The early vs. the late 20th century Arctic warming: The role of energy and aerosol fluxes in reanalysis driven datasets

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UNIVERSITÄT BERN

OESCHGER CENTRE CLIMATE CHANGE RESEARCH

Background

- **Recent Arctic warming** is one of the strongest and popular effects of global change. Sea ice decline is very prominent as well as the reduction in mass of the Greenland ice sheet.

- However, the **early 20th century Arctic warming** between 1930-1940, although discovered immediately, was scientifically forgotten until recently (Delworth & Knutson 2000, Bengtsson et al. 2004)

- Some explanations for this early warming hightlight **atmospheric circulation changes** including possible **aerosol transport** as reason (Grant et al. 2009) , some others focus on **oceanic changes** (Bengtsson et al. 2004, Semenov & Latif 2012).

- **Comparison of this early warming and the recent warming** period grants a chance to deepen knowledge about the drivers of Arctic climate and can be used to assess the anthropogenic impact.

? *Can we adress **typical circulation patterns** for the current and early Arctic warming?*

? *Which role might **poleward aerosol transport** play?*

Arctic Dipole ?

On this poster we mainly focus on the evolution of the Arctic Dipole. What is this?

- The Arctic Dipole (AD) was defined by Wu et al. 2005 as **second leading EOF** of sea level pressure north of 70 °N during the winter season (ONDJFM)

- The first leading EOF is the Arctic Oscillation

- The AD represents the **strength of meridional winds** between the pressure systems of Central Russia and Greenland

- The original AD was s**uccessful modified** to include different seasons and atmospheric levels (e.g. Overland et al. 2012)

- If not mentioned otherwise we use the original definition in our analysis

References:
Bengtsson , L.; Semenov, V.A. & Johannessen, O.M. 2004: The Early Twentieth-Century Warming in the Arctic - A Possible Mechanism. Journal of Climate (17) 4045-4057

Delworth,T. L & Knutson, T.R. 2000: Simulation of Early 20th Century Global Warming. Science (287) 2246-2250

Grant, A.; Broennimann, S.; Ewen, T.; Griesser, T. & Stickler, A. 2009: The early twentieth century warm period in the European Arctic. Meteorologische Zeitschrift (18) 425-432

Griesser, T.; Broennimann, S.; Grant, A.; Ewen, T.; Stickler, A. & Comeaux, J. 2010: Reconstruction of global monthly upper-level temperature and geopotential height fields back to 1880. Journal of Climate (23) 5590-5609

Overland, J.E.; Francis, J.A.; Hanna, E. & Wang, M. 2012: The recent shift in early summer Arctic atmospheric circulation. Geophysical Research Letters (39) L19804

Semenov, V.A. & Latif, M. 2012: The early twentieth century warming and winter Arctic sea ice.The Cryosphere (6),1231-1237

Wu,B.; Wang, J. & Walsh, J.E. 2005: Dipole Anomaly in the Winter Arctic Atmosphere and Its Association with Sea Ice Motion. Journal of Climate (19) 210-225

