3rd International Lund Regional-Scale
Climate Modelling Workshop

21st Century Challenges in Regional Climate Modelling

16-19 June 2014, Lund, Sweden

Abstract template

This first page is for our information purposes only. Do not delete it!

Begin your abstract on the next page.
Maximum is 2 pages in the given layout including figures and tables.

Here, please indicate below:

This abstract is intended for

- Oral presentation
- Poster presentation **x**

(type an x after your choice)

This abstract fits best into the topic (see the conference website for more information):

1. Regional Climate and Earth System Models
2. Very-high-resolution RCMs
3. Challenges for RCM Evaluation and Application **x**
4. RCM Ensembles

(type an x after your choice)

Corresponding author (if not First Author):

Name:

e-mail:

Diagnostic Budget Study of the Internal Variability of Ensemble Simulations of HIRHAM5 for the Arctic

Anja Sommerfeld[1], Oumarou Nikiema[2], Annette Rinke[1], Klaus Dethloff[1] and René Laprise[2]

[1] Alfred-Wegener-Institute, Helmholtz Centre for Polar and Marine Research, Potsdam, Germany (anja.sommerfeld@awi.de)

[2] Université du Québec à Montréal, Montreal, Canada

1. Introduction

The challenge in evaluating and applying regional atmospheric models is the poorly understood non-linear behavior of atmospheric processes. The non-linearities lead to an internal variability in the model. Therefore an ensemble of un-nudged simulations with different initial conditions and a diabatic budget study for potential temperature which accounts diabatic and dynamical contributions is applied on ensemble simulations to investigate the internally generated variability. Hence, the physical processes inducing inter-member variability (IV) in ensemble simulations can be analyzed and understood.

The study is applied over the Arctic with the regional model HIRHAM5 from July 6th 2012 to September 30th 2012. This time period is of particular importance because of the melting sea ice and its influence on atmospheric circulations and the resulting effect on the IV. In summer 2012 a strong sea ice melting occurred.

2. Model Setup

The hydrostatic regional atmospheric model HIRHAM5 (Christensen et al. 2007) was first applied on a circum-Arctic region by Klaus et al. 2012. The dynamical core of HIRHAM5 is provided by the regional weather forecast model HIRLAM7 (Undén et al. 2002), the physical parameterizations by ECHAM5 (Roeckner et al. 2003). The model is driven by ERA-Interim (Dee et al. 2011) and runs with a spatial resolution of 25 km covering 218x200 grid cells and 40 vertical levels up to 10 hPa.

The ensemble consists of 20 members, running with the same lateral boundary conditions, but differs in their atmospheric initial conditions. Therefore the initialization time of each simulation shifts by six hours. The first simulation starts on July 1st 2012 at 0000 UTC and the last on July 5th 2012 at 1800 UTC. Each simulation is performed until September 30th 2012. The budget study is applied for the period that is covered by all ensemble-members from July 6th to September 30th 2012.

3. Method

The applied equations of IV budget study for potential temperature was developed and described in detail by Nikiema et al. 2010 and 2011. IV of a variable φ is defined as the inter-member variance (σ^2) of the 20 ensemble-members (n) (Eq. 1). The initial equations are the first law of thermodynamics and the mass-continuity equations in vertical pressure coordinates for potential temperature and they can be combined to Eq. 2, where Θ_n is the potential temperature, V_n is the horizontal wind, ω_n is the pressure vertical motion and J_n is the diabatic heating rate combining temperature tendency due to radiation, vertical diffusion, convection and condensation. Applying the Reynolds decomposition (Eq. 3) leads to a variable φ_n split in the ensemble mean $<\varphi>$ and its deviation from the ensemble mean φ'_n. Further transposing and combining of the equations lead to seven contributions of the potential temperature IV budget study (Eq. 4).

