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The Grueling Journey of Regional Climate Model Validation

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Introduction

Validating regional climate models (RCM) has never been an easy task since difficulties come from both observations and RCMs. Even nowadays, typical RCM grid meshes are still too coarse to compare easily with station observations. Gridded observations datasets, coming from in situ or remote sensing data, are very useful but have their limitations. The emergence of simulations produced at convection-resolving resolutions will certainly exacerbate many observations-related issues. Most of RCM-related error sources fall into three main categories: formulation, inputs and configurations.

Sources of bias

Observations	RCM Formulation	RCM Inputs	RCM Configuration
• Instrument precision and errors • Missing data • Homogenization technique • Sparse Spatial coverage • Retrieval algorithm of remote sensing measurements • Etc.	• Misrepresented or missing process • Unfitted parameterization designed for coarser GCM or assimilated NWP • Etc.	• Unrealistic geophysical datasets • Problem inherited from the driving dataset – GCM or reanalysis.	• Horizontal and vertical resolution • Size and location of the regional grid • Nesting technique

Acknowledgments

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lrz

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Fifth-generation Canadian Regional Climate Model (CRCM5)

Dynamical core Gemclim v3.3.3.1	• Limited-area version of the Global Environment Multiscale model (GEM; Côté et al. 1998) • Solves primitive non-hydrostatic Eulerian equations using a semi-Lagrangian semi-implicit scheme • Horizontal discretisation: Arakawa-C grids • Terrain-following vertical coordinate based on hydrostatic pressure (Laprise 1992)
Subgrid-scale physical parameterization	• Kain-Fritsch deep convection parameterization (Kain and Fritsch, 1990). • Kuo-transient shallow convection (Kuo 1965; Bélair et al. 2005). • Sundqvist resolved-scale condensation (Sundqvist et al.1989). • Correlated-K solar and terrestrial radiations (Li and Barker 2005). • Low-level orographic blocking parameterization (Zadra et al. 2003;2012). • Planetary boundary layer parameterization and vertical diffusion (Benoit et al. 1989; Delage and Girard 1992; Delage 1997) including turbulent hysteresis (Zadra et al. 2012) and suppression of turbulent vertical fluxes under very stable conditions. • A weak lateral diffusion (6th order) • Canadian Land Surface Scheme (CLASS) version 3.5c (Verseghy 1991; Verseghy et al. 1993).
Coupled lake model	• one-dimensional lake model Flake (Mironov et al. 2010) for both the resolved- and subgrid-scale lakes following a land-surface type aggregation approach.
Nesting	• standard 10-point sponge relaxation zone (Davies, 1976) of all prognostic atmospheric variables • standard 10-point wide halo zone along the lateral boundaries for the semi-Lagrangian interpolation • Optional large scale nudging (Biner et al. 2000; Riette et Caya 2002; Laprise 2008)

Case 1: Unrealistic extent of the Boreal Forest

✔ **RCM Inputs** — In USGS vegetation dataset, strong bias in the evergreen limit

Context

Regional climate simulation analyses for the project, « Water footprint and Impact of Quebec's boreal hydroelectric reservoirs on the regional climate »

Irambona et al (2016), Theoretical and Applied Climatology, DOI 10.1007/s00704-016-2010-8

Problem

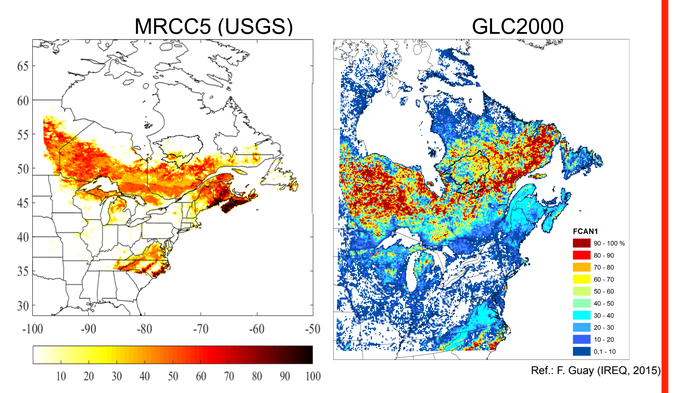
Researchers in charge of the field campaign noticed that the La Grande River watershed evergreen coverage was strongly underestimated in the model compared to reality.

Consequences

Overestimation of surface albedo that contributes to the cold bias and the excessive snowpack over the watershed.

