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**CCCSN - RCSCC**

# Climate Change Models, Verification and Ensembles – An Ontario Focus

[www.cccsn.ca](http://www.cccsn.ca)

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Environment Canada

Restoration Workshop

Sudbury October 29 2009

## AIRD - Canadian Climate Change Scenarios Network:

- **University of Toronto**
  - Site development, dataset integration, node administration
- **McGill University**
  - Canadian Regional Model data, statistical downscaling research, Data Access Integration (DAI) system
- **University of Regina**
  - PRECIS, statistical downscaling software development
- **Yukon College**
  - Arctic issues, recovery of historical baseline climate data, impacts



# The GCMs – where are we?

- There are 24 international centres which have provided model data to the last IPCC assessment (2007)
- Each of the modelling centres has provided scenarios for at least 2, sometimes 3 emission scenarios

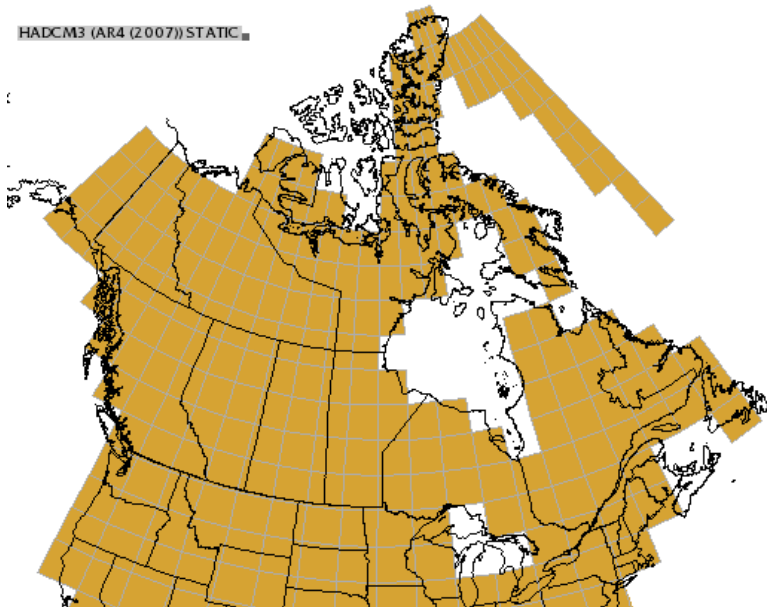
SO... we have approximately  $24 \times 3 = 72$  possible future outcomes

- Each model has varying degrees of complexity with its atmospheric and oceanic physics and their connection
- Sub-grid scale processes between models vary even more (eg. Snow? Sea ice? Soil layers?)
- ALL models must approximate (parameterize) sub-grid scale processes