$$\sigma_\varphi^2 \approx \langle \varphi_n'^2 \rangle \qquad \text{Eq. 1}$$

$$\frac{\partial \theta_n}{\partial t} + \vec{\nabla}\cdot\left(\theta_n \vec{V_n}\right) + \frac{(\theta_n \omega_n)}{\partial p} = J_n \qquad \text{Eq. 2}$$

$$\varphi_n = \langle \varphi \rangle + \varphi_n' \qquad \text{Eq. 3}$$

$$\underbrace{\frac{\partial \sigma_\theta^2}{\partial t}}_{L_\theta} = \underbrace{-\vec{\nabla}\cdot\left(\langle\vec{V}\rangle\sigma_\theta^2\right)}_{A_h} \underbrace{-\frac{\partial\left(\langle\omega\rangle\sigma_\theta^2\right)}{\partial p}}_{A_v} \underbrace{-2\langle\theta_n'\vec{V_n'}\rangle\cdot\vec{\nabla}\langle\theta\rangle}_{B_h} \underbrace{-2\langle\theta_n'\omega_n'\rangle\frac{\partial\langle\theta\rangle}{\partial p}}_{B_v}$$

$$\underbrace{+2\langle\theta_n' J_n'\rangle}_{C} \underbrace{-2\langle\theta_n'\vec{\nabla}\cdot\left(\theta_n'\vec{V_n'}\right)\rangle}_{E_h} \underbrace{-2\left\langle\theta_n'\frac{\partial}{\partial p}\left(\theta_n'\omega_n'\right)\right\rangle}_{E_v} \qquad \text{Eq. 4}$$

The left-hand side of Eq. 4 is the diagnostic potential temperature IV tendency (L_Θ) and on the right-hand side are the local changes of the inter-member spread variance in the ensemble simulations (Nikiema et al. 2010). The right-hand side consists of seven parameters contributing to IV and describing different atmospheric processes. The terms A_h and A_v are the horizontal and vertical transport terms. The terms B_h and B_v are the horizontal and vertical baroclinic terms and are linked to synoptic events. C is the diabatic source and sink term. The terms E_h and E_v are the third-order-terms.

4. Results

The amplitude of potential temperature IV of the HIRHAM5 ensemble simulations fluctuates in time (Fig. 1, left) and depends on the height in the atmosphere (Fig. 1, right). During the analyzed time period IV reaches high values between July 27th and August 7th with an absolute maximum on August 5th 2012 at 0600 UTC. The vertical profile shows strongest IV at 500 hPa. A smaller maximum is observed at 925 hPa and the lowest values of IV are found at the surface and at 300 hPa.

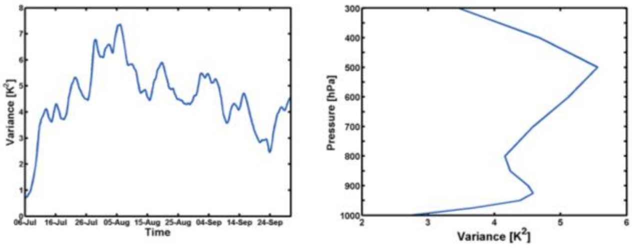

Figure 1. Time evolution (left) and vertical profile (right) of the domain averaged inter-member variability of potential temperature.

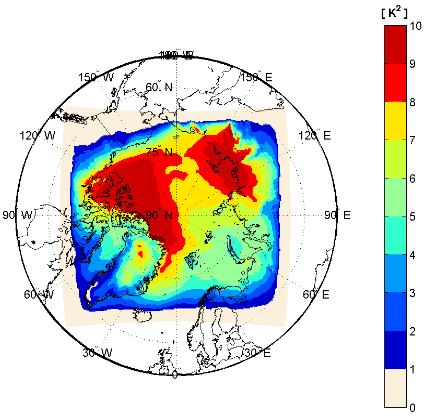

Figure 2. Spatial distribution of the time averaged inter-member variability of potential temperature at 925 hPa.

The temporal (July - September) and vertical average of IV shows the spatial distribution and highlights locations with high and low IV. From the boundary toward the center of the model domain IV increases at each level. A detailed view on the 925 hPa level (Fig. 2) points two centers of high IV out, at the Laptev Sea and Beaufort Sea/North America.

The time evolution of the seven contributions (Fig. 3) indicates that the horizontal and vertical baroclinic terms exert the strongest influence on IV. The positive values of B_h represent a generation and the negative values of B_v a reduction of IV. The other terms fluctuate around zero, because their contribution to IV in general is small (A_v, E_v and C) or they are balanced over the model domain with regions where they contribute to an increase and where they contribute to a decrease of IV (A_h and E_h).

The centers of high IV observed in Fig. 2 are mostly induced by B_h which reaches values of more than $20*10^{-5}$ K^2/s (Fig. 4, left). However B_v (Fig. 4, right) has a negative influence in these regions leading to a reduction of IV but with a weaker contribution, so that there is a strong baroclinic contribution to IV.