Solution

Replace USGS vegetation dataset by GLC2000 as a CRCM5 geophysical input – *The new simulations are underway!*



- CRCM5 v3.3.3.1 for the 1979-2014 period
- Domain: QC11d1 at 0.11° (300X300 grid points)
- 5 min timestep ; 56 atmospheric levels; 17 ground levels
- driven by 0.75° ERA-Interim every 6 h ; no large-scale nudging

Case 2 : Spurious pattern in Snow Water Equivalent

✔ **RCM Inputs** — Ad hoc modification of USGS bare soil fraction

Context

Analysis of snow related variables for Ouranos projects.

Problem

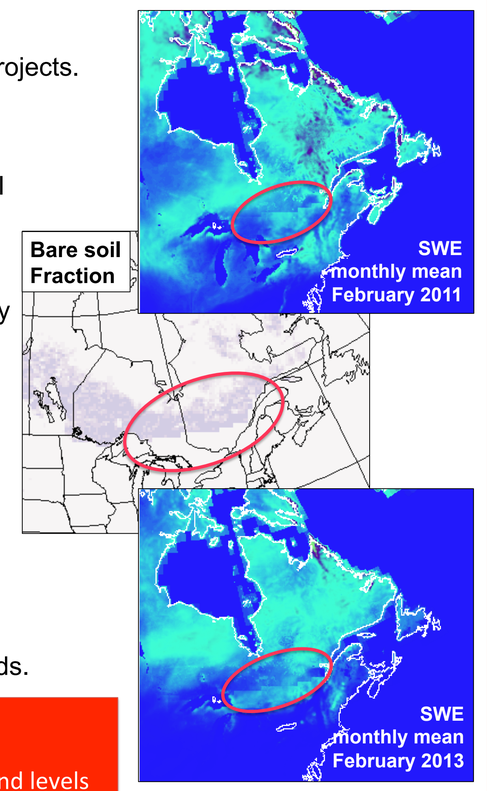
ESCER had decided to modify the USGS original datasets by reducing the evergreen fraction in order to boost the bare soil fraction at the southern limit of the Boreal Forest. This choice was motivated by an excessive evergreen density compared to reality.

Consequences

While this solution had the desired effect of a significantly improved the winter warm bias, it had the downside of generating spurious and non-physical patterns in the snow water equivalent and snow depth fields.

Solution

Use GLC2000 for CRCM5 geophysical input fields.



- CRCM5 v3.3.3.1 for the 1979-2014 period
- Domain: QC11d1 at 0.11° (300X300 grid points)
- 5 min time step ; 56 atmospheric levels; 17 ground levels
- driven by 0.75° ERA-Interim every 6 h
- no large scale nudging

Case 3: Warm bias in sea surface conditions

✔ **RCM Inputs** — Inherited bias from lower boundary conditions provided by the driving GCM

Context

Ouranos collaborators from ISMER used CRCM5 outputs to force their regional ocean model over the Gulf of St-Lawrence.

Problem

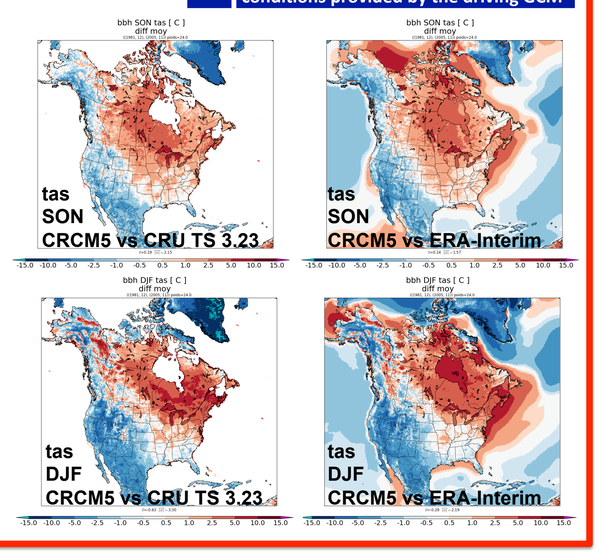
ISMER noticed that SST were much warmer than observations. In CRCM5, SST and sea ice are prescribed from the driver.

Consequences

Those inherited warm SST contribute to the warm air temperature bias around the Gulf of St-Lawrence and Hudson Bay. ISMER ocean model had difficulty to produce sea ice when forced by CRCM5.

Solution

Bias-correction of CRCM5 outputs.



- CRCM5 v3.3.3.1 for the 1950-2005 period
- driven by CanESM2 mb 2 ; large scale nudging on U and V
- Domain: AMNO22d2 at 0.22° (340X300grid points)
- 5 min time step ; 56 atmospheric levels; 17 ground levels

Case 4: Remaining precipitation extreme in the wake of a weather system

? **RCM Formulation**

? **RCM Configuration**

Context

Analysis of extreme precipitation events from the ***ClimEx CRCM5*** large ensemble.

