Relation between RCM's internal variability and residency time of the atmospheric parcels into the limited area domain

Philippe Lucas-Picher[1], Daniel Caya[2] and Sébastien Biner[2]

[1]Department of Environmental Sciences, UQAM, Montréal, Québec, Canada. (picher@sca.uqam.ca)
[2]Ouranos Consortium, Montréal, Québec, Canada.

Internal variability is an intrinsic characteristic of the climate system. It is the variability in the climate system that is observed without modification in the forcings. This variability comes from the dynamic and thermodynamic non-linear relations which govern the atmosphere and oceans circulations. This variability is also generated by the interactions between the components of the climate systems, which operate at different time scales.

The internal variability in general circulation models (GCM) is visible when two simulations started with different initial conditions diverge from one another leading to two completely different states after few days. In regional climate models (RCM), internal variability is still present but usually lower then GCM's one because the RCM domain is limited and a continual flow of information, which feeds the limited area domain at the boundaries, controls the simulation.

Lucas-Picher et al. (2004) showed that RCM's internal variability increases with domain size due to the weakening of the lateral forcing as the domain expand. Rinke et al. (2004) demonstrated that the RCM's internal variability in an Arctic domain is higher than one in the mid-latitude due to the weak atmospheric flow through the boundaries of the RCM over the Arctic which limits the flow of new information in the domain. The purpose of this work is to study the relation between the residency time of the atmospheric parcels into the limited area domain and the amplitude of the internal variability in RCMs.

To look at the internal variability, two ten-year simulations (1980-1989) are started with a one-month lag in their initial conditions using the Canadian Regional Climate Model (CRCM) (Caya and Laprise, 1999). The CRCM simulations are driven by NCEP reanalysis over a domain of 193 by 145 grid points at 45-km resolution. An ageing tracer is used to evaluate the residency time of each atmospheric parcel into the limited area domain. The tracer works as a pollutant atmospheric tracer where the concentration is replaced by the time spent in the domain. When an atmospheric parcel comes into the domain, its tracer is initialized to 0 and at every time step, the tracer is ageing 15 minutes. The tracers are fully advected by the model circulation.

Figure 1 shows the mean summer and winter residency time at 850 hPa for the ten-year simulation. Because of the westward general circulation, the time spent in the domain is shorter on the west side of the domain than on the east side. According to the faster circulation in winter, the residency time is shorter in winter than in summer. The residency time over the Rocky Mountains and Greenland have to been ignored because a simple interpolation is done through the mountains to get the values at 850 hPa. These values will be masked in the subsequent analysis.

The internal variability is measured from the differences between each lagged simulation using the temporal root mean square difference (TRMSD):

$$TRMSD(i,j,k) = \sqrt{\frac{1}{NT}\sum_{t=1}^{NT}\left(A(i,j,k,t) - B(i,j,k,t)\right)^2} ,$$

where A and B are the two simulations and NT is the length of the simulation in number of time steps. Figure 2 presents the TRMSD of mean sea level pressure (MSLP) for summer and winter. The summer and winter figures are similar. On the western side of the domain, the differences between each simulation are low because the atmospheric flow just came into the domain. At the opposite, on the eastern side of the domain, the differences are high because the simulations have time to diverge from one another and the lateral forcing is weak.

To study a relation between the residency time and the MSLP TRMSD, a scatter plot using each cells of the domain is drawn (see fig. 3). On each plot, the best linear fit is drawn and the equation of this fit is indicated. Also, the linear correlation is computed. The cloud of points exhibits approximately a linear fit where small

TRMSD have a short residency time and high TRMSD have a long residency time. The correlation between the residency time and the TRMSD is of 0.94 in summer and winter, meaning that the relation is strong. With the same pattern of TRMSD, it is the slope of the fit that differentiate the summer from the winter. For a same residency time, each simulation has higher differences in winter than is summer. This can be explained by the stronger gradients in winter where different behavior for each simulation created large differences. This is a preliminary study and it is expected that this relation will not be present for all atmospheric variables.

References

Caya, D. and R. Laprise, 1999: A semi-implicit semi-Lagrangian regional climate model: The Canadian RCM, *Mon. Wea. Rev.,* 127 (3), 341-362.

Lucas-Picher, P., D. Caya and S. Biner, 2004: RCM's internal variability as function of domain size. *Research activities in Atmospheric and Oceanic Modelling*, WMO/TD, J. Côté, Ed., 1220 (34): 7.27-7.28.

Rinke, A., P. Marbaix and K. Dethloff, 2004: Internal variability in arctic regional climate simulations: Case study for the SHEBA year, *Climate research*, 27, 197-209.