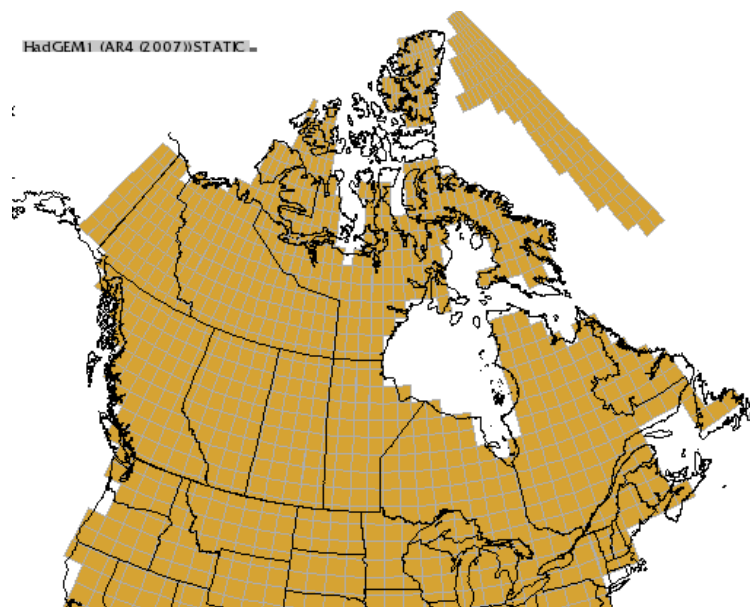


# The GCMs – land/ocean distribution

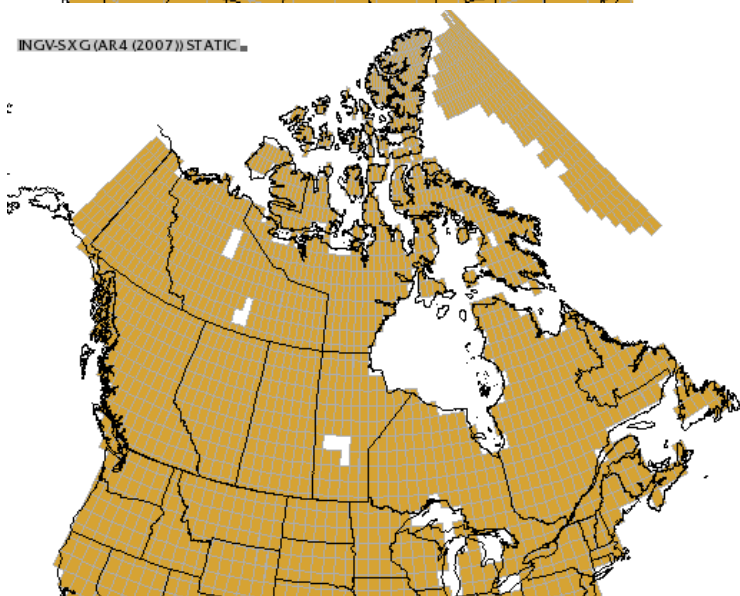
HADCM3 (AR4 (2007)) STATIC



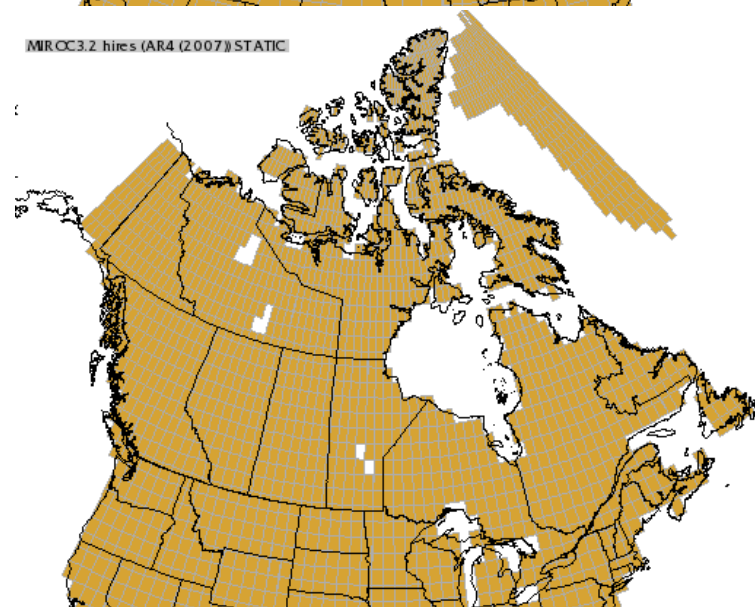
HadGEM1 (AR4 (2007)) STATIC



INGV-SXG (AR4 (2007)) STATIC



MIROC3.2 hires (AR4 (2007)) STATIC



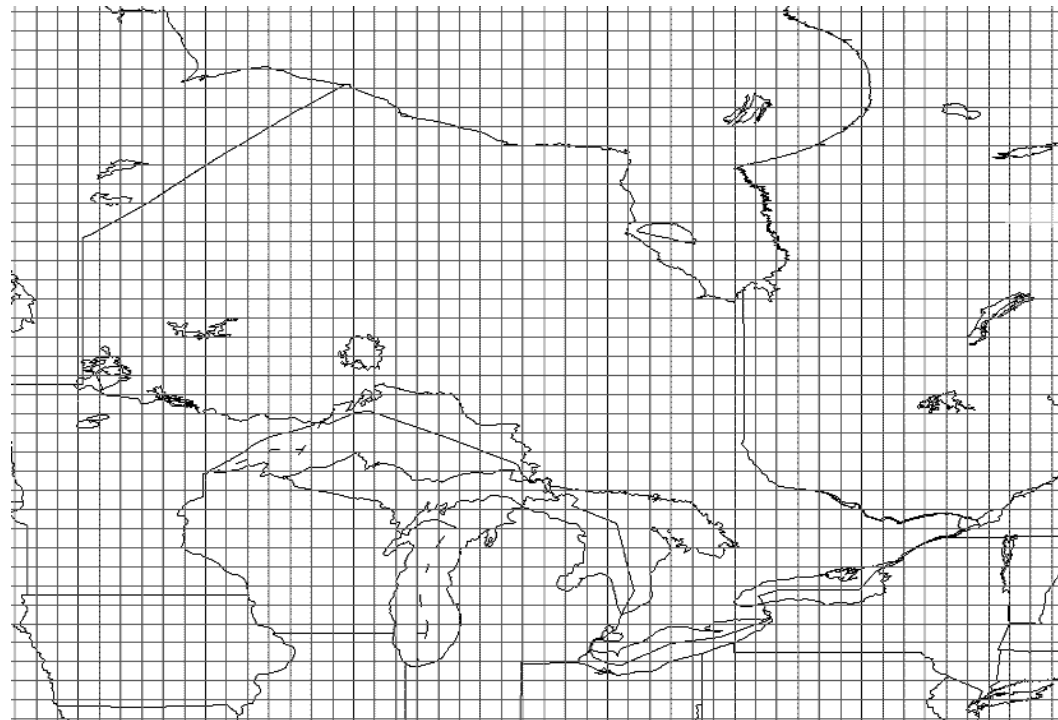
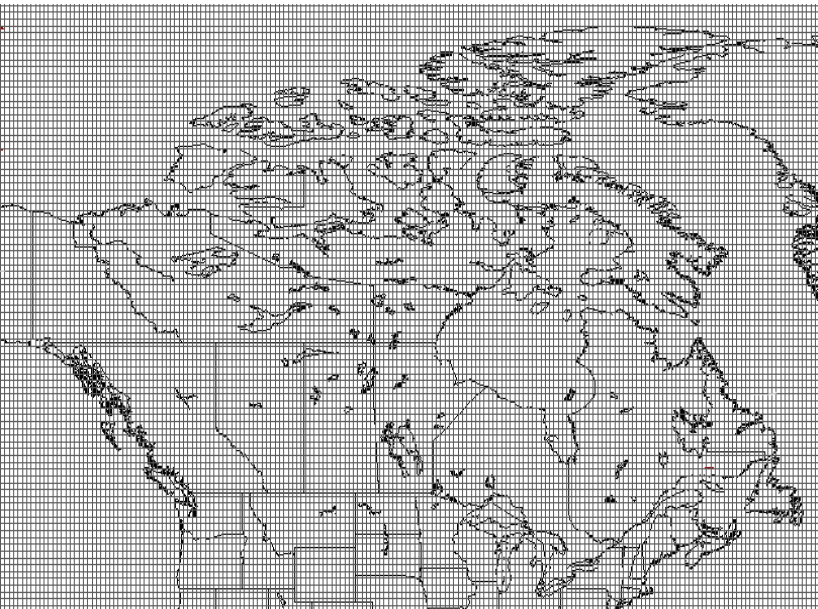
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# What about Regional Climate Models (RCMs)?

- In Canada we have the Canadian Regional Climate Model (CRCM) available
- Resolution ~50 x 50 km
- ~ 1000 points in Ontario

