Downscaling and Climate Projections

Justin Guilbert

Brian Beckage, PhD

Gabriela Bucini, PhD

			Units	2040-2069			2070-2099		
				2.5%	50%	97.5%	2.5%	50%	97.5%
Change in Temperature from Base Period (1970-1999)	Mean	Annual	°C	2.9	3.1	3.3	4.3	4.6	4.9
		Spring (MAM)	°C					4.1	
		Summer (JJA)	°C	2.6	2.9	3.1	3.9	4.2	4.5
		Fall (SON)	°C						
		Winter (DJF)	°C	3.2	3.7	4.2	5.0	5.5	6.0
	5th	Annual	°C						
		Spring (MAM)	°C	2.9	3.5	4.0	4.6	5.1	5.7
		Summer (JJA)	°C						
		Fall (SON)	°C	2.4	2.8	3.3	3.9	4.4	4.9
		Winter (DJF)	°C						
	95th	Annual	°C	2.6	2.8	3.0	3.8	4.0	4.2
		Spring (MAM)	°C						
		Summer (JJA)	°C	2.6	2.9	3.2	3.8	4.1	4.4
		Fall (SON)	°C						
		Winter (DJF)	°C	2.2	2.8	3.3	3.4	4.0	4.5
Change in Precipitation from Base Period (1970-1999)	Mean	Annual	mm/day						
		Spring (MAM)	mm/day	0.1	0.2	0.4	0.3	0.4	0.6
		Summer (JJA)	mm/day						
		Fall (SON)	mm/day	-0.1	0.1	0.3	0.0	0.2	0.4
		Winter (DJF)	mm/day						
	95th	Annual	mm/day	0.8	1.1	1.4	1.3	1.5	1.8
		Spring (MAM)	mm/day						
		Summer (JJA)	mm/day	0.4	1.2	2.0	0.7	1.4	2.2
		Fall (SON)	mm/day						
		Winter (DJF)	mm/day	0.3	0.9	1.5	0.5	1.1	1.7
	99th	Annual	mm/day						
		Spring (MAM)	mm/day	0.9	1.8	2.8	1.7	2.6	3.7
		Summer (JJA)	mm/day						
		Fall (SON)	mm/day	0.5	1.8	3.1	1.4	2.8	4.3
		Winter (DJF)	mm/day						

Change in Temperature from Base Period (1970-1999)			Units	2040-2069			2070-2099		
				2.5%	50%	97.5%	2.5%	50%	97.5%
	Mean	Annual	ºC	2.9	3.1	3.3	4.3	4.6	4.9
		Spring (MAM)	ºC		3.1			4.5	
		Summer (JJA)	ºC	2.6	2.9	3.1	3.9	4.2	4.5
		Fall (SON)	ºC		2.8			4.2	
		Winter (DJF)	**ºC**	3.2	**3.7**	4.2	5.0	**5.5**	6.0
	5th	Annual	ºC						
		Spring (MAM)	ºC	2.9	3.5	4.0	4.6	5.1	5.7
		Summer (JJA)	ºC						
		Fall (SON)	ºC	2.4	2.8	3.3	3.9	4.4	4.9
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	95th	Annual	ºC	2.6	2.8	3.0	3.8	4.0	4.2
		Spring (MAM)	ºC						
		Summer (JJA)	ºC	2.6	2.9	3.2	3.8	4.1	4.4
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Change in Precipitation from Base Period (1970-1999)	Mean	Annual	mm/day						
		Spring (MAM)	mm/day	0.1	0.2	0.4	0.3	0.4	0.6
		Summer (JJA)	mm/day						
		Fall (SON)	mm/day	-0.1	0.1	0.3	0.0	0.2	0.4
		Winter (DJF)	mm/day						
	95th	Annual	mm/day	0.8	1.1	1.4	1.3	1.5	1.8
		Spring (MAM)	mm/day						
		Summer (JJA)	mm/day	0.4	1.2	2.0	0.7	1.4	2.2
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		Winter (DJF)	mm/day	0.3	0.9	1.5	0.5	1.1	1.7
	99th	Annual	mm/day						
		Spring (MAM)	mm/day	0.9	1.8	2.8	1.7	2.6	3.7
		Summer (JJA)	mm/day						
		Fall (SON)	mm/day	0.5	1.8	3.1	1.4	2.8	4.3

