Documentation for the ClimEx CRCM5 Large Ensemble (v2.1)

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1 Important notes

1.1 Terms of use

- References, credits, and technical information to include for the ClimEx CRCM5 Large Ensemble (CRCM5-LE) are provided in the ‘Terms of use’ document.

1.2 Experimental framework and overview of the results

A general description of the ClimEx CRCM5 Large ensemble is provided in the following paper:


1.3 Data use: removing the spin-up time

As described in Leduc et al. (2019), a spin-up period in the beginning of each simulation should be discarded from analysis, as the CRCM5 and CanESM2 models need some time to forget their initial conditions. More specifically, the analysis period should be:

- **1955-2099** for all simulations driven by CanESM2 (kb*, kc*, kd* and ke*). The first five years (1950-1954) should not be considered for analysis in order to obtain 50 independent members from the driving model CanESM2.

- **1980-2013** for all simulations driven by the ERA-Interim reanalysis. The first year (1979) should not be considered in order to account for the CRCM5 spin-up.
Figure 1: Integration domains (380x380 grid points) used by CRCM5 to produce the ClimEx large ensemble. Are also shown the "free domain" (340x340 grid points, in red) where the model is technically free from direct imposition of lateral boundary conditions. Finally, the "analysis domain" (280x280, in green) is the region where are archived all the output fields.

2 Simulations and terminology

Table 1: List of CRCM5 simulations produced within the ClimEx project.

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Table 2: Table of correspondence between the CanESM2 and CRCM5 ensemble runs terminologies.

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### List of archived variables

Table 3: List of archived variables for the ClimEx CRCM5 large ensemble, with $\Delta t$ being the archiving frequencies for the Europe (EU) and northeastern North America (NNA) domains. The last column gives the type of data archive: (I) instantaneous value provided every archival time, (M) mean value during the archival period and (N) or (X) for miNim or maXim value between archival times. The choice of CRCM5 variables to be archived was made to comply with the needs of hydrological studies in the context of the ClimEx project. We archived additional variables that could be useful in other applications, but limitations on the total volume of data have restricted their number.

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<td>I</td>
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<tr>
<td>lit</td>
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<tr>
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<td>K</td>
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<tr>
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<td>day</td>
<td>Soil Frozen Water Content</td>
<td>kg m$^{-2}$</td>
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</tr>
<tr>
<td>mrro</td>
<td>day</td>
<td>day</td>
<td>Total Runoff</td>
<td>kg m$^{-2}$ s$^{-1}$</td>
<td>M</td>
</tr>
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<td>mrros</td>
<td>day</td>
<td>day</td>
<td>Surface Runoff</td>
<td>kg m$^{-2}$ s$^{-1}$</td>
<td>M</td>
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<tr>
<td>mrs</td>
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<tr>
<td>prc</td>
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<td>M</td>
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</tr>
<tr>
<td>prfr</td>
<td>day</td>
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<td>Freezing Rain</td>
<td>kg m$^{-2}$ s$^{-1}$</td>
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</tr>
<tr>
<td>pr</td>
<td>1h 1h</td>
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<td>Precipitation</td>
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<td>Water Vapor Path</td>
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Table 3: (continued)

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<th>∆t NNA</th>
<th>Description</th>
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<th>Type</th>
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<td>Sea Level Pressure</td>
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<td>Surface Downwelling Longwave Radiation</td>
<td>W m-2</td>
<td>M</td>
</tr>
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<td>3h</td>
<td></td>
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<td>M</td>
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<td>3h</td>
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<td>W m-2</td>
<td>M</td>
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<td>M</td>
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<td>3h</td>
<td>3h</td>
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<td>W m-2</td>
<td>M</td>
</tr>
<tr>
<td>rsdt</td>
<td>3h</td>
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<td>TOA Incident Shortwave Radiation</td>
<td>W m-2</td>
<td>M</td>
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<td>rsus</td>
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<td>W m-2</td>
<td>M</td>
</tr>
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<td>3h</td>
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<td>M</td>
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<td>snc</td>
<td>day</td>
<td>day</td>
<td>Snow Area Fraction</td>
<td>%</td>
<td>I</td>
</tr>
<tr>
<td>snd</td>
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<td></td>
<td>Snow Depth</td>
<td>m</td>
<td>I</td>
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<tr>
<td>snw</td>
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<td>Surface Snow Amount</td>
<td>kg m-2</td>
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</tr>
<tr>
<td>tas</td>
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<td>K</td>
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<td>Daily Minimum Near-Surface Temperature</td>
<td>K</td>
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<td>ts</td>
<td>day</td>
<td>day</td>
<td>Surface Temperature</td>
<td>K</td>
<td>I</td>
</tr>
<tr>
<td>uas</td>
<td>3h</td>
<td>3h</td>
<td>Eastward Near-Surface Wind</td>
<td>m s-1</td>
<td>I</td>
</tr>
<tr>
<td>vas</td>
<td>3h</td>
<td>3h</td>
<td>Northward Near-Surface Wind</td>
<td>m s-1</td>
<td>I</td>
</tr>
</tbody>
</table>

