Statistically downscaled climate scenarios

1. Overview

Statistically downscaled climate scenarios based on global climate model projections from the Coupled Model Intercomparison Project Phase 5 (CMIP5) are provided. Statistically downscaled multi-model ensembles of modelled output and projected change are available for historical simulations and three emission scenarios, RCP2.6, RCP4.5, RCP8.5, at a 10km resolution. Projected changes are expressed as anomalies with respect to the reference period of 1986-2005. A range of percentiles across the multi-model ensembles are available for download.

Projections among climate models can vary because of differences in their underlying representation of earth system processes. Thus, the use of a multi-model ensemble approach has been demonstrated in recent scientific literature to likely provide better projected climate change information.

Table 1. Main Characteristics

Variables and units	Mean temperature (°C) Projected change in mean temperature (°C) Minimum temperature (°C) Projected change in minimum temperature (°C) Maximum temperature (°C) Projected change in maximum temperature (°C) Total precipitation (mm/day) Projected relative change in total precipitation (%)
Geographic Area	Canada
Spatial Resolution	10km grid resolution
Time Period	1951 to 2100 *20-year averages of projected change are available for four future time periods:* 2021-2040; 2041-2060; 2061-2080; 2081-2100
Temporal Resolution	Monthly, seasonal, and annual *Seasons:* The standard meteorological seasons are used: March to May (spring), June to August (summer), September to November (autumn/fall), and December to February (winter).
Emission Scenarios	RCP2.6 RCP4.5 RCP8.5

2. Data and processing

Statistically downscaled multi-model ensembles have been constructed using output from twenty-four Coupled Model Intercomparison Project Phase 5 (CMIP5) global climate models (GCM) available at the Program For Climate Model Diagnosis and Intercomparison (PCMDI) site. Statistically downscaled multi-model ensemble datasets of minimum, maximum and mean temperature and total precipitation comprise 24/24/24 scenario experiments for RCP2.6/4.5/8.5 from 24 climate models (Table 2).

Only concentration-driven experiments are used (i.e., those in which concentrations rather than emissions of greenhouse gases are prescribed) and only one ensemble member from each model is selected, even if multiple realizations exist with different initial conditions and different realizations of natural variability. Hence each model is given equal weight.

Daily minimum temperature (°C), daily maximum temperature (°C) and daily precipitation (mm/day) outputs from twenty four GCMs were downscaled using the Bias Correction/Constructed Analogues with Quantile mapping version 2 (BCCAQv2) algorithm. Historical 1/12° gridded daily datasets of minimum temperature, maximum temperature and precipitation of Canada (McKenney et al., 2011) were used as the respective downscaling targets. BCCAQv2 was calibrated using a 1950-2010 historical reference period and was applied to each variable separately. Downscaled daily mean temperature was calculated by averaging the downscaled daily minimum and maximum temperature for each respective individual model. Note: downscaling different variables independently can lead to small numbers of cases of physical inconsistency (i.e., minimum temperatures that occasionally exceed maximum temperatures), although tests indicate that ad hoc "correction" of inconsistent temperatures (e.g., by swapping affected minima and maxima) generally results in negligible differences in calculated climate indices (Li et al., 2018).

Bias Correction/Constructed Analogues with Quantile mapping (BCCAQ) is a hybrid downscaling algorithm that combines downscaling by BCCA (Bias Correction/Constructed Analogues) (Maurer et al. 2010) with quantile mapping. Details are provided by Werner and Cannon (2016). The use of Quantile Delta Mapping (Cannon et al., 2015), a change-preserving form of quantile mapping, distinguishes BCCAQv2 from the previous version of the algorithm.

It should be noted that the calibration and application of the statistical downscaling method requires historical simulations to be concatenated to a RCP projection. As an artifact, statistically downscaled historical simulations concatenated to the three RCPs are not identical, though differences are generally negligible. For simplicity, the multi-model historical simulation ensemble concatenated to the multi-model RCP4.5 ensemble is made available for download.

3. Reference period for anomaly results (projected change)

Projected changes are expressed as anomalies with respect to the reference period of 1986-2005 for both anomaly time series and spatial maps (i.e., differences between the future period and the reference period). Therefore, twenty-year averages of projected change (in the climate variable) for the four future time periods (2021-2040; 2041-2060; 2061-2080; 2081-2100) are with respect to the reference period of 1986-2005.