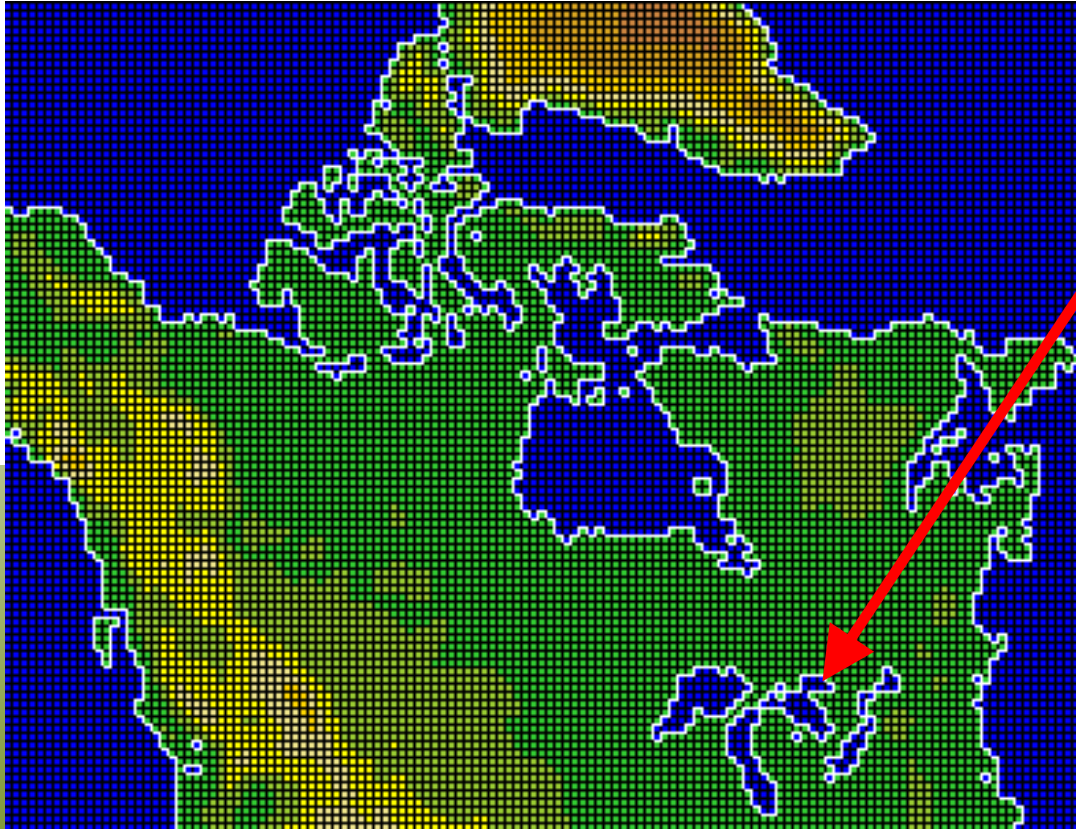


# The RCMs

- RCMs are provided boundary conditions from GCMs
- Sub-daily resolution possible – down to 1 hour
- Sub-grid scale processes better resolved (eg. convection, lake temperatures, soil layers, snow)
- Mesoscale effects like lake breezes, lake induced precipitation, temperature modification are possible
- The complexity between RCMs also varies as seen in the NARCCAP (North American Regional Climate Change Assessment Program) – a comparison of RCM results over North America
- Our CCCSN partners at the University of Regina are running the PRECIS regional model as well over Canada with results coming to the website...



# CRCM Land/Ocean Distribution

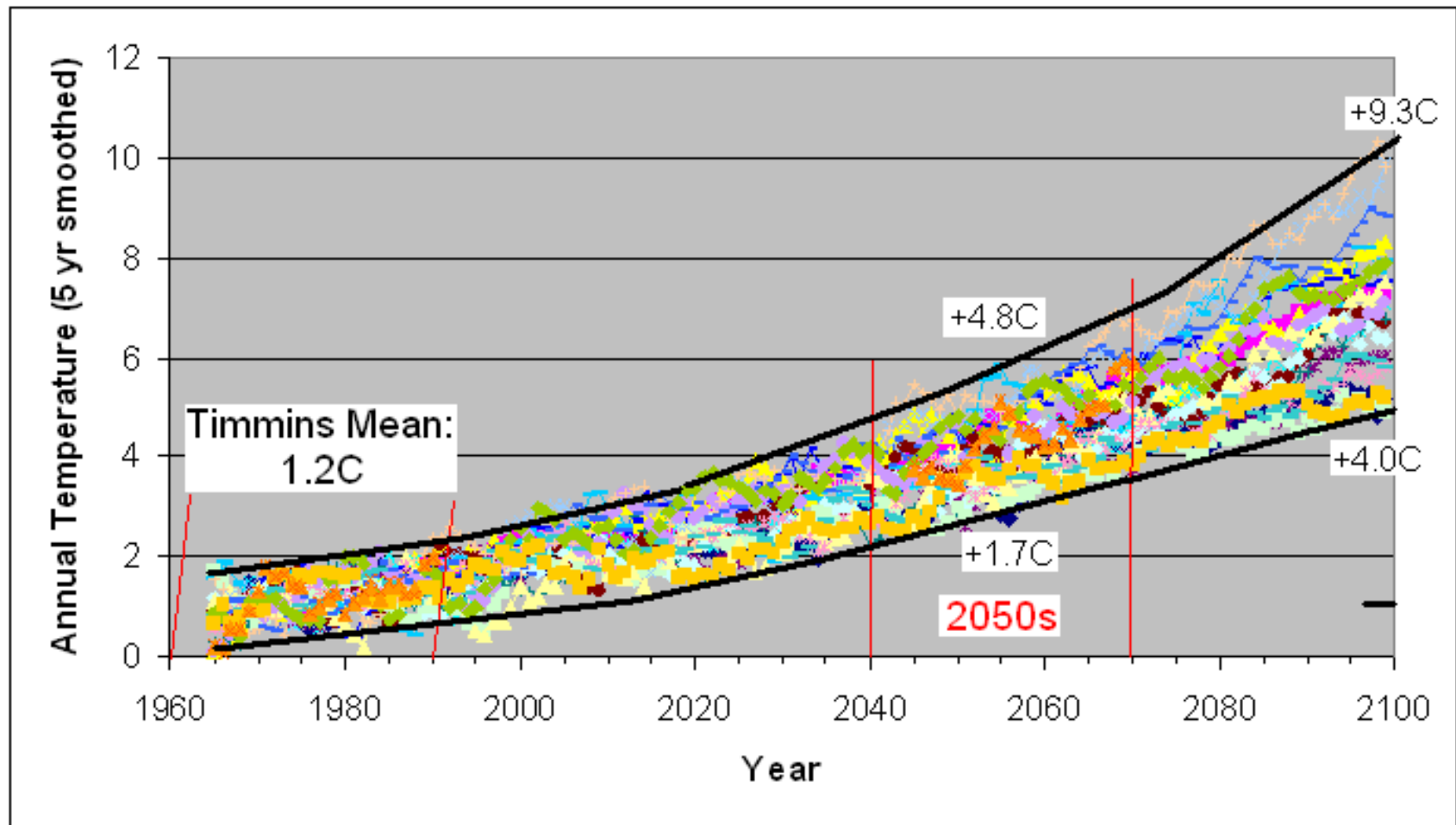


- The Great Lakes are represented by water grid cells
- Allows for a more realistic lake environment climatology
- Lakes are still treated quite simply though



