Variability of temperature-derived climate indices in the Arctic – Observation and RCM

Heidrun Matthes*, Annette Rinke, Klaus Dethloff
Alfred Wegener Institute, Potsdam, Germany

1. INTRODUCTION

Arctic temperature is analyzed in view of its extremes based on climate indices derived from daily mean, maximum, minimum temperature. This analysis is done for the pan Arctic domain and region-specific for the eastern and western Russian Arctic. The variability of temperature-related indices over the last four decades is presented. The spatial distribution and regional differences as well as temporal trends are discussed. Results of a simulation with the regional climate model HIRHAM for 1958-2001 over the Arctic domain are shown. The aim is to analyze the ability of the model to capture the calculated climate extreme indices.

2. MODEL AND DATA

Two data sets are used: the ERA40 reanalysis data for spatial comparison of the model results and the station data set "Global Summary of the Day" (GSOD by National Climatic Data Center) for regional comparison.The climate simulation over the Arctic domain is performed using the regional atmospheric climate model HIRHAM. HIRHAM includes prognostic equations for temperature, surface pressure, horizontal wind components, specific humidity and cloud water.

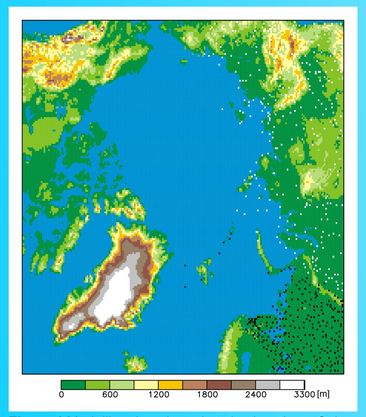

Figure 1 Modelling domain and station locations. Colors refer to orography as it is represented in the model. Black squares show stations contained in the GSOD west data set. White squares depict stations within the GSOD east data set.

station data set

- 644 stations located north of 60°N (Fig. 1)
- split into two parts using the Ural mountains as separation to account for different climatologies
- GSOD east (324 stations), GSOD west (320 stations) www.ncdc.noaa.gov//oa/mpp/freedata.html

model set up

- integration domain: Arctic north of ca 60°N (Fig. 1)
- horizontal resolution of 0.25° (or ca. 25 km)
- vertical resolution: 19 levels
- simulation is driven by the ERA40 reanalysis data on the lateral and lower boundaries
- simulation period 1958-2001
- sea ice is prescribed daily from the ERA40 data (Uppala et al., 2005)

3. RESULTS

3.1 FROST DAYS

Frost days are the number of days per season, where the daily minimum temperature is smaller than 0°C.

spatial distribution

- maximum numbers of Frost Days occur over the central Arctic and Greenland
- comparison of model output and ERA40 shows high pattern correlation coefficients (0.93) for both seasons, however, the model is too cold over most of the Arctic
- trends in Frost Days from ERA40 data show warming along the sea ice boundaries

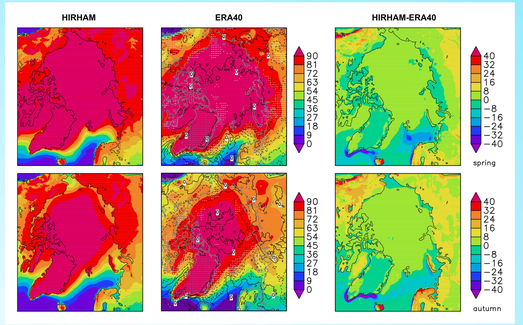

Figure 2 Spatial distribution of climatological mean (1958-2001) of Frost Days [days] for spring (upper row) and autumn (lower row). In the middel panel, the black isolines refer to calculated trends, isoline spacing is 1day/decade.

regional analysis

- regional analysis demonstrates distinct differences in variability and amount of Frost Days between eastern and western Russian stations (Fig 3)
- very high inter-annual variability for both seasons and regions, very well reproduced by the model
- both seasons show positive, non-significant long-term trends for GSOD west, long-term trends for GSOD east are negative and even significant for spring (-0.69 days/decade)
- HIRHAM reproduces the signs in the trends, though the magnitudes differ eventually

