Arctic Budget Study of Inter-member Variability using HIRHAM5 Ensemble Simulations

REKLIM – Topic 1

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Arctic Budget Study of Inter-member Variability using HIRHAM5 Ensemble Simulations

Outline:

1) Introduction and motivation

2) Model set-up: HIRHAM5 over Arctic

3) Inter-member variability (IV)

4) Diagnostic budget equation for potential temperature

5) First results of the budget study

6) Summary and Outlook

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1) Introduction and motivation:

- chaotic and non-linear behavior of atmospheric processes

  → internal variability in regional models

    → changes in initial conditions (IC) influence the evolution of simulations

- ensemble of simulations with different IC

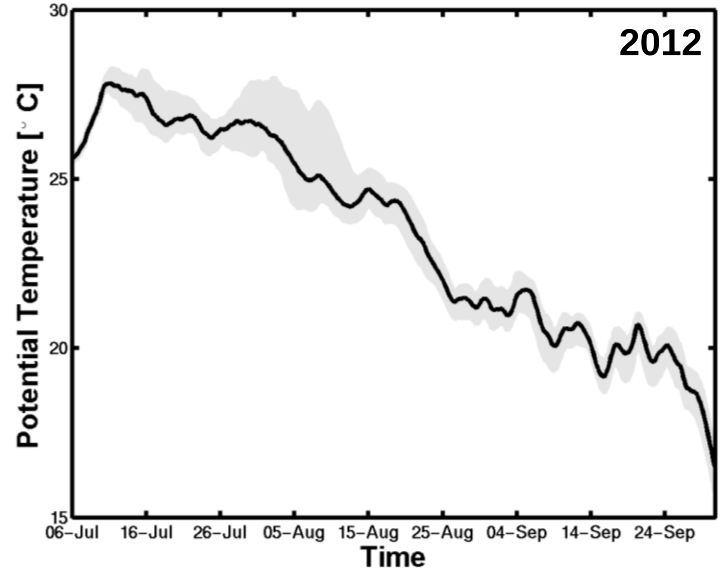
  → physical processes inducing inter-member variability (IV) and its changes can be analyzed and understood

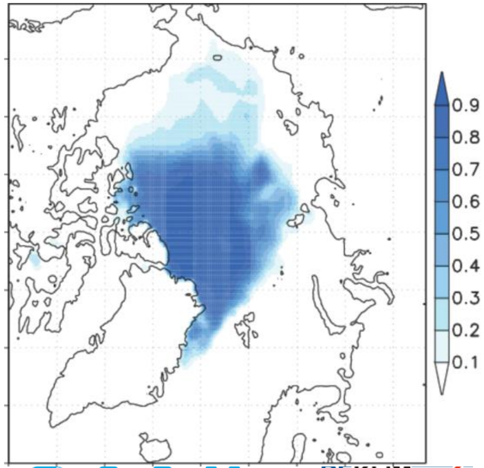
- study is applied over the Arctic for summer 2012

  → strong sea ice melting

    → investigation of its influence on atmospheric circulations and resulting effect on IV

Ensemble-mean and spread of vertical and domain averaged potential temperature





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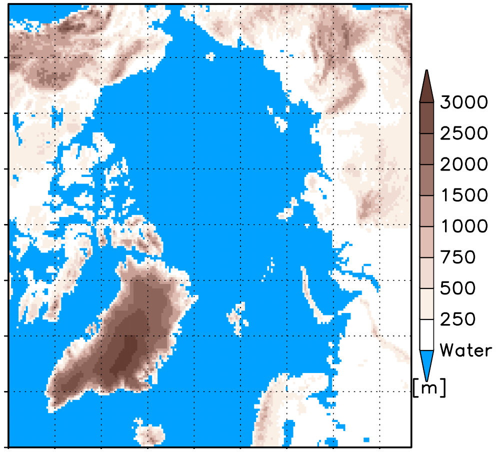