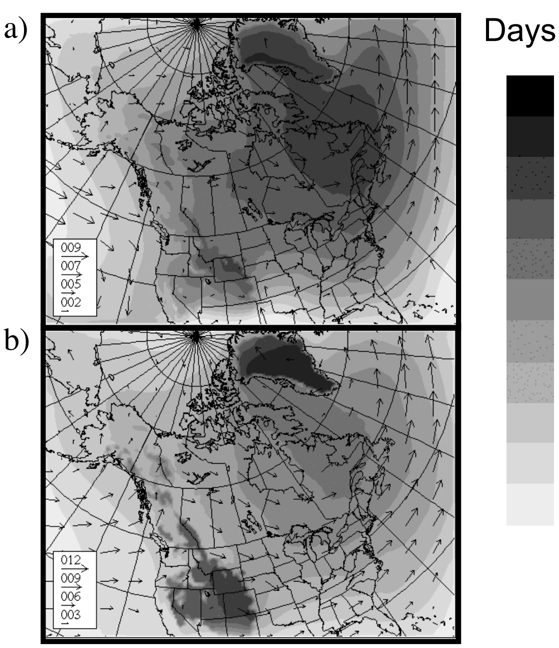

Figure 1. Mean residency time in a) summer (JJA) and b) winter (DJF) at 850 hPa for the ten-year simulation. The arrows indicate the wind circulation.

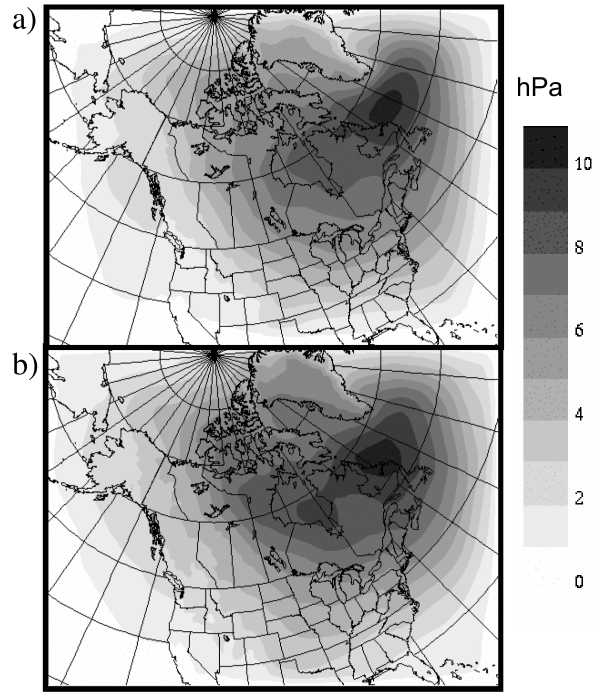

Figure 2. MSLP TRMSD for a) summer (JJA) and b) winter (DJF) for the ten-year simulation.

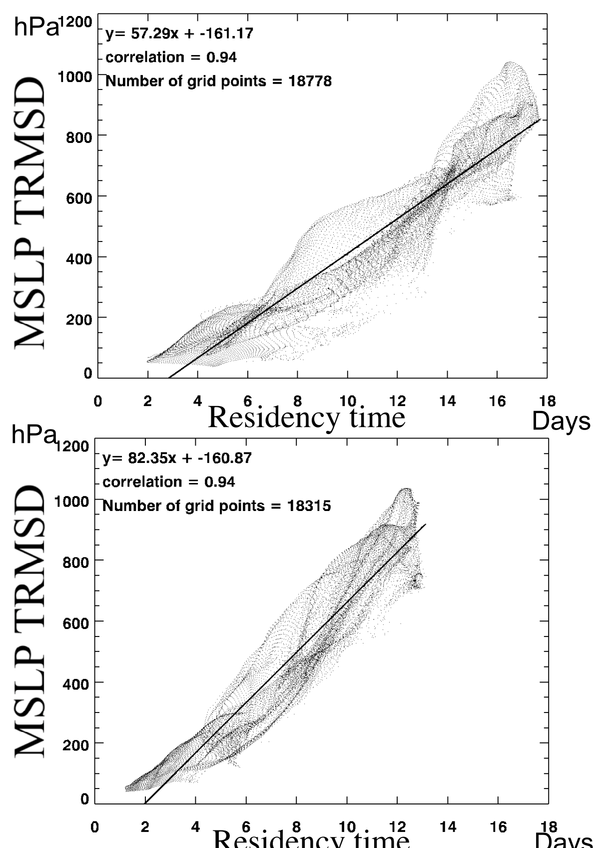

Figure 3. Scatter plot between the MSLP TRMSD and the residency time in a) summer (JJA) and b) winter (DJF).