4. Equal model weighting

The different statistically downscaled CMIP5 models used for the projections are all considered to give equally likely projections in the sense of 'one model, one vote'. Models with variations in physical parameterization schemes are treated as distinct models.

5. Model range through the use of ensemble percentiles

As local projections of climate change are uncertain, a measure of the range of model projections is provided (i.e., 5^{th}, 25^{th}, 75^{th}, 95^{th} percentiles) in addition to the median response (50^{th} percentile) of the statistically downscaled multi-model ensemble. It should again be emphasized that this range does not represent the full uncertainty in the projection. The distribution combines the effects of natural variability and model spread.

6. Best practice

Given the range of natural climate variability and uncertainties regarding future greenhouse gas emission pathways and climate response, changes projected by one climate model should not be used in isolation. Rather, it is good practice to consider a range of projections from multiple climate models (ensembles) and emission scenarios.

While likelihoods are not associated with particular climate change scenarios, the use of a range of scenarios may help convey to users the potential spread across a range of possible emission pathways.

7. Use Limitation

8. Contact Information

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9. References

Cannon, A.J., S.R. Sobie, and T.Q. Murdock, 2015: Precipitation by Quantile Mapping: How Well Do Methods Preserve Changes in Quantiles and Extremes? Journal of Climate, 28(17), 6938-6959, doi:10.1175/JCLI-D-14-00754.1.

Li, G., X. Zhang, A.J. Cannon, T.Q. Murdock, S. Sobie, F.W. Zwiers, K. Anderson, and B. Qian, 2018. Indices of Canada's future climate for general and agricultural adaptation applications. Climatic Change, 148(1-2):249-263. doi:10.1007/s10584-018-2199-x

Maurer, E.P., and H.G. Hidalgo, 2008: Utility of daily vs. monthly large-scale climate data: an intercomparison of two statistical downscaling methods. Hydrology and Earth System Sciences, 12, 2, 551-563. doi:10.5194/hess-12-551-2008.

McKenney, D. W., M. F. Hutchinson, P. Papadopol, K. Lawrence, J. Pedlar, K. Campbell, E. Milewska, R. F. Hopkinson, D. Price, and T. Owen, 2011: Customized Spatial Climate Models for North America. Bull. Amer. Meteor. Soc., 92 12, 1611-1622.

Werner, A.T. and A.J. Cannon, 2016: Hydrologic extremes–an intercomparison of multiple gridded statistical downscaling methods. Hydrology and Earth System Sciences, 20(4), 1483-1508. doi:10.5194/hess-20-1483-2016

Table 2. List of climate models used in the statistically downscaled multi-model ensembles.

	CMIP5 model name	Historical	RCP2.6	RCP4.5	RCP8.5
#1	BNU-ESM	1	1	1	1
#2	CCSM4	1	1	1	1
#3	CESM1-CAM5	1	1	1	1
#4	CNRM-CM5	1	1	1	1
#5	CSIRO-Mk3-6-0	1	1	1	1
#6	CanESM2	1	1	1	1
#7	FGOALS-g2	1	1	1	1
#8	GFDL-CM3	1	1	1	1
#9	GFDL-ESM2G	1	1	1	1
#10	GFDL-ESM2M	1	1	1	1
#11	HadGEM2-AO	1	1	1	1
#12	HadGEM2-ES	1	1	1	1
#13	IPSL-CM5A-LR	1	1	1	1
#14	IPSL-CM5A-MR	1	1	1	1
#15	MIROC-ESM	1	1	1	1
#16	MIROC-ESM-CHEM	1	1	1	1
#17	MIROC5	1	1	1	1
#18	MPI-ESM-LR	1	1	1	1
#19	MPI-ESM-MR	1	1	1	1
#20	MRI-CGCM3	1	1	1	1
#21	NorESM1-M	1	1	1	1
#22	NorESM1-ME	1	1	1	1
#23	bcc-csm1-1	1	1	1	1
#24	bcc-csm1-1-m	1	1	1	1