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			Units	2.5%	50%	97.5%	2.5%	50%	97.5%
Change in Temperature from Base Period (1970-1999)	**Mean**	**Annual**	**ºC**	2.9	**3.1**	3.3	4.3	**4.6**	4.9
		Spring (MAM)	ºC						
		Summer (JJA)	ºC	2.6	2.9	3.1	3.9	4.2	4.5
		Fall (SON)	ºC						
		Winter (DJF)	ºC	3.2	3.7	4.2	5.0	5.5	6.0
	5th	**Annual**	**ºC**	3.2	**3.5**	3.8	4.9	**5.3**	
		Spring (MAM)	ºC	2.9	3.5	4.0	4.6	5.1	5.7
		Summer (JJA)	ºC						
		Fall (SON)	ºC	2.4	2.8	3.3	3.9	4.4	4.9
		Winter (DJF)	ºC						
	95th	**Annual**	**ºC**	2.6	**2.8**	3.0	3.8	**4.0**	4.2
		Spring (MAM)	ºC						
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	99th	Annual	mm/day						
		Spring (MAM)	mm/day	0.9	1.8	2.8	1.7	2.6	3.7
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		Fall (SON)	mm/day	0.5	1.8	3.1	1.4	2.8	4.3

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		Winter (DJF)	°C	2.2	2.8	3.3	3.4	4.0	4.5
Change in Precipitation from Base Period (1970-1999)	**Mean**	**Annual**	**mm/day**	0.2	**0.2**	0.3	0.2	**0.3**	0.3
		Spring (MAM)	mm/day	0.1	0.2	0.4	0.3	0.4	0.6
		Summer (JJA)	mm/day						
		Fall (SON)	mm/day	-0.1	0.1	0.3	0.0	0.2	0.4
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Change in Precipitation from Base Period (1970-1999)	Mean	Annual	mm/day						
		Spring (MAM)	**mm/day**	0.1	**0.2**	0.4	0.3	**0.4**	0.6
		Summer (JJA)	**mm/day**	0.1	**0.3**	0.5	0.1	**0.3**	0.5
		Fall (SON)	**mm/day**	0.1	**0.1**	0.3	0.0	**0.2**	0.4
		Winter (DJF)	**mm/day**	0.1	**0.2**	0.4	0.2	**0.3**	0.4
	95th	Annual	mm/day	0.8	1.1	1.4	1.3	1.5	1.8
		Spring (MAM)	mm/day						
		Summer (JJA)	mm/day	0.4	1.2	2.0	0.7	1.4	2.2
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Change in Precipitation from Base Period (1970-1999)	Mean	Annual	mm/day	0.2	0.2	0.3	0.2	0.3	
		Spring (MAM)	mm/day	0.1	0.2	0.4	0.3	0.4	0.6
		Summer (JJA)	mm/day						
		Fall (SON)	mm/day	-0.1	0.1	0.3	0.0	0.2	0.4
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		Spring (MAM)	mm/day						
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		Spring (MAM)	mm/day	0.9	1.8	2.8	1.7	2.6	3.7
		Summer (JJA)	mm/day						
		Fall (SON)	mm/day	0.5	1.8	3.1	1.4	2.8	4.3