Problem

A precipitation event dissipates except for one persistent grid point with very high accumulations. After a few hours, a new cell develops and moves away with the circulation.

Consequences

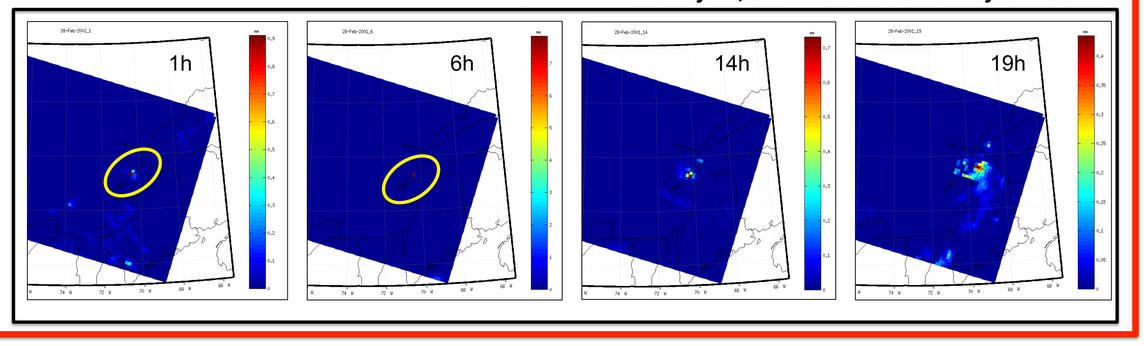
Off the charts 24h-total precipitation over a single ocean grid point, no matter the driver.

Solution

Under investigation. In the mean time, those unrealistic events are discarded from the study.

- CRCM5 v3.3.3.1
- 1979-2014 if driven by 0.75° ERA-Interim
- 1950-2100 if driven by the CanESM2 50 members
- Domain: QC11d3 at 0.11° (280X280 grid points)
- 5 min time step ; 56 atm. levels; 17 ground levels
- Large scale nudging on U and V.

February 28, 2001 - CRCM5 driven by CanESM2



Case 5: Insufficient moisture transport from Gulf of Mexico

? **RCM Inputs** — Potential moisture flux bias in lateral boundary conditions from ERA-Interim

✔ **RCM Configuration** — Choice of the regional domain

Context

Regional climate simulation validation for the needs of « *Climat reconstruit à Ouranos pour le Québec (CROQ)* » project.

Problem

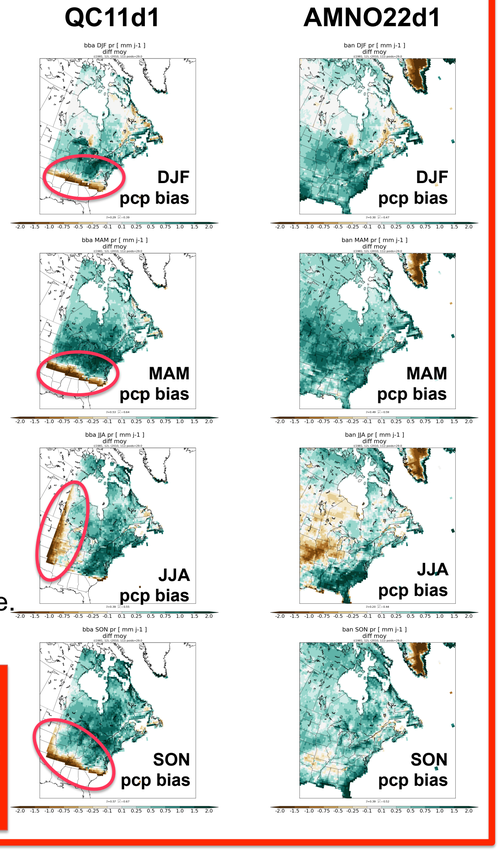
Due to computer resources limitations, the QC11d1 domain does not include the Gulf of Mexico leading to an insufficient moisture transport through the inflow boundaries. Potential lack of moisture transport in ERA-Interim data.

Consequences

Strong precipitation deficit with respect to *CRU TS 3.23* gridded observations along the south and west inflow boundaries of the QC11d1 grid despite the overall wet bias.

Solution

Extend regional domain further south and further west to include this key area for Quebec's climate. Activate large scale nudging.



- CRCM5 v3.3.3.1 for the 1979-2014 period
- Domains: QC11d1 at 0.11° ; AMNO22d1 at 0.22°
- 5 min time step ; 56 atm. levels; 17 ground levels
- driven by 0.75° ERA-Interim every 6 h
- No large scale nudging