These results for the Arctic are different to those Nikiema et al. 2010 and 2011 found for North America using the Canadian RCM. They obtain that the diabetic term C, followed by B_h contribute to a generation of potential temperature IV and B_v, followed by A_h are responsible for the reduction of potential temperature IV.

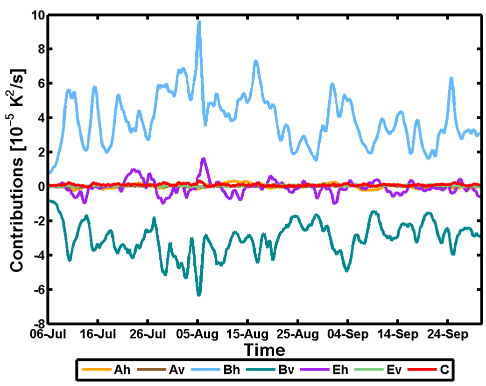

Figure 3. Time evolution of the vertical and domain averaged contributions to the inter-member variability of potential temperature.

5. Summary and Outlook

In this study a budget equation for potential temperature is applied to investigate IV generated in a regional arctic atmospheric model HIRHAM5 with ensemble simulations differing in their initial conditions for the period from July 6th 2012 to September 30th 2012. IV fluctuates strongly in time and reaches its maximum at 500 hPa. IV is mainly generated by horizontal (B_h) and reduced by vertical baroclinicity (B_v).

Further subjects will be analysis of IV and its contributions by investigating shorter time periods and individual events of high and low IV depending on sea ice melting. A further aim will be the application of the budget study for other years.

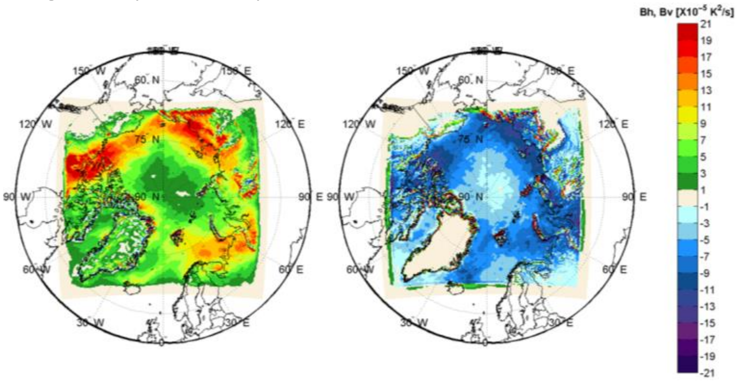

Figure 4. Spatial distribution of the time averaged horizontal baroclinic term B_h (left) and vertical baroclinic term B_v (right) contributing to the inter-member variability of potential temperature at 925 hPa.

References

Christensen O.B., Drews M., Christensen J.H. (DMI); Dethloff K., Ketelsen K., Hebestadt I., Rinke A. (AWI) (2007) The HIRHAM Regional Climate Model Version 5 (β), Technical Report 06-17, Danish Meteorological Institute (DMI): Copenhagen, Denmark

Dee D.P., Uppala S.M., Simmons A.J., Berrisfort P., Poli P., Kobayashi S., Andrae U., Balmaseda M.A., Balsamo G., Bauer P. (2011) The ERA-Interim reanalysis: Configuration and performance of the data assimilation system, Q.J.R.Meteorol.Soc., 137, pp. 553-597

Nikiema O., Laprise R. (2010) Diagnostic budget study of the internal variability in ensemble simulations of the Candian RCM, Clim Dyn, 36, pp. 2313-2337

Nikiema O., Laprise R. (2011) Budget study of the internal variability in the ensemble simulations of the Canadian Regional Climate Model at the seasonal scale, Journal of Geophysical Research, 116, pp. 1-18

Roeckner E., Bäuml E., Bonaventura L., Brokopf R., Esch M., Giorgetta M., Hagemann S., Kirchner I., Kornblueh L., Manzini E., Rhodin A., Schlese U., Schulzweida U., Tompkins A. (2003) The Atmospheric General Circulation Model ECHAM5-Part 1: Model Description, Technical report 349, Max-Planck-Institut (MPI) for Meteorology: Hamburg, Germany

Undén P., Rontu L., Järvinen H., Lynch P., Calvo J., Cats G., Cuxart J., Eerola K., Foortelius C., Garcia-Moya J.A. (2002) HIRHLAM-5 Scientific Documentation., In HIRHAM-5 Project, Swedish Meteorological and Hydrological Institute (SMHI): Norrköping, Sweden