2) Model set-up: HIRHAM5 over Arctic:

- HIRHAM5 = hydrostatic regional atmospheric model *(Christensen et al. 2007)*

Dynamical core:	**Physical parameterizations:**
regional weather forecast model HIRLAM7 *(Undén et al. 2002)*	atmospheric general circulation model ECHAM5 *(Roeckner et al. 2003)*

- driven by ERA-Interim
- horizontal resolution 25 km, 40 vertical levels up to 10 hPa
- 20 ensemble members differing in IC
  - → first simulation starts on July 1st 2012 at 0000 UTC
  - → last simulation starts on July 5th 2012 at 1800 UTC

  } initialization time shifts by 6 hours
  - → analyzed period from July 6th to September 30th 2012

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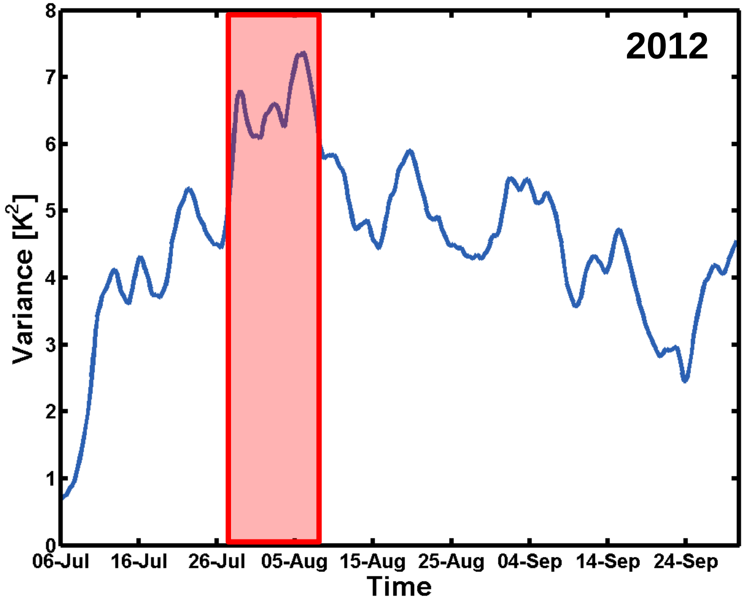
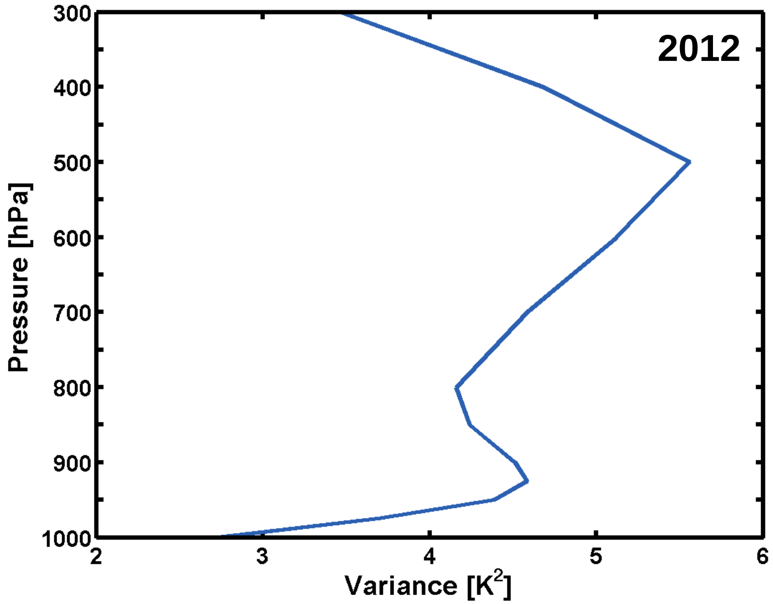
3) Inter-member variability (IV):