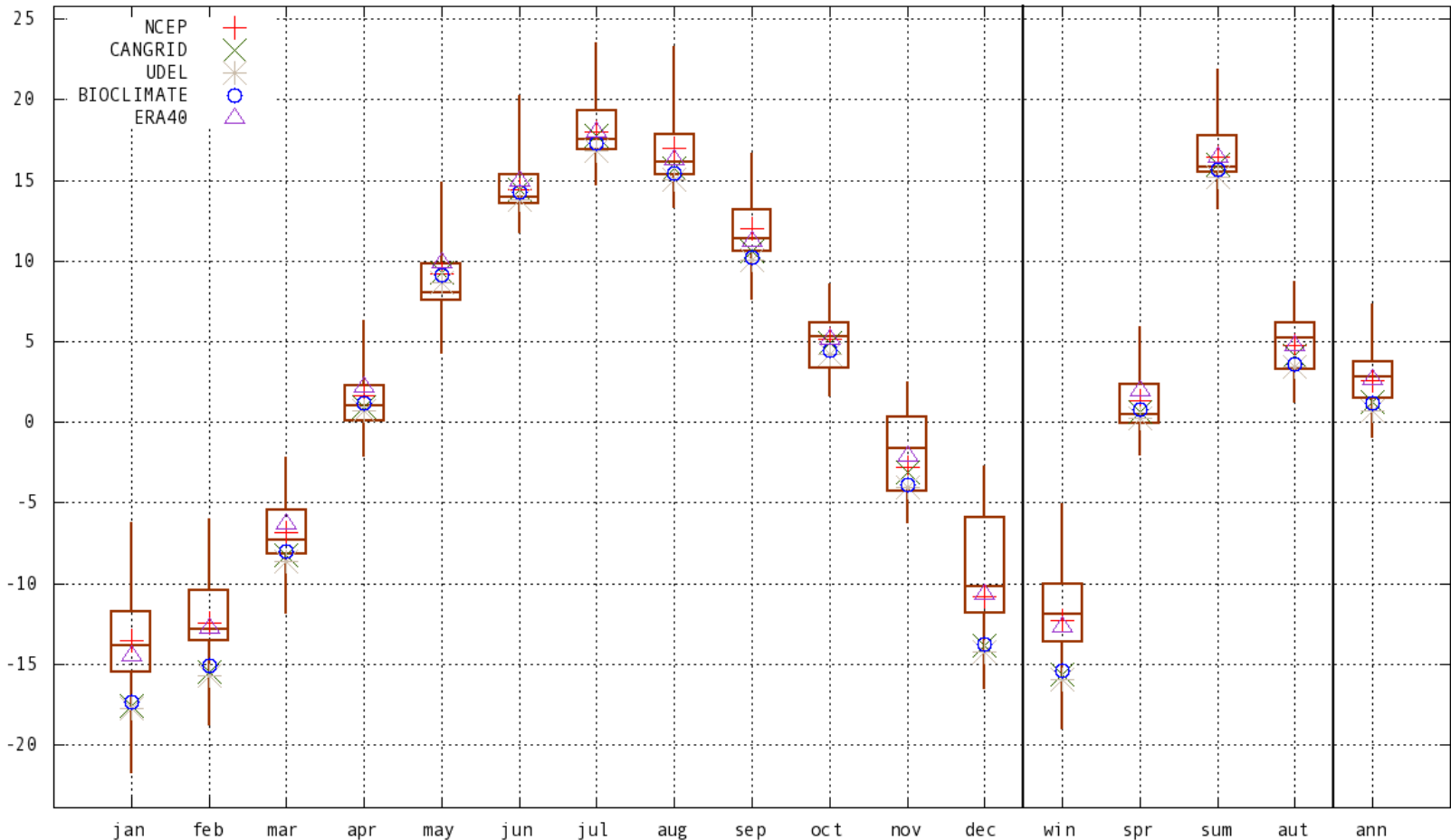
# Timmins – All Model Timeseries

- A2 Scenario (high) normalized by 1961-1990 period
- 5 year running mean



# Timmins Validation – 1961-1990 Temperature

Baseline Comparison [Regridded Models]  
Variable: Air Temperature - Mean (2m) (°C)  
Coordinate Selected: 48.570°N, 81.372°W  
Years: 1961 - 1990  
Closest Bioclimate Station: Timmins A



