Scale Decomposition of the Water Budget in a Regional Climate Model

Soline Bielli* and René Laprise
Département des Sciences de la Terre et de l'Atmosphère, Université du Québec à Montréal

1. Introduction

The purpose of this work is to study the added value (AV) provided by a regional climate model (RCM) with respect to the global climate model (GCM) or global analyses used to drive the regional simulation. Three main factors contribute to the AV: the lateral boundary conditions (negative feedback), the discretisation (positive feedback) and finally the non-linear interactions between different scales (positive feedback). The objective is to assess the contribution of this later factor to the AV. The water plays a key role in the energetics of the climate and a better understanding of its cycle is necessary to better understand climate change. Also, precipitation produced by GCM shows large differences compared to precipitation produced by RCM as it is greatly influenced by topographic and small-scale regional features as well as regional mesoscale circulation. The water budget is thus chosen for the scale decomposition.

2. Water Budget and Methodology

The water budget is defined as: $d_t\overline{Q} = -\nabla.\overline{F} + E - P$

where $\overline{F} = \overline{UQ} = \frac{1}{g}\int_{sfc}^{top} U(x,y,p) \cdot Q(x,y,p)dp$

is the horizontal moisture flux, Q is the humidity, U is the horizontal wind, E the evapotranspiration and P the precipitation. To isolate the contribution of different scales, the Discrete Cosine Transform (DCT) is used as it allows efficient decomposition of non-periodic fields (see Denis *et al.* 2002 for details). The divergence of the moisture flux, which is a quadratic term, is handled as follow. The humidity Q is defined as: $Q=Q_0+Q_L+Q_S$ where Q_0 represents the very large scales that are not resolved by the RCM (as a first approximation it is defined as the domain-mean value), Q_L represents large scales that are both resolved by the RCM and the NCEP analyses (scales greater than 600 km) and Q_S represents the small scales that are only resolved by the RCM (scales smaller than 600 km), which represents the AV of the RCM. The same decomposition is applied to both components of the horizontal wind U. The vertically integrated moisture flux is then written as:

$$\overline{F} = \overline{F}_0 + \overline{F}_G + \overline{F}_S \text{ and}$$

$$\overline{F} = \sum_{k\in(0,G,P)}\sum_{l\in(0,G,P)}\overline{U_kQ_l} = \overline{U_0Q_0} + \overline{U_0Q_L} + \overline{U_0Q_S} + \overline{U_LQ_0} + \overline{U_LQ_L} + \overline{U_LQ_S} + \overline{U_SQ_0} + \overline{U_SQ_L} + \overline{U_SQ_S}$$

Finally the divergence of each of the 9 terms is calculated. One must keep in mind that each term can contribute to any of the 3 defined scales as they represent non-linear interactions.

3. The Canadian Regional Climate Model and its driving data

The Canadian regional Climate Model (CRCM) described in Caya and Laprise (1999) is used for a simulation with 45-km horizontal resolution and 29 sigma levels, and driven by NCEP reanalyses. A winter month simulation (Feb. 1990) is used over a domain of about 6000 km by 6000 km centred over Canada. The simulation outputs are interpolated on the 17 pressure levels of the NCEP reanalyses. The NCEP analyses have a T32 resolution and are interpolated over the CRCM 45-km horizontal grid. A mask (Boer 1982) is used to remove the values that are below the ground level using the CRCM surface pressure.

4. Divergence of the moisture flux and its decomposition

The divergence of the moisture flux for 15 Feb. 1990 is displayed on Fig. 1 where one can see two main structures: a dipole of convergence-divergence over the east coast of America associated with a north-south band of precipitation often observed during winter time, a second dipole over the ocean with a west-east orientation. Fig. 2 displays the 9 decomposed terms of the divergence flux. It shows that large-scale dominant terms are those involving the large-scale humidity (U_0Q_L and U_LQ_L). The dominant small-scale terms are those related to the small-scale humidity with large and very large scale winds (U_0Q_S and U_LQ_S). These last two terms tend to modulate the large-scale structures that are represented in the large-scale terms such as to increase the central amplitude of the features and to decrease their spatial extension. The term involving only small scales U_SQ_S is weaker but shows also an interesting signal. The same decomposition is applied to the NCEP driving data (not shown) and results show that the cross-

* *Corresponding author address*: Soline Bielli, Université du Québec à Montréal, Ouranos, 550 rue Sherbrooke Ouest, 19e, Montréal, QC, H3A 1B9, Canada. E-mail: bielli@sca.uqam.ca

term that involved small-scale terms have no contribution, as expected. Indeed, the added value of the RCM is dominantly represented by non-linear interactions between small- and large- scale features in this case. The large-scale structure of the divergence is very close to the pattern seen on the CRCM decomposition.