Metric		Units	Base Average	2040-2069 2.5%	50%	97.5%	2070-2099 2.5%	50%	97.5%
Freezing Days	Annual	days	117	83	85	87	69	72	74
	Nov-Dec	days							
	Jan-Feb	days	53	43	45	46	38	39	41
	Mar-Apr	days							
Snowfall	Annual	cm	676	413	432	450	321	340	359
	Fall (SON)	cm							
	Winter (DJF)	cm	477	305	328	351	242	263	285
	Spring (MAM)	cm							
Above 32.2°C	Annual	days	6	23	24	25	35	37	40
Heat Index	Annual	°C·days							
	Summer (JJA)	°C·days	118	389	416	442	597	642	687
Growing Season	Annual	days							
Maple Sap Production	Annual	days	60	52	53	54	48	49	50
	Fall (SON)	days							
	Winter (DJF)	days	14	20	21	23	22	23	24
	Spring (MAM)	days							
Heating Requirements	Annual	°C·days	5294	4216	4307	4398	3785	3885	3985
	Fall (SON)	°C·days							
	Winter (DJF)	°C·days	2527	2159	2197	2235	1992	2033	2074
	Spring (MAM)	°C·days							
Cooling Requirements	Annual	°C·days	0	11	13	15	35	40	46
	Spring (MAM)	°C·days							
	Summer (JJA)	°C·days	0	10	12	14	32	37	43
	Fall (SON)	°C·days							
rPPET	Summer (JJA)	ratio	1.14	1.10	1.15	1.20	1.06	1.11	1.16

Metric		Units	Base	2040-2069			2070-2099		
			Average	2.5%	50%	97.5%	2.5%	50%	97.5%
Freezing Days	Annual	days	117	83	85	87	69	72	74
	Nov-Dec	days							
	Jan-Feb	days	53	43	45	46	38	39	41
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Snowfall	Annual	cm	676	413	432	450	321	340	359
	Fall (SON)	cm							
	Winter (DJF)	cm	477	305	328	351	242	263	285
	Spring (MAM)	cm							
Above 32.2ºC	Annual	days	6	23	24	25	35	37	40
Heat Index	Annual	ºC·days	130	449	475	501	548	553	575
	Summer (JJA)	ºC·days	118	389	416	442	597	642	687
Growing Season	Annual	days	141	166	169	171	181	184	186
Maple Sap Production	Annual	days	60	52	53	54	48	49	50
	Fall (SON)	days	19	15	15	16		7	17
	Winter (DJF)	days	14	20	21	23	22	23	24
	Spring (MAM)	days	27	16	18	20	16	18	20
Heating Requirements	Annual	ºC·days	5294	4216	4307	4398	3785	3885	3985
	Fall (SON)	ºC·days							
	Winter (DJF)	ºC·days	2527	2159	2197	2235	1992	2033	2074
	Spring (MAM)	ºC·days							
Cooling Requirements	Annual	ºC·days	0	11	13	15	35	40	46
	Spring (MAM)	ºC·days							
	Summer (JJA)	ºC·days	0	10	12	14	32	37	43
	Fall (SON)	ºC·days							
rPPET	Summer (JJA)	ratio	1.14	1.10	1.15	1.20	1.06	1.11	1.16

Update on Downscaling
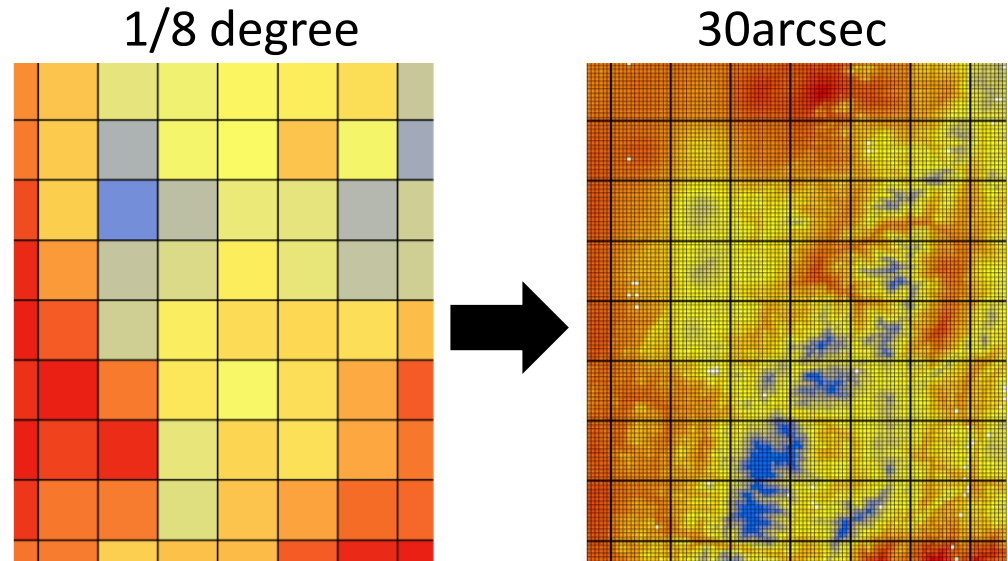
Downscaling from Models