# Timmins Validation – 1961-1990 Temperature

Least  
Model  
Bias



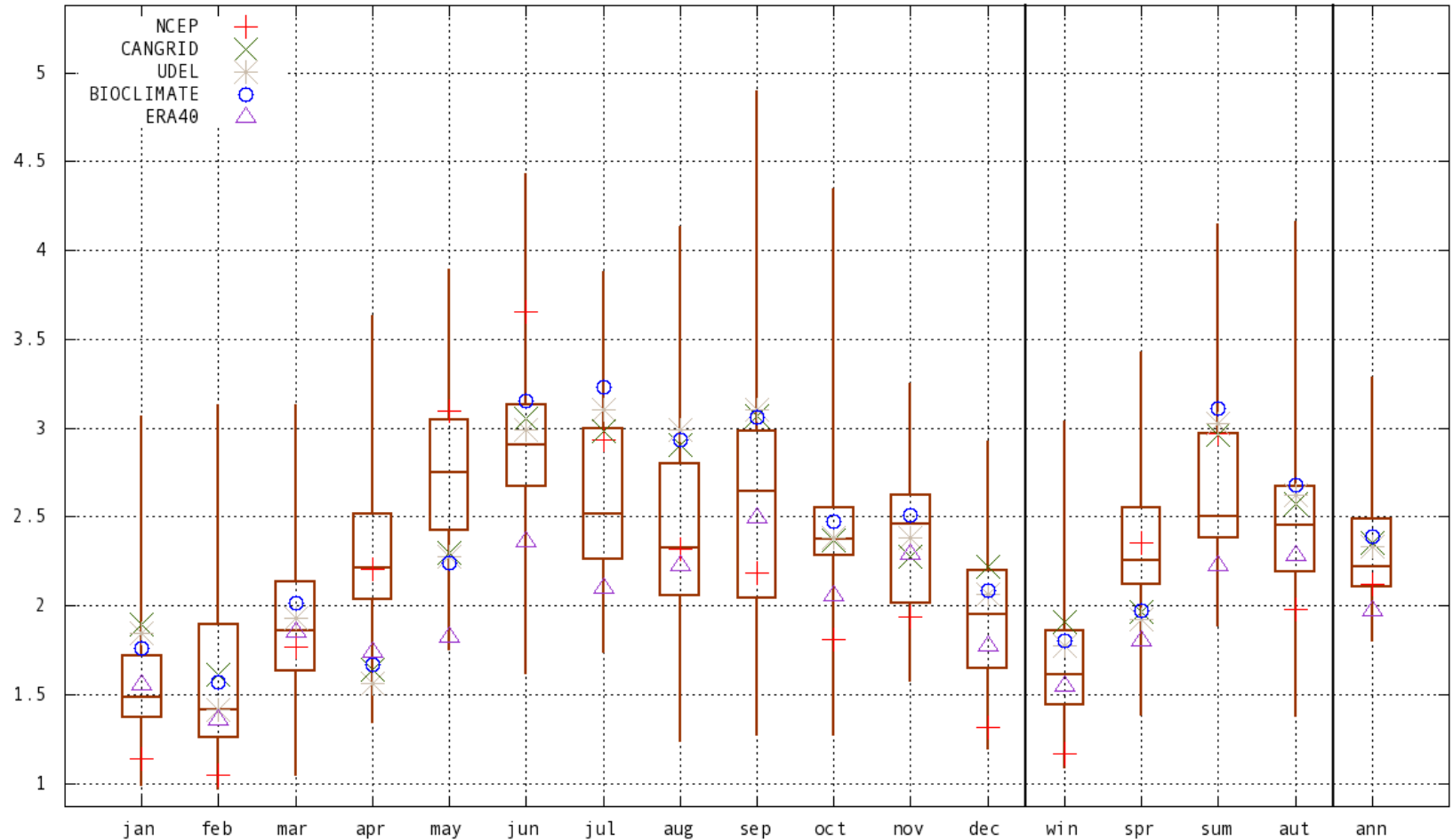
Greatest  
Model  
Bias

model	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	winter	spring	summer	autumn	ann
NCARCCSM3	-1.3520	0.0430	1.0120	1.6890	0.3990	-0.0580	-0.3090	-0.3030	0.1170	-0.3960	-0.0360	0.0120	-0.3940	1.0340	-0.2240	-0.1050	0.0680
INMCM3.0	1.0680	0.9300	-0.8110	-0.2840	1.3590	0.3320	-1.1420	-1.6730	-1.2060	0.5540	1.8340	2.2450	1.4520	0.0880	-0.8280	0.3940	0.2670
CNRMCM3	-0.4420	0.0630	1.4650	-1.1770	-0.0240	0.6590	-0.3720	0.1040	0.9500	0.1980	1.4110	1.4150	0.3840	0.0880	0.1300	0.8530	0.3540
CGCM3T47 - Mean	1.6350	-0.2830	-0.3710	-0.8210	-1.5040	-0.7380	-0.8120	-1.0960	-0.4400	0.7240	3.2080	4.8550	2.1070	-0.8990	-0.8830	1.1640	0.3630
CSIROMk3.0	-0.5950	-0.7530	1.5890	1.8930	1.4890	2.2850	1.8680	0.8710	0.2370	-1.7490	-1.0990	0.2050	-0.3430	1.6570	1.6740	-0.8700	0.5200
CGCM3T63	0.6180	-1.0900	-1.4750	-2.1870	-2.7770	-1.6810	-1.7350	-1.8560	-1.1460	0.1240	2.7480	3.8790	1.1740	-2.1460	-1.7580	0.5750	-0.5480
GFDLCM2.1	-0.3120	-0.3730	-2.1150	-1.1770	-0.8670	1.5120	0.6150	-0.6360	-1.7800	-2.1560	-0.9090	0.1420	-0.1430	-1.3860	0.4960	-1.6150	-0.6710
MRI CGCM2.3.2a	-2.0650	-0.4870	0.3220	0.5930	-0.3010	0.2290	-0.0290	-0.3130	-1.3960	-2.2890	-1.6260	-1.0350	-1.1580	0.2050	-0.0380	-1.7700	-0.7000
HadGEM1	-4.0420	-2.7530	-1.2280	-0.3670	-0.0810	2.1120	2.0980	1.0540	1.1140	-1.7960	-2.1660	-2.6050	-3.0950	-0.5590	1.7540	-0.9490	-0.7220
IPSLCM4	-0.7790	-0.3970	-1.1450	-3.4040	-0.8910	0.8490	0.8910	0.2440	-1.6100	-3.3360	-2.8820	-0.7880	-0.6160	-1.8130	0.6610	-2.6090	-1.1040
GISS-ER	-1.6750	-0.8130	0.3990	-0.5970	-2.4740	-0.9350	-0.2820	-0.6990	-1.3830	-1.6120	-1.5390	-1.6410	-1.3390	-0.8910	-0.6390	-1.5110	-1.1040
ECHAM5OM	2.0850	3.1530	2.4190	1.2930	-0.4140	0.4920	-0.2420	-0.6260	0.3270	0.7180	1.1280	3.5520	2.9680	1.0990	-0.1260	0.7240	1.1570
GISS-EH	0.3950	2.3170	2.6720	0.5890	0.6090	0.9250	1.7150	1.3340	1.5700	0.6510	1.7940	0.4420	1.0890	1.2900	1.3240	1.3390	1.2510
2CRCM4.2.0	-1.6690	-2.5870	-1.3910	-1.7840	-2.3740	-1.6710	-0.8220	-2.2430	-1.2900	-1.1620	0.6940	0.1420	-1.3330	-1.8500	-1.5790	-0.5860	-1.3460
GISS-AOM	2.1850	2.2300	1.3320	-0.3240	-1.1610	-0.5250	-0.3550	0.1170	1.1140	2.6080	4.0210	5.0290	3.1860	-0.0510	-0.2550	2.5810	1.3560
2CRCM4.2.3	-2.7920	-3.0400	-1.2880	-1.5570	-1.5310	-1.2710	-0.7890	-2.2790	-1.3860	-1.2820	-0.4860	-1.5080	-2.4090	-1.4590	-1.4470	-1.0510	-1.6010
2CRCM3.7.1	2.5380	3.0400	0.8850	-2.0440	-1.8040	-1.3150	2.6280	5.0970	3.6340	1.4910	2.4580	2.8450	2.8460	-0.9880	2.1360	2.5270	1.6210
ECHO-G	-1.9790	-2.5300	-1.3610	-3.3140	-3.2470	-2.2480	-2.3620	-1.6530	-0.7230	-0.8520	-0.1720	0.5890	-1.2690	-2.6410	-2.0880	-0.5830	-1.6540
NCARPCM	-6.7390	-5.9870	-2.6510	0.3160	-0.1940	0.7350	-1.0520	-1.9760	-1.0700	-2.0590	-2.1590	-3.6750	-5.4290	-0.8430	-0.7650	-1.7630	-2.2090
BCM2.0	-4.3750	-0.8930	-0.4580	-3.7340	-4.8910	-0.4780	-0.9020	-1.4160	-2.0860	-3.0490	-1.4590	-3.0780	-2.7440	-3.0280	-0.9330	-2.1980	-2.2350
HADCM3	-6.5520	-5.9430	-2.9280	-0.1540	0.6230	-0.0280	-1.5950	-1.9490	-1.8000	-2.3690	-3.0820	-4.4680	-5.6160	-0.8200	-1.1920	-2.4170	-2.5200
MIROC3.2 medres	1.5180	2.0300	2.5220	4.0630	5.6160	5.7750	3.4750	2.1240	2.5400	2.0010	1.6680	2.8920	2.1850	4.0670	3.7910	2.0700	3.0190
GFDLCM2.0	-3.1350	-2.3100	-3.9710	-2.8740	-3.1210	-2.6610	-3.2850	-3.6890	-4.4030	-3.4790	-2.6820	-2.3480	-2.5600	-3.3220	-3.2130	-3.5210	-3.1630
FGOALS-g1.0	-8.1820	-6.2870	-4.9210	-1.6710	-1.3710	-0.6550	-2.0920	-2.3630	-2.0630	-3.1490	-3.4620	-5.7250	-6.6930	-2.6540	-1.7040	-2.8910	-3.4950
INGV-SXG	4.8910	4.0800	3.7750	2.0160	1.9260	3.0020	3.5410	4.6140	4.5940	3.2080	3.7610	6.3950	5.1600	2.5720	3.7180	3.8540	3.8170
MIROC3.2 hires	7.2580	6.1700	4.1950	4.5830	4.7960	3.8950	1.3180	0.8240	2.3840	3.3140	5.2010	8.0220	7.1880	4.5250	2.0120	3.6330	4.3300
CSIROMk3.5	6.8710	6.4230	4.6450	2.4990	2.4230	4.2920	5.4510	6.1940	3.6240	2.8140	3.7940	6.8490	6.7520	3.1890	5.3120	3.4110	4.6570