Time evolution of vertical and domain averaged potential temperature IV



Vertical profile of temporal and domain averaged potential temperature IV



- IV fluctuates in time
- high values between July 27th and August 7th with

- highest IV at 500 hPa
- second peak at 925 hPa
- lowest values at the surface and at 300 hPa

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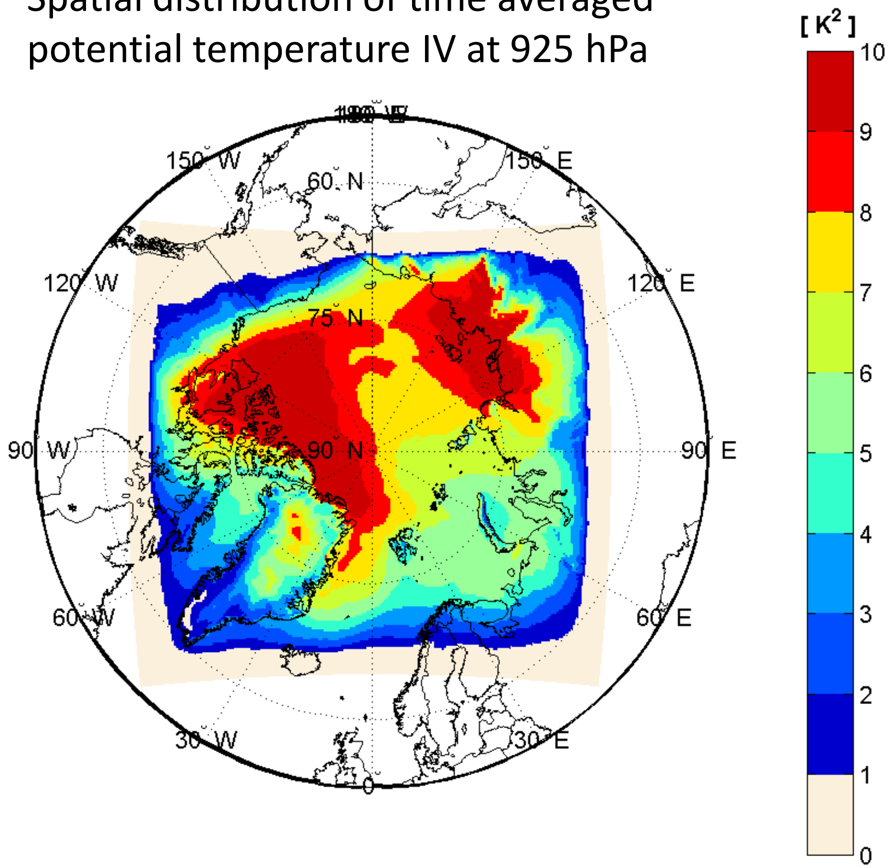
3) Inter-member variability (IV):

Spatial distribution of time averaged potential temperature IV at 925 hPa



- IV increases toward the center of model domain in each level
- 2 centers of high IV at the Laptev Sea and Beaufort Sea/North America