- **Objective**:

to create higher spatial resolution climate data from Intermediate Downscaled Climate Model data

- **Approach**:

Statistical downscaling:

Elevation adjustment using relationship between climate and elevation:

LAPSE RATE

1/8 degree

30arcsec

ENSEMBLES

Combinations of:

GCMs

x

Intermediate downscaling method (BCCA, ARR, BCSD)

x

Story lines (RCP 4.5 and 8.5, scenario A1B and 2A)

x

Downscaling method (linear, Liston&Elder's equations)

x

Interpolation method (inverse distance and kriging)

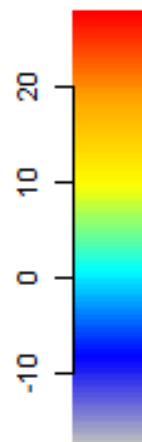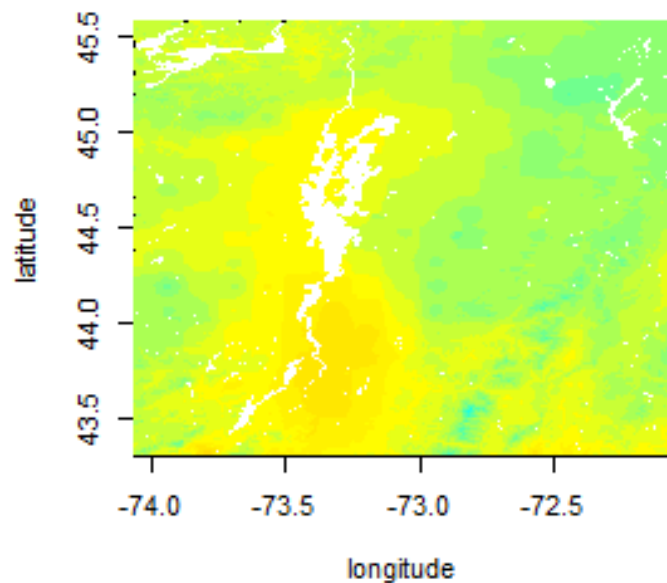# Downscaling methods to Intermediate Downscaled Climate Models

- **Bias Corrected Constructed Analog model (BCCA)**

  by BLM, "Bias Corrected and Downscaled WCRP CMIP3/5 Climate and Hydrology Projections" web archive

- **Asynchronous Regional Regression model (ARR)**

  by Katharine Hayhoe, ARRM Eighth degree-CONUS Daily Downscaled Climate Projections