# Timmins Validation – 1961-1990 Precipitation

Baseline Comparison [Regridded Models]  
Variable: Precipitation - Total (mm/d)  
Coordinate Selected: 48.570°N, 81.372°W  
Years: 1961 - 1990  
Closest Bioclimate Station: Timmins A



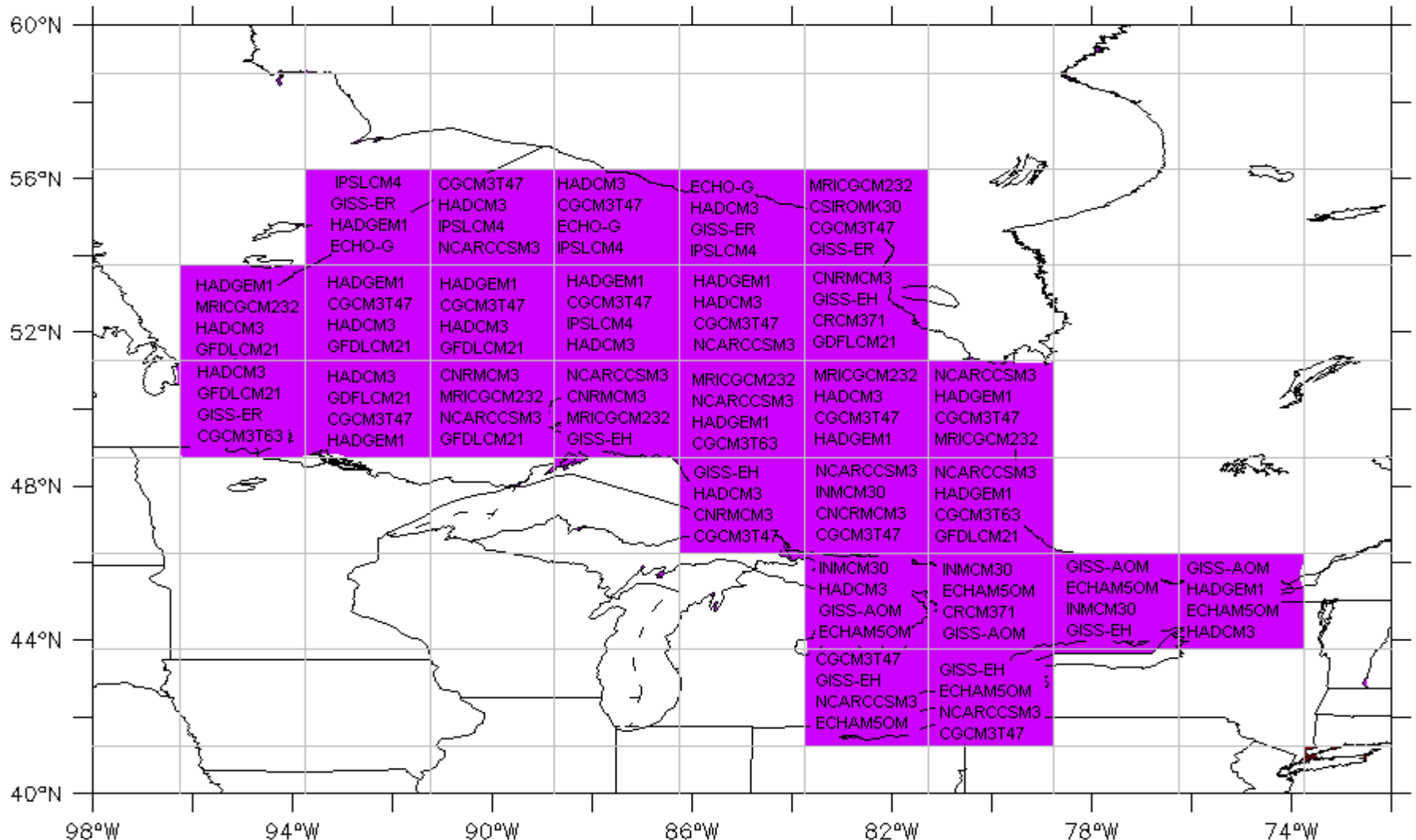
# A Ranking of Models is Possible:

- The same analysis can be done on a month by month or seasonal basis versus looking at annual period
- The mean annual value may be well reproduced, but the seasonal pattern can be wrong
- We can assign scores for each model based upon both agreement with historical period means and with historical trends
- This method is best used to reject models which are far from observed
- Which variables are tested depend upon the intended application



# Ontario Validation

All Models - Regridded to NCEP, 1961-1990 Mean Annual Temperature - Least Model Bias



# Why Ensembles?

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- Individual model biases are avoided
- Ensemble results are likely to be our best estimate
- Results can give some indication of where there is model agreement and disagreement
- Recent journal articles have focussed on the use of ensembles
- IPCC recommends the use of multiple models for projection information
- Only recently in literature is there discussion of 'weighting' of ensemble models
- Currently each model has '1 vote' (no 'good or bad' filter)



# CCCSN has produced

## “Ensemble Scenarios for Canada, 2009”

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- CCCSN releasing the Ensembles document
- Uses all available AR4 (2007) models (24 in total) and 2 most recent versions of CRCM (4.2.0 and 4.2.3)
- Considers annual and seasonal temperature and precipitation ANOMALIES for the 2050s (2041-2070) compared to the 1961-1990 baseline
- All models are regridded to a common NCEP resolution (2.5 x 2.5 degree) resolution
- 2 versions of the RCM are treated separately (higher resolution)



## More details...









































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- A 'high', 'medium' and 'low' ensemble is presented  
→ High = A1B    → Low = B1    → Medium = mean of 2
- A1B selected since in 2050s, it shows greater temperature increase than A2 on average (A2 'wins' by 2080s)
- B1 emission scenario is always the lowest
- These 2 scenarios represent the upper and lower boundaries of emissions for the 2050s