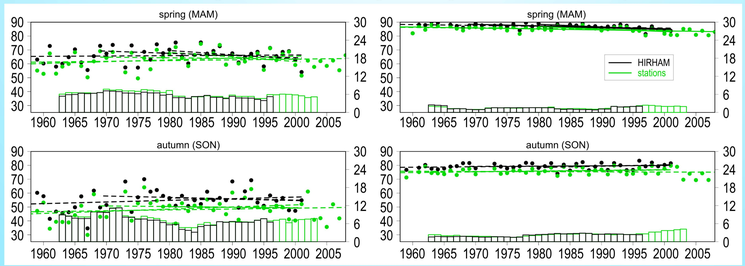

Figure 3 Year-to-year variability and trends of Frost Days in spring (upper panels) and autumn (lower panels), station data: green dots and lines, HIRHAM: black dots and lines. The left y-axis is for the Frost Days [days] (dots), and the right y-axis is for the inter-annual variability [days] (bars). Left panel: GSOD west, right panel: GSOD east.

3.2 GROWING DEGREE DAYS

Growing Degree Days are the sum of the daily mean temperatures above 4°C per season.

spatial distribution

- Growing Degree Days reflect the north-south temperature gradient in the Arctic, high mountains can be identified by up to 300°C lower values compared with regions of same latitudes (Fig. 4)

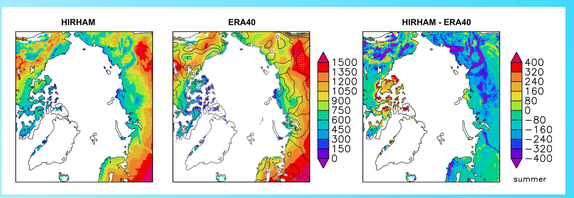

Figure 4 Spatial distribution of climatological mean (1958-2001) of Growing Degree Days [days] for summer. In the middel panel the black isolines refer to calculated trends, isoline spacing is 10°C/decade.

- positive trends were calculated over most of the Arctic, significant in some areas (northern Alaska and northeastern Canada)
- HIRHAM reproduces the spatial pattern (pcc=0.87)
- model underestimates Growing Degree Days, partly because of the more accurate orography (better resolution than ERA40)

regional analysis

- regional analysis shows positive trends for both eastern and the western Russia (Fig. 5)
- trend magnitudes increase with decreasing length of the analyzed period, indicating that the warming increased over the last two decades, this is reproduced by the model
- inter-annual variability in the western part is larger than in the eastern part, there is a pronounced decadal variability, the model captures this variability well

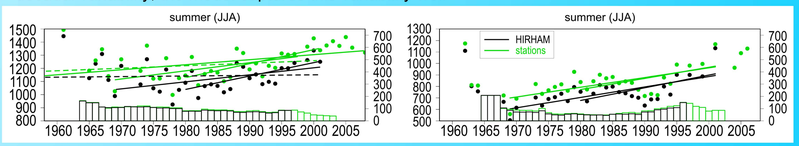

Figure 5 Year-to-year variability and trends of Growing Degree Days in summer, station data: green dots and lines, HIRHAM: black dots and lines. The left y-axis is for the frost days [days] (dots), and the right y-axis is for the inter-annual variability [°C] (bars). Left panel: GSOD west, right panel: GSOD east. Statistically significant trends are plotted as solid lines.

4. CONCLUSIONS AND OUTLOOK

- the warming in seasonal mean temperature found e.g. by Serreze and Francis (2006) can also be partly confirmed in the temperature-related climate indices
- indices are characterized by large inter-annual variability which in turn shows distinct decadal variability
- the HIRHAM model captures the spatial and temporal patterns as well as the variability and trends well
- a range of further climate indices was calculated, e. g. cold and warm spell days
- indices will be calculated and analyzed for future climate projections using HIRHAM

* corresponding author: Heidrun Matthes
Alfred Wegener Institute for Polar and Marine Research
Telegrafenberg A43, D-14473 Potsdam, Germany
e-mail: Heidrun.Matthes@awi.de
phone: +49 331 2882101; fax: +49 331 2882178

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