- **Bias Corrected Spatially Disaggregated model (BCSD)**
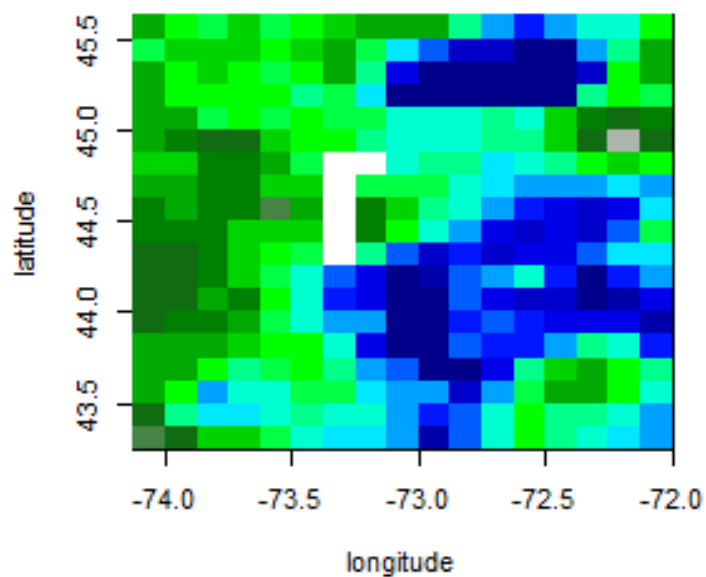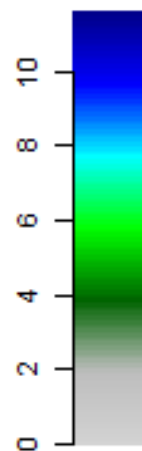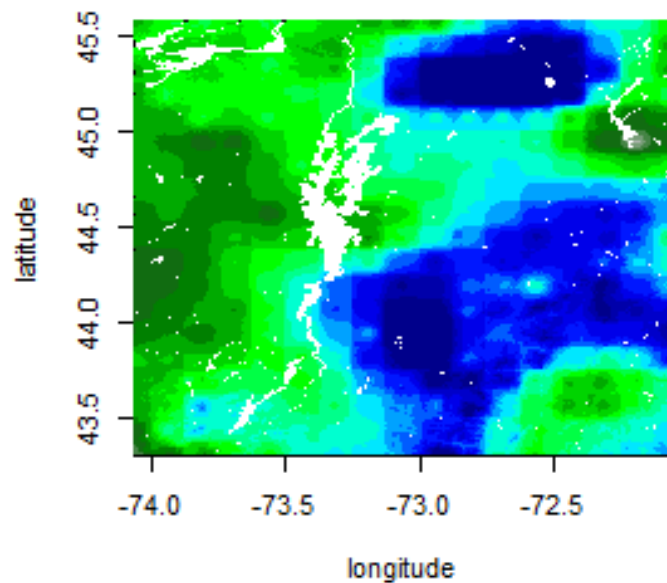
  by Bridget Thrasher

May 03 2050

Full Tables

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				2.5%	50%	97.5%	2.5%	50%	97.5%
Change in Temperature from Base Period (1970-1999)	Mean	Annual	°C	2.9	3.1	3.3	4.3	4.6	4.9
		Spring (MAM)	°C	2.7	3.1	3.5	4.1	4.5	5.0
		Summer (JJA)	°C	2.6	2.9	3.1	3.9	4.2	4.5
		Fall (SON)	°C	2.5	2.8	3.1	3.8	4.2	4.5
		Winter (DJF)	°C	3.2	3.7	4.2	5.0	5.5	6.0
	5th	Annual	°C	3.2	3.5	3.8	4.9	5.3	5.6
		Spring (MAM)	°C	2.9	3.5	4.0	4.6	5.1	5.7
		Summer (JJA)	°C	2.5	2.9	3.3	3.8	4.2	4.6
		Fall (SON)	°C	2.4	2.8	3.3	3.9	4.4	4.9
		Winter (DJF)	°C	4.1	4.7	5.3	6.6	7.3	7.9
	95th	Annual	°C	2.6	2.8	3.0	3.8	4.0	4.2
		Spring (MAM)	°C	2.4	2.9	3.4	3.5	4.0	4.6
		Summer (JJA)	°C	2.6	2.9	3.2	3.8	4.1	4.4
		Fall (SON)	°C	2.3	2.7	3.1	3.4	3.8	4.2
		Winter (DJF)	°C	2.2	2.8	3.3	3.4	4.0	4.5
Change in Precipitation from Base Period (1970-1999)	Mean	Annual	mm/day	0.2	0.2	0.3	0.2	0.3	0.3
		Spring (MAM)	mm/day	0.1	0.2	0.4	0.3	0.4	0.6
		Summer (JJA)	mm/day	0.1	0.3	0.5	0.1	0.3	0.5
		Fall (SON)	mm/day	-0.1	0.1	0.3	0.0	0.2	0.4
		Winter (DJF)	mm/day	0.1	0.2	0.4	0.2	0.3	0.4
	95th	Annual	mm/day	0.8	1.1	1.4	1.3	1.5	1.8
		Spring (MAM)	mm/day	0.5	1.1	1.8	1.1	1.8	2.5
		Summer (JJA)	mm/day	0.4	1.2	2.0	0.7	1.4	2.2
		Fall (SON)	mm/day	0.0	0.8	1.7	0.4	1.3	2.3
		Winter (DJF)	mm/day	0.3	0.9	1.5	0.5	1.1	1.7
	99th	Annual	mm/day	2.0	2.5	2.9	2.9	3.4	3.9
		Spring (MAM)	mm/day	0.9	1.8	2.8	1.7	2.6	3.7
		Summer (JJA)	mm/day	1.2	2.4	3.7	1.4	2.6	3.8
		Fall (SON)	mm/day	0.5	1.8	3.1	1.4	2.8	4.3
		Winter (DJF)	mm/day	0.5	1.4	2.2	1.3	2.2	3.2