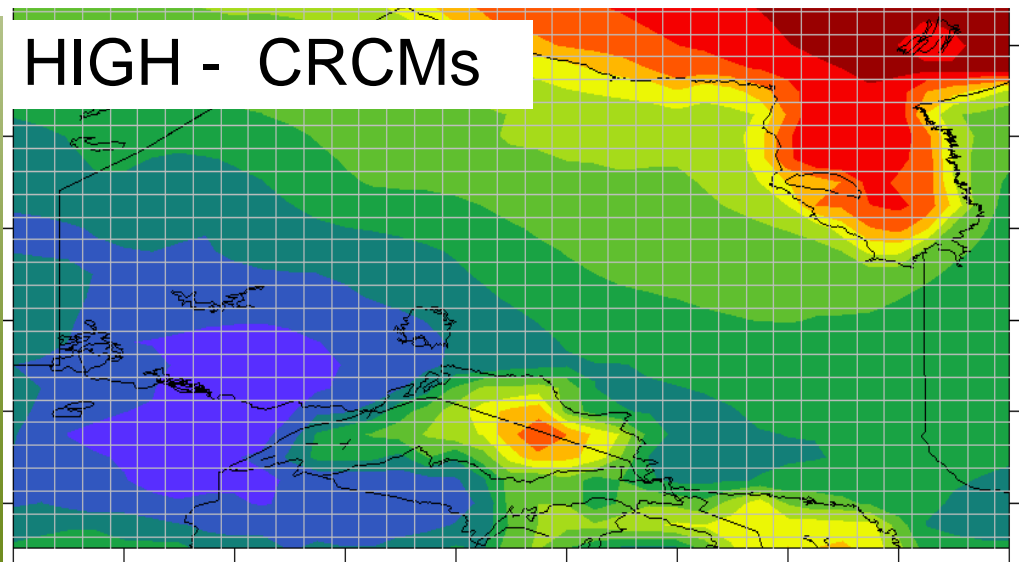
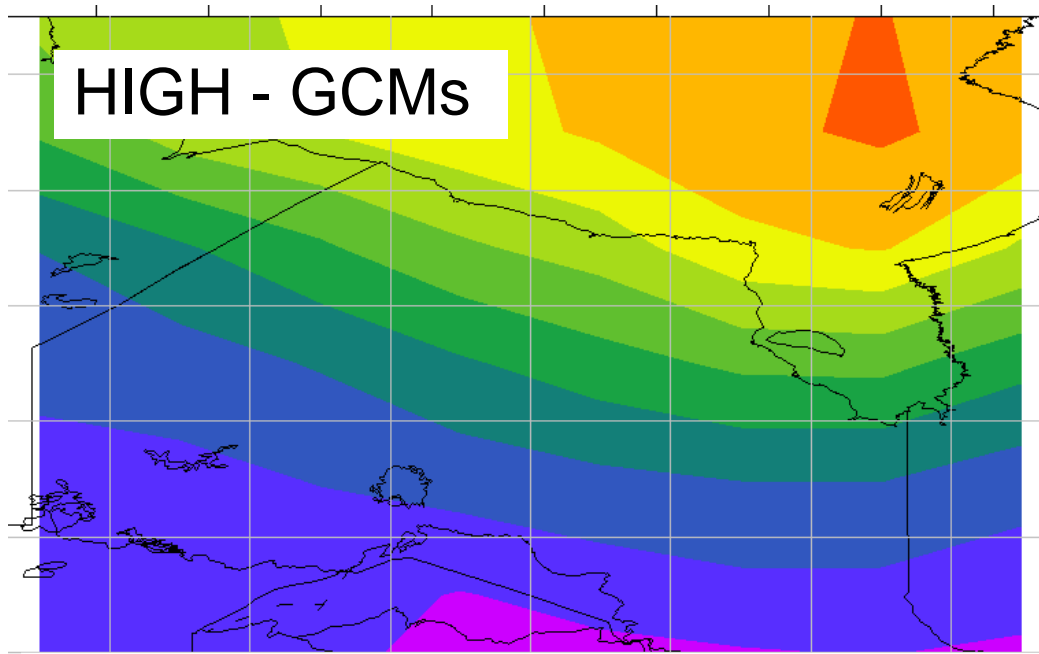


## ONTARIO ENSEMBLE SCENARIOS

2050s Change relative to 1961-1990

Variable	Low Ensemble	Medium Ensemble	High Ensemble	CRCM High Ensemble
Annual Temperature				
Winter Temperature				
Spring Temperature				
Summer Temperature				
Autumn Temperature				
Annual Precipitation				
Winter Precipitation				
Spring Precipitation				
Summer Precipitation				
Autumn Precipitation				





## Ensemble –

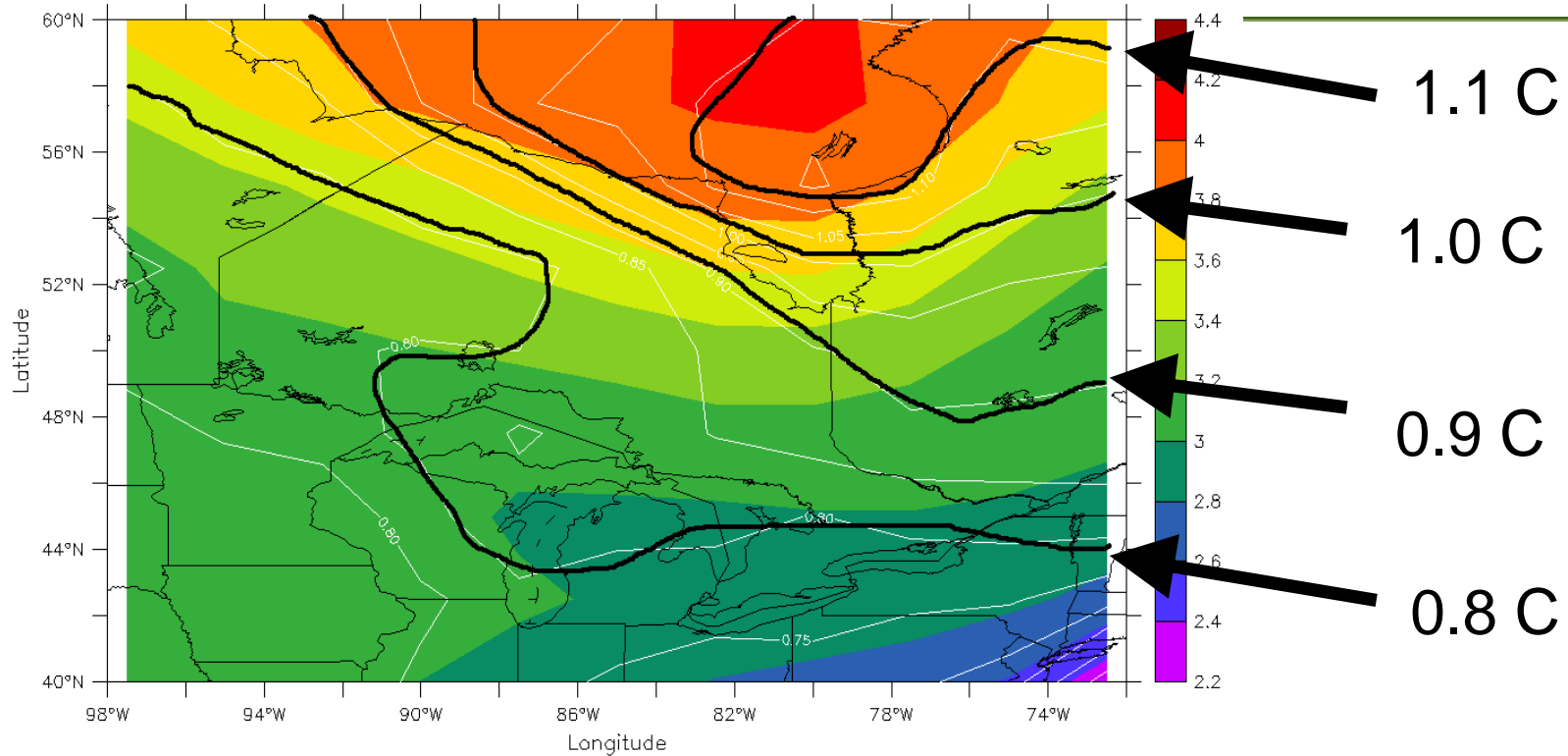
### Mean Annual Temperature Change in 2050s