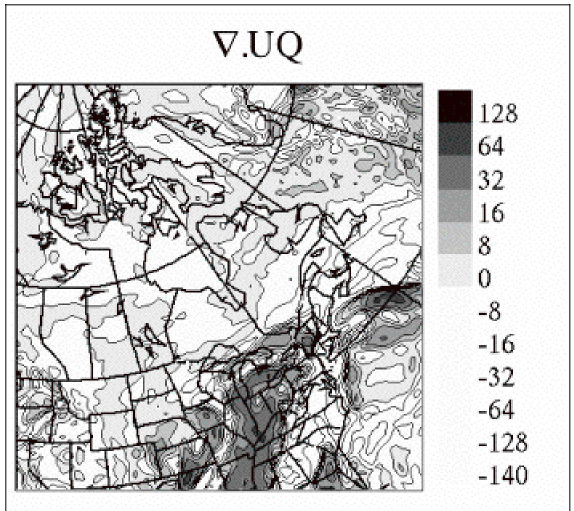

Figure 1: Divergence of the moisture flux for 15 Feb. in mm/da

References

Boer, G. J. 1982: Diagnostic equations in isobaric coordinates. *Mon. Wea. Rev.*, 110, 1801-1820

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

Denis, B., J. Côté and R. Laprise, 2002: Spectral decomposition of two-dimensional atmospheric fields on limited-area domains using the discrete cosine transform (DCT). *Mon. Wea. Rev.*, 130, 1812-1829

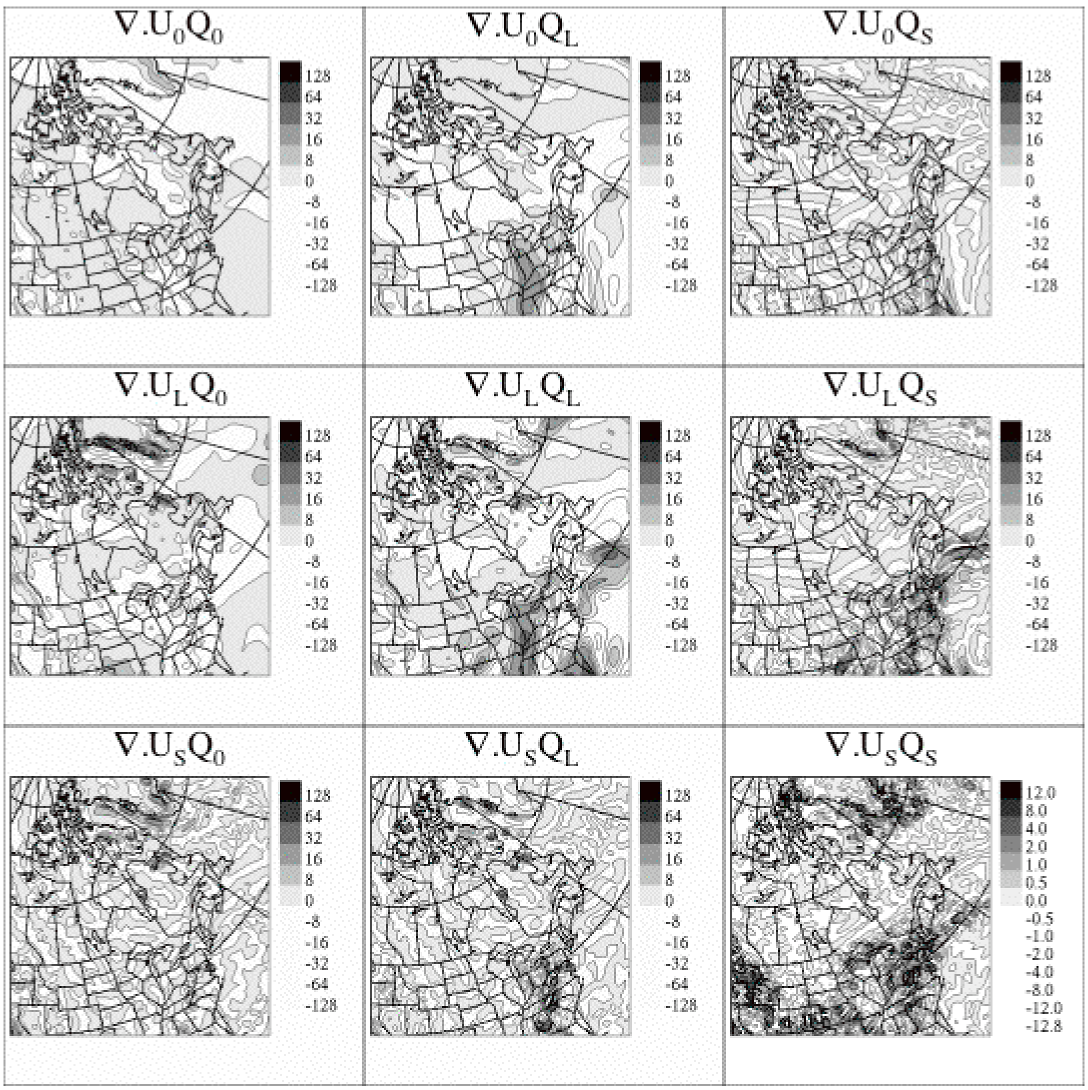

Figure 2: The 9 terms of the scale decomposition of divergence of the moisture flux for 15 Feb. 1990 in mm/da for the CRCM simulation. The U_SQ_S term is displayed with a different colour scale than the other terms.