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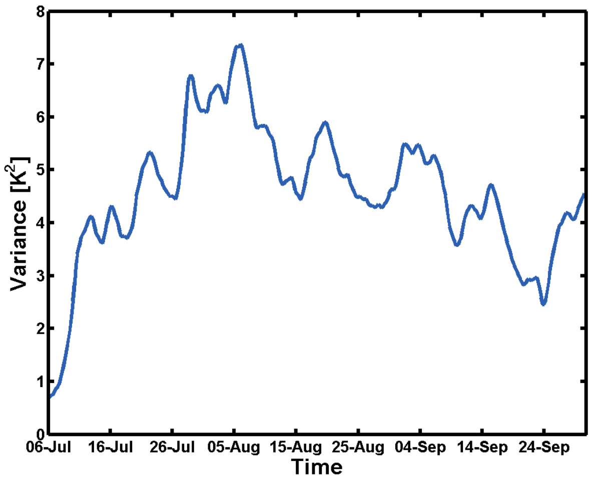
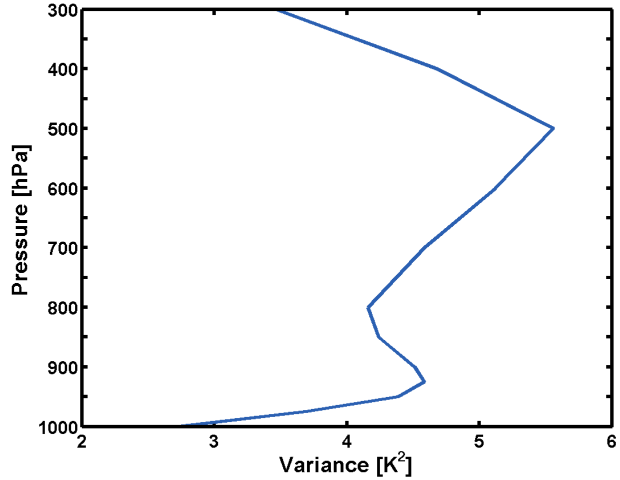
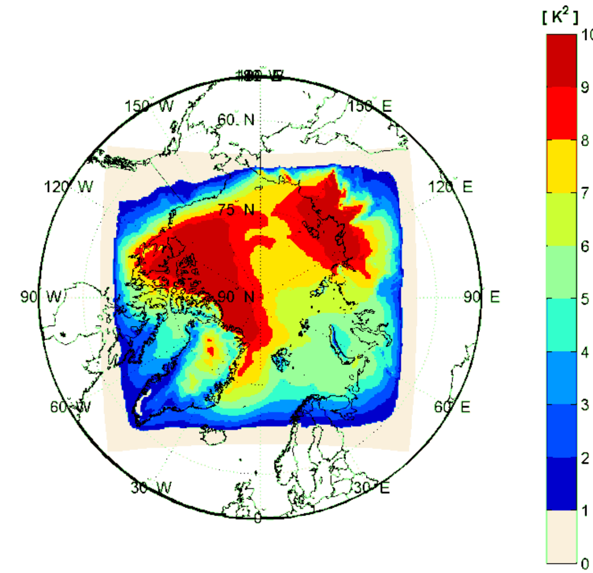
3) Inter-member variability (IV):







aim of this study:

- **understanding the reasons of IV and its temporal changes**

  → applying the diabatic budget study (*O. Nikiema et al. 2010)*

  → diabatic and dynamical contributions to IV

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4) Diagnostic budget equation for potential temperature :

$$\frac{\partial \sigma_\theta^2}{\partial t} = -\vec{\nabla} \cdot \left(\langle \vec{V} \rangle \sigma_\theta^2\right) - \frac{\partial\left(\langle \omega \rangle \sigma_\theta^2\right)}{\partial p} - 2\,\langle \theta'_n \overrightarrow{V'_n} \rangle \cdot \vec{\nabla} \langle \theta \rangle - 2 \langle \theta'_n \omega'_n \rangle \frac{\partial \langle \theta \rangle}{\partial p}$$

diagnostic tendency of potential temperature IV

A_h horizontal transport

A_v vertical transport

B_h horizontal baroclinicity

B_v vertical baroclinicity

$$+2\langle \theta'_n J'_n \rangle - 2\,\langle \theta'_n \vec{\nabla} \cdot \left(\theta'_n \overrightarrow{V'_n}\right) \rangle - 2\,\langle \theta'_n \frac{\partial}{\partial p} \left(\theta'_n \omega'_n\right) \rangle$$

