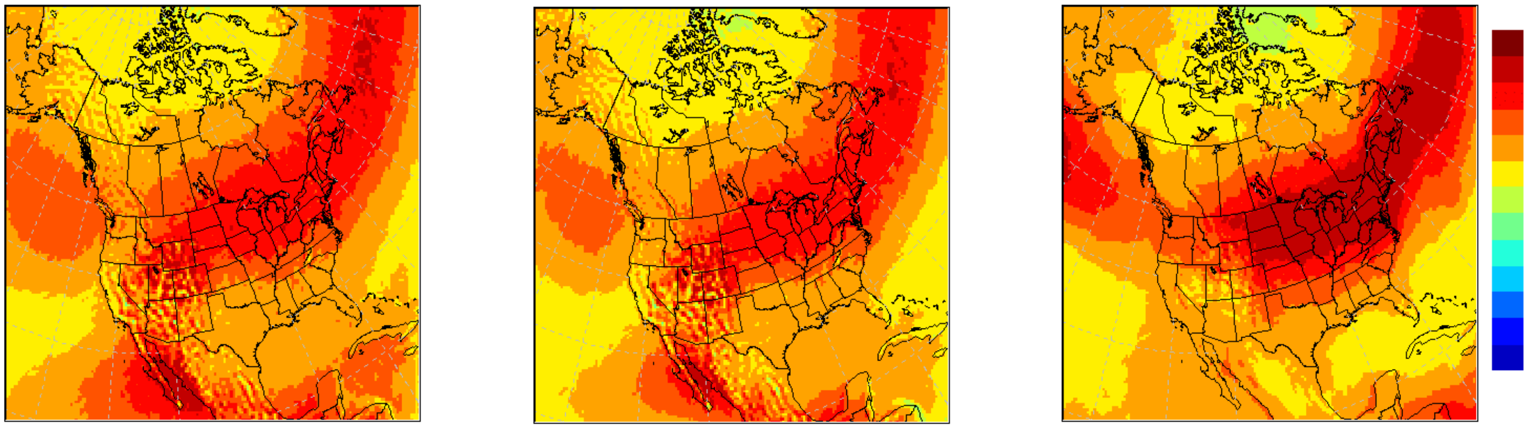
Example of RCM predictor: Daily Maximum of Horizontal Advection of Humidity from CRCM vs NARR

@ 500 hPa

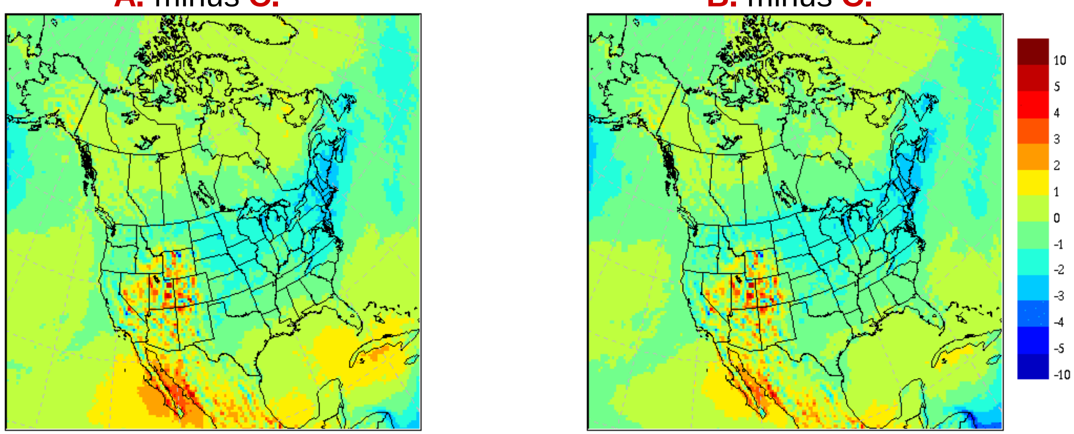
Monthly Mean comparison for July over 1979-2001 between RCM and NARR

x 10^{-8} kg/(kg ·s)

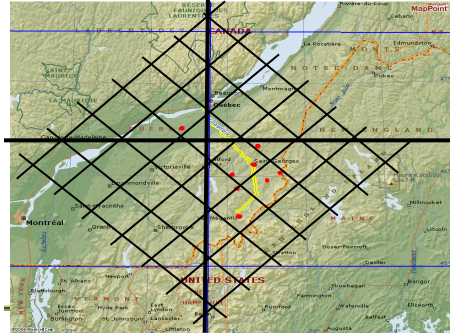
A. CRCM4.1.1 nested with ERA40 **B.** CRCM4.1.1 nested with NCEP **C.** NARR interpolated on PS grid of CRCM