3-D Atmospheric variables
(at 1000, 925, 850, 700, 500 and 200 hPa)

| hus         | 3h    | 3h     | Specific Humidity                               | 1      | I    |
| ta          | 3h    | 3h     | Air Temperature                                 | K      | I    |
| ua          | 3h    | 3h     | Eastward Wind                                   | m s-1  | I    |
| va          | 3h    | 3h     | Northward Wind                                  | m s-1  | I    |
| zg          | 3h    | 3h     | Geopotential Height                             | m      | I    |

3-D Soil variables
(9 layers from surface to bedrock)

| mrfsl       | day   | day    | Soil Layer Frozen Water Content                  | kg m-2 | I    |
| mrlsl       | day   | day    | Water Content of Soil Layer                      | kg m-2 | I    |

The 9 layers are taken from the 17 soil layers reaching a depth of 15 meters. Starting from the surface, the thickness of each layer in meters is: 0.1, 0.2, 0.3, 0.4, 0.5, 0.5, 0.5, 0.5, 0.5 meters, giving a corresponding depth for each layer in meters of: 0.1, 0.3, 0.6, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 meters.
Table 4: List of invariant fields for the ClimEx CRCM5 large ensemble. These fields are enclosed into invariant simulations labeled as kax and kay for the EU and NNA domains respectively.

<table>
<thead>
<tr>
<th>NetCDF Name</th>
<th>Description</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>areacella</td>
<td>Atmosphere Grid-Cell Area</td>
<td>m²</td>
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<tr>
<td>bedrock</td>
<td>Bedrock Depth</td>
<td>m</td>
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<tr>
<td>clayfrac</td>
<td>Clay Fraction</td>
<td>%</td>
</tr>
<tr>
<td>cropFrac</td>
<td>Crop Fraction</td>
<td>%</td>
</tr>
<tr>
<td>grassFrac</td>
<td>Grass Fraction</td>
<td>%</td>
</tr>
<tr>
<td>lakeFrac</td>
<td>Lake Area Fraction</td>
<td>%</td>
</tr>
<tr>
<td>ldepth</td>
<td>Lake Depth</td>
<td>m</td>
</tr>
<tr>
<td>orogf</td>
<td>Filtered Orography</td>
<td>m</td>
</tr>
<tr>
<td>sandfrac</td>
<td>Sand Fraction</td>
<td>%</td>
</tr>
<tr>
<td>sftgrf</td>
<td>Grounded Ice Area Fraction</td>
<td>%</td>
</tr>
<tr>
<td>sftlf</td>
<td>Land Area Fraction</td>
<td>%</td>
</tr>
<tr>
<td>sftof</td>
<td>Sea Area Fraction</td>
<td>%</td>
</tr>
<tr>
<td>treeFracPrimDec</td>
<td>Total Primary Deciduous Tree Fraction</td>
<td>%</td>
</tr>
<tr>
<td>treeFracPrimEver</td>
<td>Total Primary Evergreen Tree Fraction</td>
<td>%</td>
</tr>
<tr>
<td>urbanFrac</td>
<td>Urban Fraction</td>
<td>%</td>
</tr>
<tr>
<td>wetlandFrac</td>
<td>Wetland Fraction</td>
<td>%</td>
</tr>
</tbody>
</table>

4 Suggested reading for a first contact with a regional climate model


5 Templates for the description of CRCM5-LE simulations (and driving data)

In reports/publications, a description of CRCM5-LE simulations should include the following information to describe the configuration of the run:

- CRCM5 version (CRCM5 v3.3.3.1) and
- the run’s name(s) following either Ouranos’ operational 3-letter name of simulation (ex. kda) or the CORDEX naming convention;
- prescribed reference(s) and acknowledgements,
- regional domain and horizontal resolution,

- time window of simulation,

- driving data (e.g. reanalyses or GCM VERSION, member, and RCP if future projection).

- The lake model (implemented at the sub-grid scale and the resolved grid scale) should also be cited with reference(s) if relevant for the analysis (see note on the lakes below).

**Suggestion of text on regional domain and resolution:**
The ClimEx simulations were performed using the same configuration over the European and Northeastern North America domains:

- ...over a domain covering Europe (EU) or Northeastern North America (NNA) with a horizontal grid-size mesh of 0.11 degrees (on a rotated latitude-longitude grid), corresponding to a 12-km resolution, using 5-minute time steps.