Metric		Units	Base Average	2040-2069 2.5%	50%	97.5%	2070-2099 2.5%	50%	97.5%
Freezing Days	Annual	days	117	83	85	87	69	72	74
	Nov-Dec	days	38	25	26	27	20	21	22
	Jan-Feb	days	53	43	45	46	38	39	41
	Mar-Apr	days	24	13	14	15	11	11	12
Snowfall	Annual	cm	676	413	432	450	321	340	359
	Fall (SON)	cm	68	29	32	35	18	21	23
	Winter (DJF)	cm	477	305	328	351	242	263	285
	Spring (MAM)	cm	131	64	72	80	48	56	63
Above 32.2ºC	Annual	days	6	23	24	25	35	37	40
Heat Index	Annual	ºC·days	130	449	475	501	540	553	555
	Summer (JJA)	ºC·days	118	389	416	442	597	642	687
Growing Season	Annual	days	141	166	169	171	181	184	186
Maple Sap Production	Annual	days	60	52	53	54	48	49	50
	Fall (SON)	days	19	12	12	13	9	9	10
	Winter (DJF)	days	14	20	21	23	22	23	24
	Spring (MAM)	days	27	18	19	20	15	16	17
Heating Requirements	Annual	ºC·days	5294	4216	4307	4398	3785	3885	3985
	Fall (SON)	ºC·days	1153	897	916	935	778	800	823
	Winter (DJF)	ºC·days	2527	2159	2197	2235	1992	2033	2074
	Spring (MAM)	ºC·days	1395	1078	1106	1133	965	995	1024
Cooling Requirements	Annual	ºC·days	0	11	13	15	35	40	46
	Spring (MAM)	ºC·days	0	0	0	0	1	1	1
	Summer (JJA)	ºC·days	0	10	12	14	32	37	43
	Fall (SON)	ºC·days	0	0	0	1	1	2	3
rPPET	Summer (JJA)	ratio	1.14	1.10	1.15	1.20	1.06	1.11	1.16

Lapse Rate Downscaling

- **Goal**: downscale from 1/8 degree (~12 km) to 30 arcsec (~0.8 km)

- **Method**: height adjustment

  1. Climate adjustment to the reference elevation 0 m a.s.l. using linear lapse rate

  2. Spatial interpolation (change cell resolution) using inverse-distance weighted interpolation

  3. Climate adjustment to high resolution elevation (topographic adjustment) using lapse rate

Climate Stations

1950-2012
daily temperature
and
precipitation

STUDY AREA
- CocoRaHS stations
- GHCN stations
- WMO stations

SUBBASIN
- Winooski River
- Mississquoi River
- Lamoille River
- Lake Champlain Direct

Kilometers
0 15 30   60