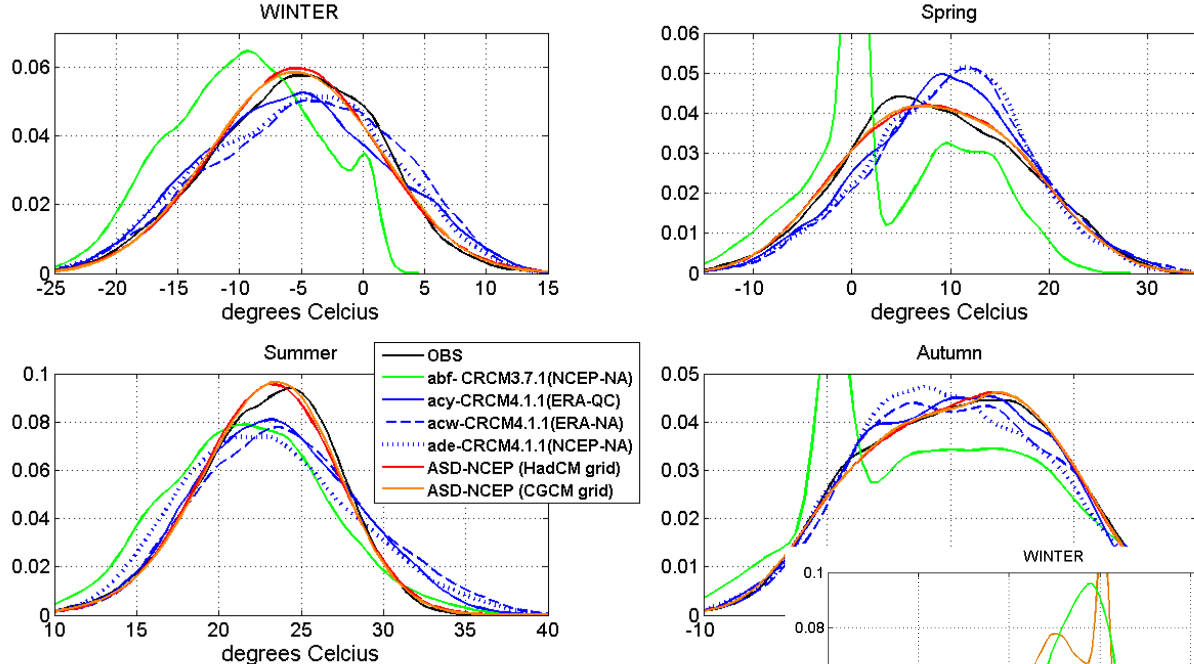


A. minus **C.** **B.** minus **C.**

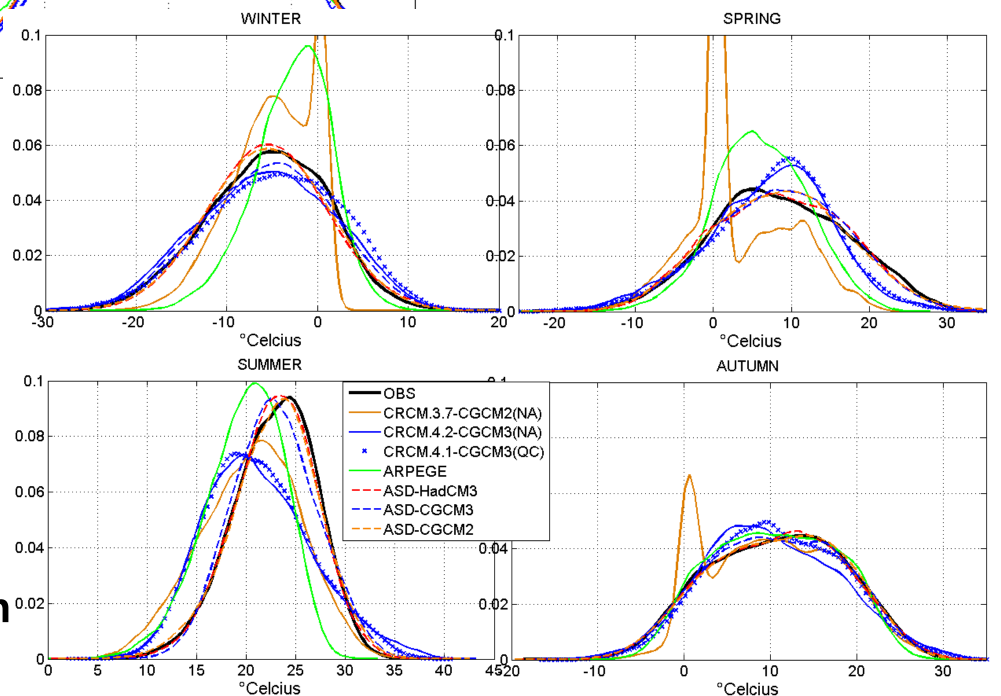


(4) Evaluate the RCM outputs & inter-compare over small areas with SDs





NCEP driven



GCM driven

Preliminary Analysis with ≠ CRCM versions & with ARPEGE

Results over Southern Québec (krigging daily data using co-variables from ERA40)