- Same general pattern
- CRCM has more 'extreme' values
- +3.0C at Great Lakes, and up to +3.7C along Hudson Bay



# What about model uncertainty?

## → 2050s Mean Annual Temperature Change (HIGH - 24 models)



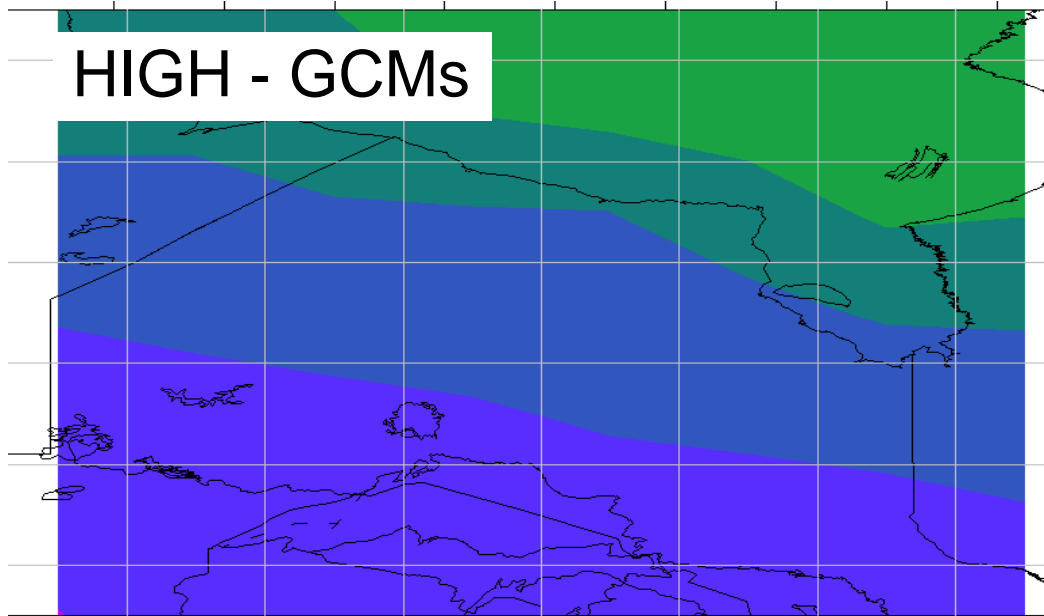
Air Temperature – Mean (2m)  
degC

colours = Projected Change of 24 models

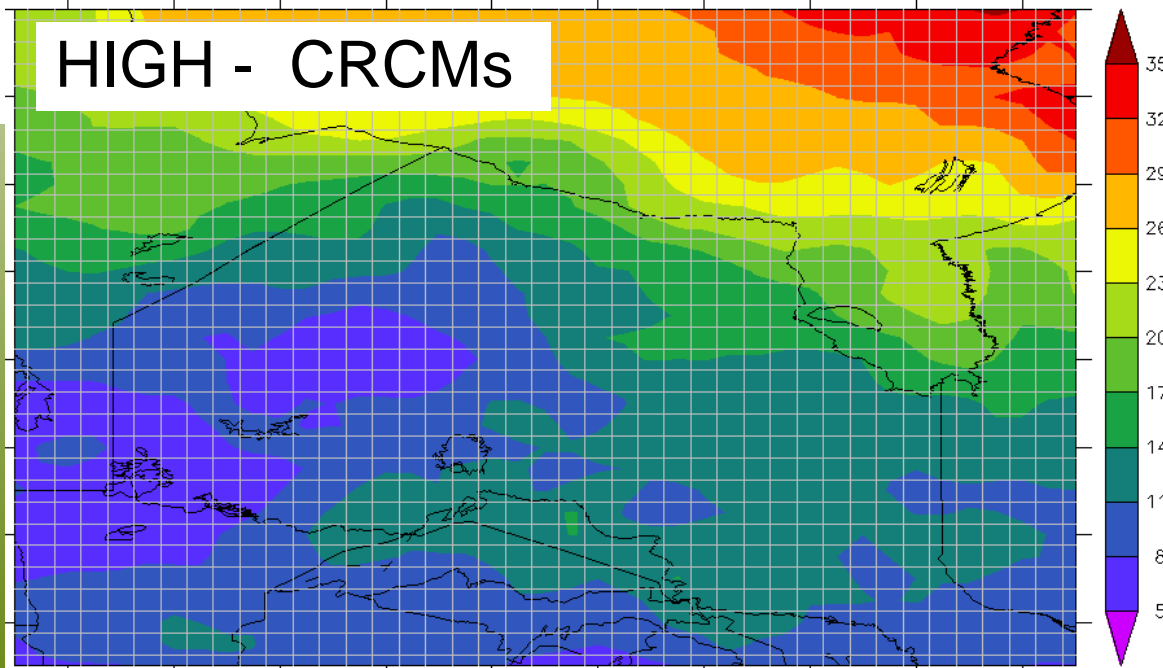
contours = Standard Deviation of 24 models



## HIGH - GCMs



## HIGH - CRCMs



## Ensemble – Annual Precipitation Change (%) in 2050s

- Same general pattern
- CRCM has more 'extreme' values, especially over HB
- +5% in south, with +12 to +15% along HB



# Summary:

- Due diligence requires us to consider more than simply one model output → an 'ENSEMBLE'
- Generating ensembles requires TB of data and computations; admittedly not an easy task to undertake by many stakeholders and decision-makers
- 'Ensemble Scenarios for Canada, 2009' addresses this issue by consideration of many models into a mean value with medium, upper and lower emission boundaries
- Amongst models - precipitation uncertainties are greater than temperature uncertainties
- ***There is uncertainty in any projection, but this uncertainty should not prevent us from action; we deal with uncertainty every day***



# *Thank you*

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Full Ensemble Document at [cccsn.ca](http://cccsn.ca)



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