C diabatic source and sink

E_h horizontal third-order term

E_v vertical third-order term

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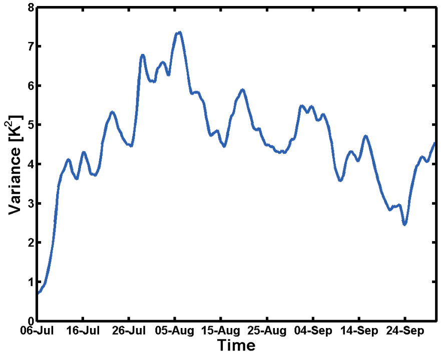
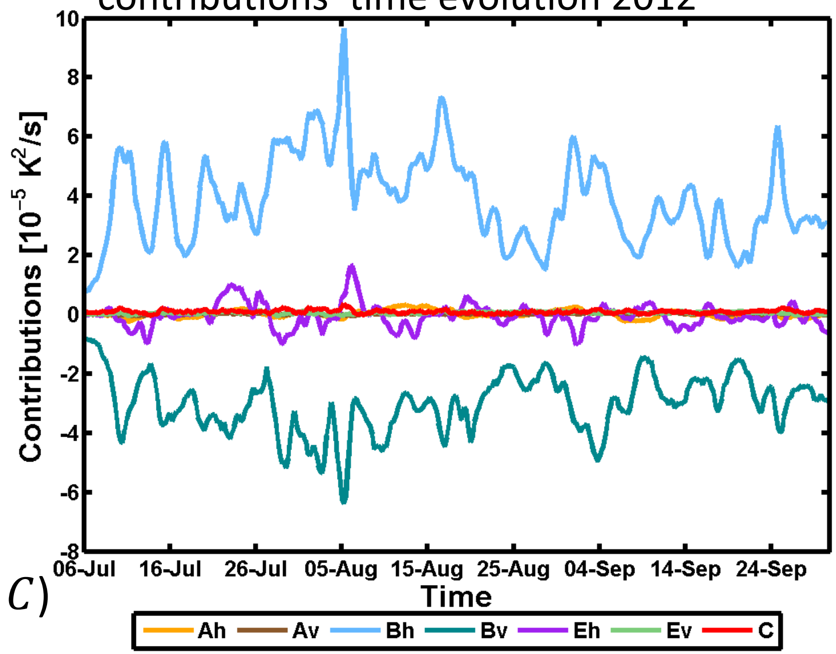
5) First results of the budget study :



$L_\theta = \frac{\partial \sigma_\theta^2}{\partial t}$ diagnostic tendency of potential temperature IV = A_h horizontal transport + A_v vertical transport + B_h horizontal baroclinicity + B_v vertical baroclinicity + C diabatic source and sink + E_h horizontal third-order term + E_v vertical third-order term

Domain and vertical averaged contributions' time evolution 2012



- like IV, contributions fluctuate in time
- positive contribution = generation of IV
- negative contribution = reduction of IV
- B_h and B_v strongest influence on IV
  → B_h contributes to generation of IV
  → B_v contributes to reduction of IV
- other terms fluctuates around zero
  a) contribution to IV in general is small (A_v, E_v, C)
  b) balanced over the model domain (A_h, E_h)