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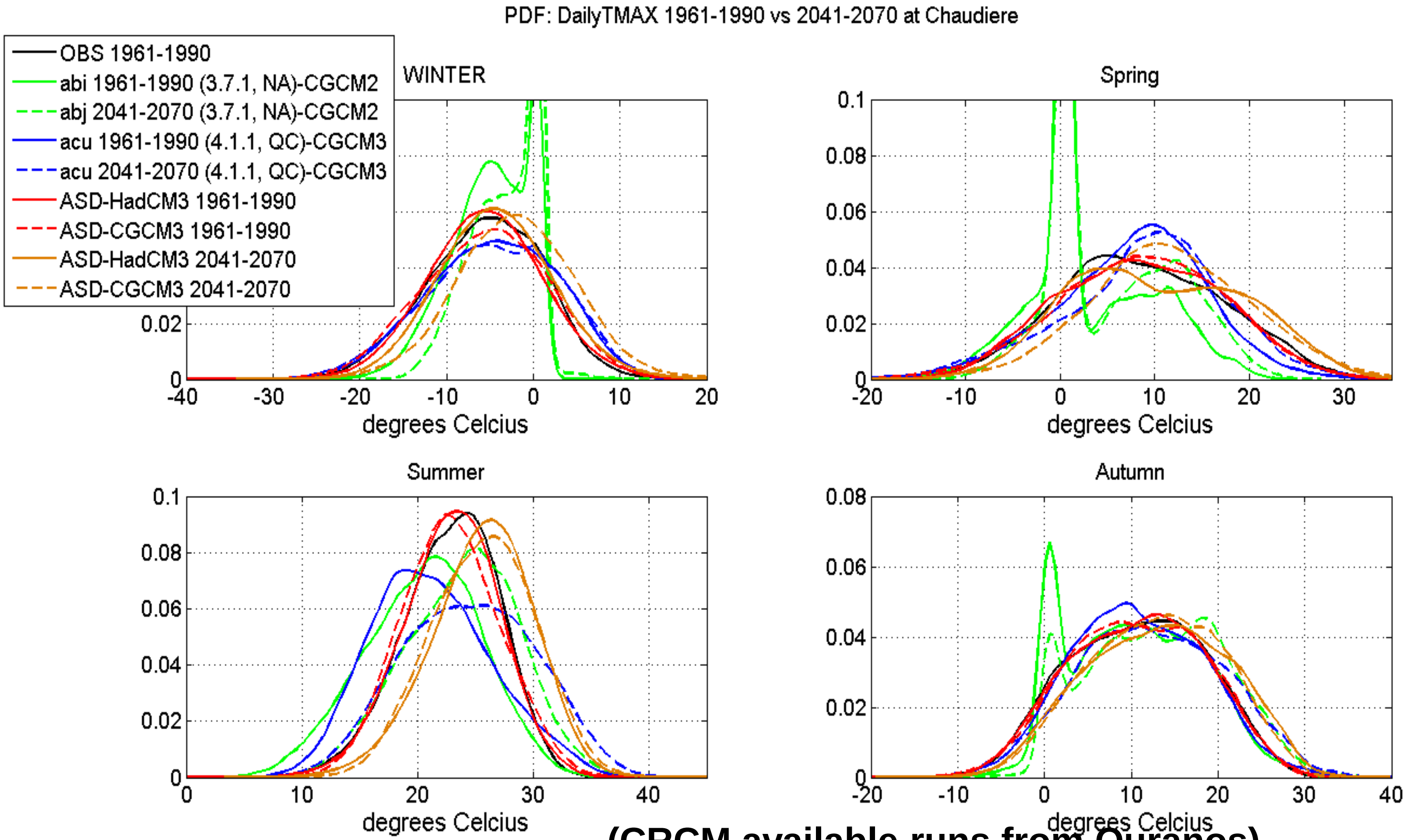
(4) CONSTRUCT PDF of future climate change from an ensemble of statistical & dynamical downscaling models

Ensemble of runs from CRCM & ASD - PDF of Tmax

Example in Chaudière River basin, 2041-2070 vs 1961-1990



(CRCM available runs from Ouranos)

Next Steps for Statistical Downscaling Research, RCMs evaluation & climate scenarios

- **Improve the interannual variability of the multi-site MLR, i.e. link to atmospheric variables (downscaling) in modifying the parameters in the stochastic part & using Regional-scale predictors;**
- **Develop multivariate statistical downscaling approaches (done for multisite & multivariate Tmin and Tmax);**
- **Develop/Identify Links between predictand and other regional-scale predictors from RCMs runs in extreme occurrences (from new predictors & test the stability of the statistical relationships);**
- **Develop ensembles runs with various GCMs/RCMs SDs driven conditions & with RCMs (from Ouranos, CRCMD & NARCCAP runs, i.e. 13 independent RCM runs) and probabilistic scenarios.**

Web sites links:

Climate Analysis Group (Projects & Publications) :
http://quebec.ccsn.ca/GAC/

Data Access Integration : http://quebec.ccsn.ca/local/data/DAI-e.html

Canadian Climate Change Scenarios Network (CCCSN) :
http://www.cccsn.ca

Thank you for your attention!