The CRCM5 was run on larger grids than those kept for validation. The real size of the computational domain was 380x380 and a 50-point depth security zone was removed surrounding the domain to avoid artefacts from coarse resolution boundary conditions. This gives a free zone for analysis of 280x280 grid points.

**Suggestion of text on spectral nudging (when applicable for the CRCM5 simulation used):**

- ... a spectral nudging technique was applied to large-scale winds (Riette and Caya 2002) within the interior of the regional domain to keep CRCM's large-scale flow close to its driving data.

**Suggestion of text on the driving data:**
... for historical simulations, the run was driven by atmospheric and oceanic fields taken from...

- 6-hourly ECMWF ERA-Interim global reanalyses (European Center for Medium-Range Weather Forecasts ReAnalyses; Dee et al. 2011), publicly available on a grid of approximately 80 km spatial resolution.

... for climate change projections, the run was driven by atmospheric and oceanic fields taken from...

- 6-hourly atmospheric simulation and daily ocean outputs of each of the 50 members of the Canadian Earth System Model version 2 Large Ensemble (CanESM2-LE; Fyfe et al. 2017; Sigmundet al. 2018; T63 approximately corresponding to 2.8oX2.8o on a latitude-longitude grid). Regional simulations were performed using the IPCC RCP 8.5 future greenhouse gas projected evolution from 2006 (Meinshausen et al. 2011), as was the global driving model.
More information on the CanESM2-LE:
For the historical period (1850–1950), each of the five CMIP5 members takes its initial 1850 year at 50-year intervals from a preindustrial CMIP5 `piControl’ simulation that has reached equilibrium. With a constant 284.7 ppm atmospheric CO2 concentration, this equilibrated control simulation has a stationary climate. Then, employing a small random perturbation, 10 new simulations are launched from each of the original 5 historical CMIP5 simulations on 1 January 1950 up till 2100. "The random perturbation to the initial atmospheric state is introduced via a parameterization of one aspect of model cloud properties. This parameterization employs a random number generator with a pre-set seed; the 50 individual simulations were based on different seeds. In this way, different climate change realizations were produced without any change to the model dynamics, physics or structure." (Fyfe et al. 2017). Observed emissions (in CO2 and non-CO2 GHGs, aerosols and land cover) are used during the historical period up to 2005 with observed explosive volcanoes and solar cycle forcings. For the 2006-2100 period, each member is a continuation of each of the five historical simulations employing the future RCP 8.5 scenario of forcings. These future simulations employ a solar cycle forcing comprised of a repetition of roughly the last observed solar cycle prior to 2006 but no explosive volcanic forcing. This generates 50 equally likely runs of 150 years (1950-2100), resulting in an artificial timeline of 50 x 150 = 7500 years of modelled climate over the domains. This enables to catch rare events in the data - and by this to investigate extreme events and natural variability with probabilistic approaches. Note that the basic reference for CanESM2 is: Arora et al. (2011).

Information on the lakes in CRCM5:
CRCM5 is coupled to sub-grid scale lakes (when the lake covers less than 100% of a model tile, the ground part being taken over by the CLASS land surface scheme) and to resolved lakes (when the lake covers 100% of a tile such as is the case for the Great Lakes and Lake Winnipeg for example). Unless otherwise specified, the lake model used is FLake, the Freshwater Lake model (Mironov et al. 2010). Martynov et al. (2010) describe the resolved lake model, namely over the American Great Lakes, while Martynov et al. (2012) look at the regional climate effect of sub-grid scale lakes. The data defining the percent coverage of lakes over each grid tile of a specified regional domain and resolution is available as an output from the CRCM5.

Note on possible analyses of CRCM5 simulations:
RCMs driven by reanalysis can be evaluated against observations for specific simulated periods, not only on a long-term statistical basis but also on an event basis, because the reanalyses represent actual climate periods (with assimilation of observed meteorological data). Consequently, temporal correlation of the simulation with the observations is meaningful and generally positive at all temporal scales. Correlations of large-scale dominated variables such as temperature or geopotential height can reach values near unity for small domains or for strong spectral nudging. For variables where small scales play a more important role such as precipitation, correlations are generally lower than those for temperature, and even lower in the case of the summer seasons. In GCMs, there is no assimilation of observed meteorological data, only the concentration/emissions of greenhouse gases and
aerosols (and land-use change, etc.) evolve following observed and possible future values. Hence, in the GCM-driven simulations, no temporal correlation can be expected, and no link to specific years can be made, the analysis needs to occur in terms of climatological statistics, which requires runs of sufficient length (typically a minimum of 20–30 years).

6 List of references

Specific to ClimEx


Specific to CRCM5:


Others:


