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

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Introduction

- chaotic and non-linear nature of atmospheric dynamics [1]
  → internal variability in the model
- ensemble simulations with different initial conditions (IC) result in inter-member variability (IV) [2 and references therein, 3] (Fig. 1, 2)
  → estimating diabatic and dynamical contribution leading to IV

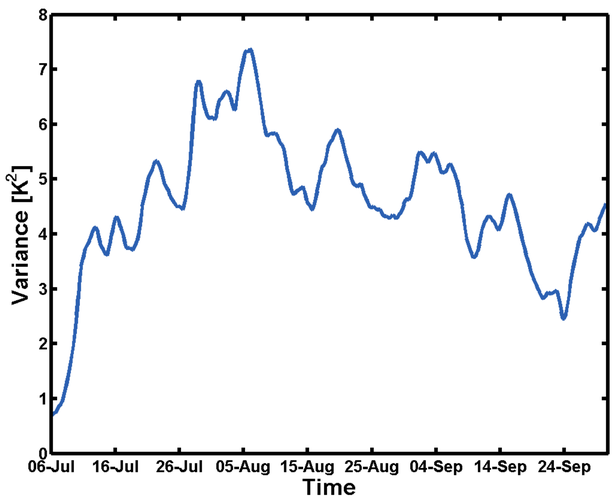

Fig. 1: Domain and vertical averaged potential temperature IV

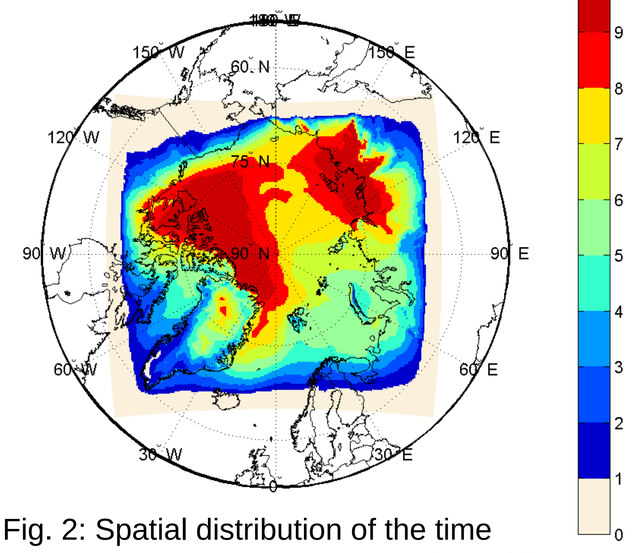

Fig. 2: Spatial distribution of the time averaged potential temperature IV at 925 hPa

Model Setup

- HIRHAM5 [4] is a hydrostatic regional atmospheric model applied on a circum-Arctic region by [5]
- combination of HIRLAM [6] (dynamics) and ECHAM5 [7] (physical parameterization)
- driven by ERA-Interim [8]
- horizontal resolution: 25 km
- vertical resolution: 40 levels up to 10 hPa
- runs without nudging
- 20 ensemble members differing in their IC
  → initialization time shifts by six hours
  → first simulation starts: July 1st 2012 at 0000 UTC
  → last simulation starts: July 5th 2012 at 1800 UTC
  → analyzed time period: July 6th to September 30th 2012

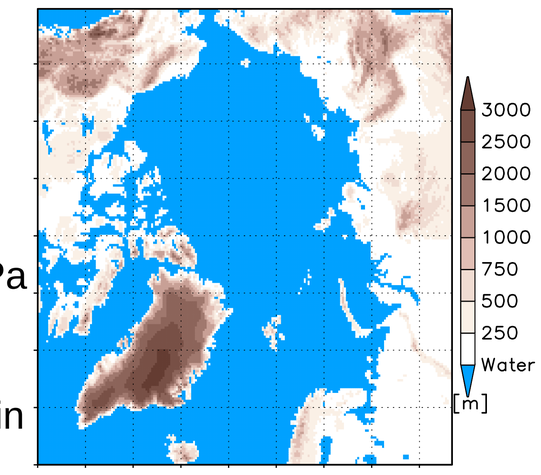

Fig. 3: Integration area and the orography in the model

Equations and Method

- IV is defined as the inter-member variance of the potential temperature $\boldsymbol{\theta}$ [2, 3] of the 20 ensemble-members $\boldsymbol{n}$ $\quad \boldsymbol{\sigma_\theta^2 \approx \langle \theta_n'^2 \rangle}$ (Eq. 1)
- emanating from the first law of thermodynamics and the mass-continuity equation in vertical pressure coordinates for potential temperature applying the Reynolds decomposition
  → the variable $\boldsymbol{\theta_n}$ split in the ensemble mean $\langle \boldsymbol{\theta_n} \rangle$ and the deviation from ensemble mean $\boldsymbol{\theta_n'}$ $\quad \boldsymbol{\theta_n = \langle \theta \rangle + \theta_n'}$ (Eq. 2)
- results in a IV budget equation (Eq. 3) developed by [2, 3]

$$\frac{\partial \sigma_\theta^2}{\partial t} = -\vec{\nabla} \cdot \left(\langle \vec{V} \rangle \sigma_\theta^2 \right) - \frac{\partial \left(\langle \omega \rangle \sigma_\theta^2 \right)}{\partial p} - 2 \left\langle \theta_n' \vec{V}_n' \right\rangle \cdot \vec{\nabla} \langle \theta \rangle - 2 \left\langle \theta_n' \omega_n' \right\rangle \frac{\partial \langle \theta \rangle}{\partial p} + 2 \left\langle \theta_n' J_n' \right\rangle - 2 \left\langle \theta_n' \vec{\nabla} \cdot \left(\theta_n' \vec{V}_n' \right) \right\rangle - 2 \left\langle \theta_n' \frac{\partial}{\partial p} \left(\theta_n' \omega_n' \right) \right\rangle \quad \text{(Eq. 3)}$$

$\frac{\partial \sigma_\theta^2}{\partial t}$	$-\vec{\nabla} \cdot \left(\langle \vec{V} \rangle \sigma_\theta^2 \right)$	$-\frac{\partial \left(\langle \omega \rangle \sigma_\theta^2 \right)}{\partial p}$	$-2 \left\langle \theta_n' \vec{V}_n' \right\rangle \cdot \vec{\nabla} \langle \theta \rangle$	$-2 \left\langle \theta_n' \omega_n' \right\rangle \frac{\partial \langle \theta \rangle}{\partial p}$	$+2 \left\langle \theta_n' J_n' \right\rangle$	$-2 \left\langle \theta_n' \vec{\nabla} \cdot \left(\theta_n' \vec{V}_n' \right) \right\rangle$	$-2 \left\langle \theta_n' \frac{\partial}{\partial p} \left(\theta_n' \omega_n' \right) \right\rangle$
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/sink term	E_h horizontal third-order term	E_v vertical third-order term

Results

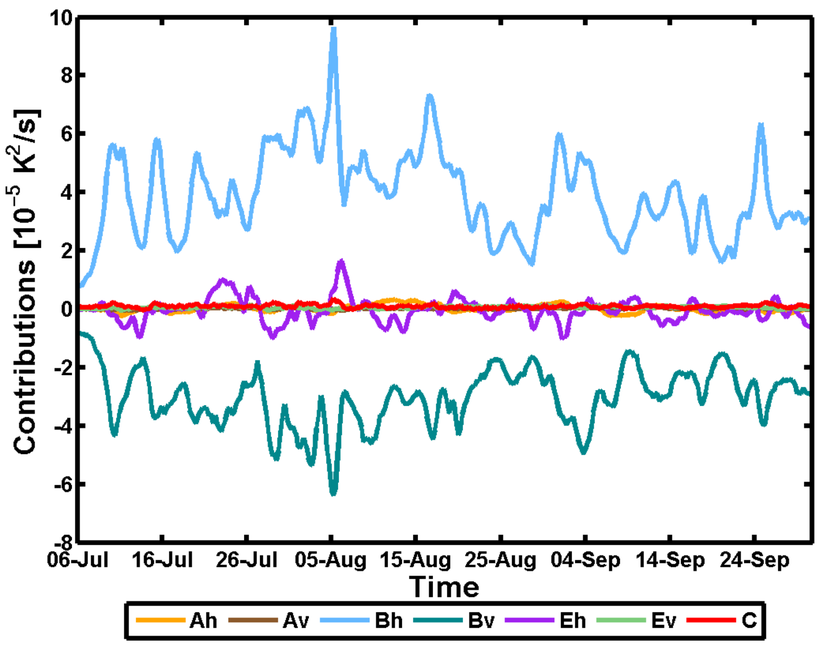

Fig. 4: Time evolution of the vertical and domain averaged contributions to potential temperature IV tendency

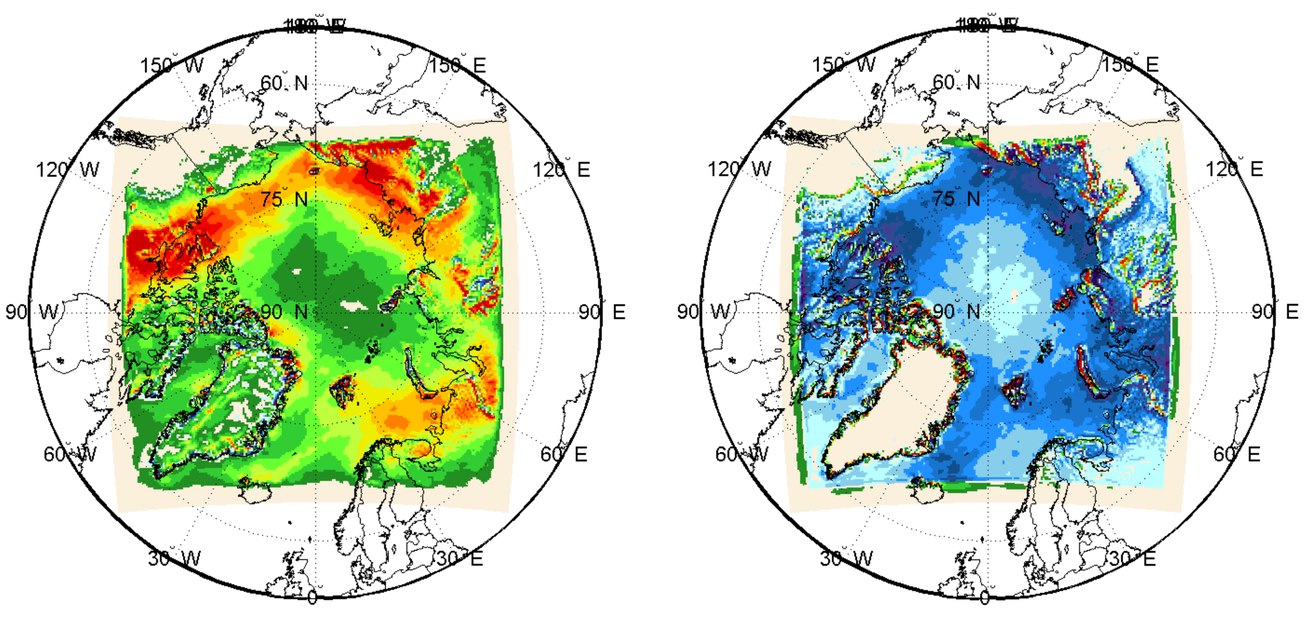

Fig. 5: Spatial distribution of the time averaged horizontal baroclinic term B_h (left) and vertical baroclinic term B_v (right) contributing to potential temperature IV tendency at 925 hPa

Summary and Outlook

- quantification of reasons of high/low IV with budget study
  → strongest generation: horizontal baroclinicity ($\boldsymbol{B_h}$)
  → strongest reduction: vertical baroclinicity ($\boldsymbol{B_v}$)
- investigation of shorter time periods and special regions of high and low IV
- application of budget study for different years
  → relation between Arctic sea ice anomalies and IV

References

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