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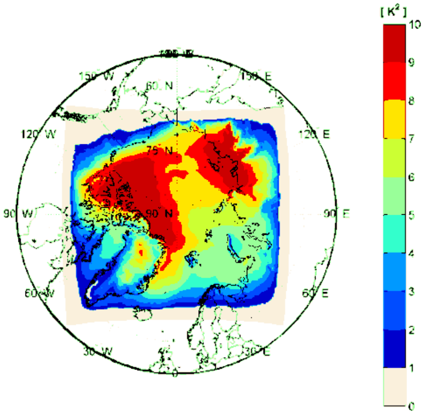
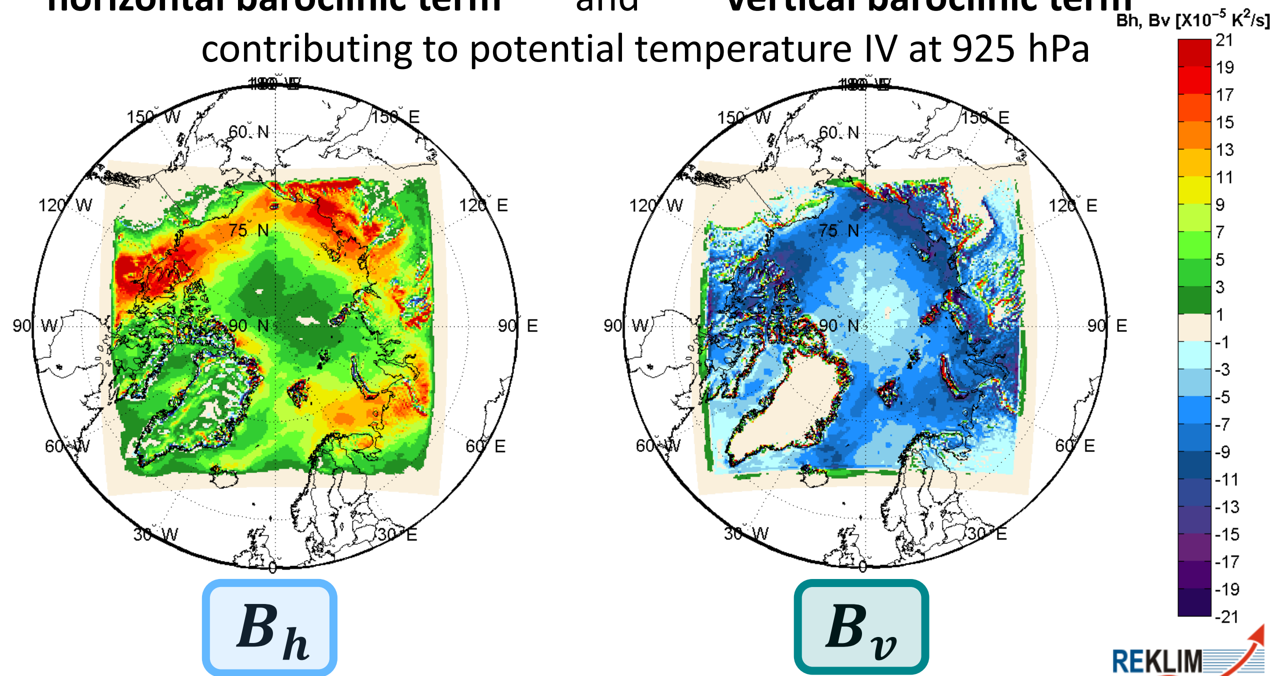
5) First results of the budget study :



$$L_\theta = \frac{\partial \sigma_\theta^2}{\partial t}$$ diagnostic tendency of potential temperature IV $=$ A_h horizontal transport $+$ A_v vertical transport $+$ B_h horizontal baroclinicity $+$ B_v vertical baroclinicity $+$ C diabatic source and sink $+$ E_h horizontal third-order term $+$ E_v vertical third-order term

Spatial distribution of time averaged **horizontal baroclinic term** and **vertical baroclinic term** contributing to potential temperature IV at 925 hPa



- B_h/B_v always positive/negative

  → generating/reducing IV tendency

- absolute values of B_h are higher than absolute values of B_v

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6) Summary and Outlook:

- budget study for potential temperature to investigate IV tendency in ensemble simulations of HIRHAM5
- IV fluctuates strongly in time and reaches its maximum in 500 hPa
- IV tendency is mainly generated by horizontal (B_h) and reduced by vertical baroclinicty (B_v)
- results for the Arctic differ to those obtained by *Nikiema et al. 2010* and *2011* for North America using the Canadian RCM

→ generation of potential temperature IV: diabatic term C followed by B_h
→ reduction of potential temperature IV: B_v, followed by transport term A_h

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- investigating shorter time periods and individual events of high and low IV
- IV depending on sea ice melting
- application of the budget study for other years

Thanks for

your

attention