General Results

Arctic Dipole

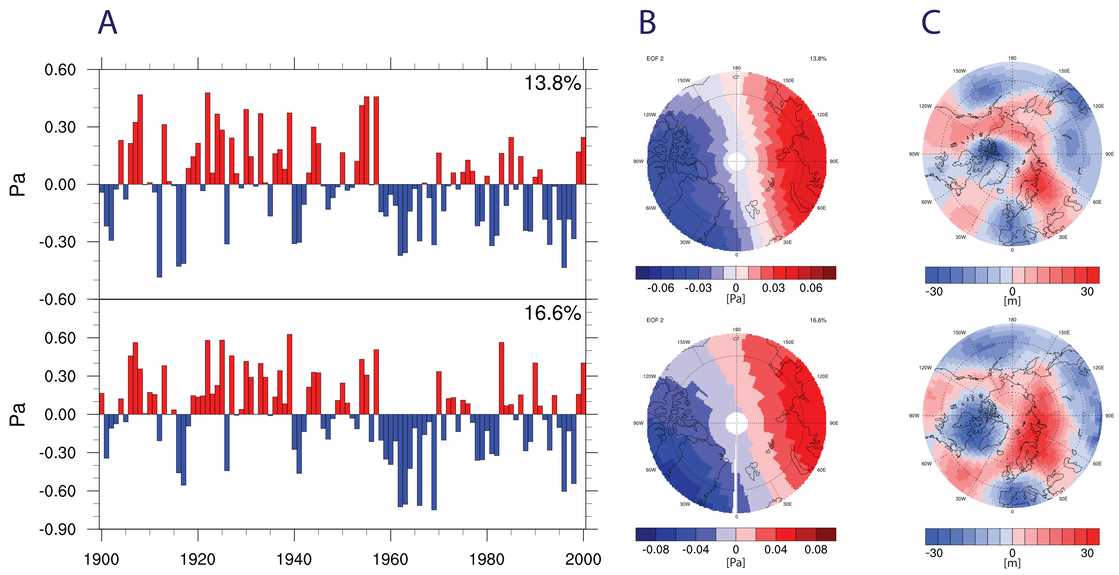

Fig 1: A) *AD timeseries for the combined datasets of REC1 and ERA40 (upper panel) and 20th century reanalysis (lower panel)* ***B)*** *AD pattern in both datasets.* ***C)*** *700 hPa geopotential height anomalies for OND of 1920-1939 with reference to 1971-2000 in both datasets*

Arctic Temperature

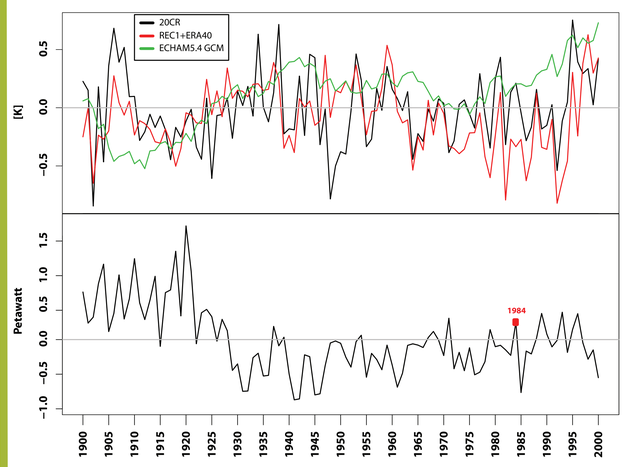

Fig 2: Upper Panel) *Shows the Arctic (60 - 90° N) temperature anomaly (ref. 1900-2000) timeseries for 700 hPa for 3 different datasets. Both Arctic warming episodes in the 20th century are visible in all three products.* ***Lower Panel)*** *Yearly integrated (1000 - 100 hPa) sensible heat flux anomalies (ref. 1900-2000) passing through the atmosphere at 70 ° N. It was computed from uncorrected 6-hourly 20CR data.*

Case Study: 1984

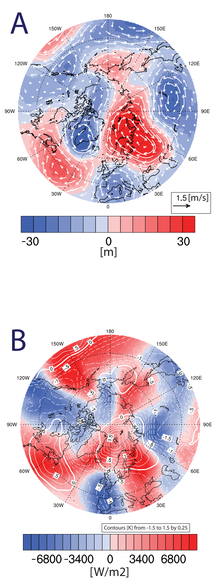

Fig 3: ***A)*** *Geopotential height and wind velocity anomalies at 700 hPa level for 1984 with referenc to 1979-2008 in ERA-Interim.*
B) *Anomalies of integrated northward heat flux and tempature at 700 hPa for 1984 with reference to 1979-2008 in ERA-Interim*

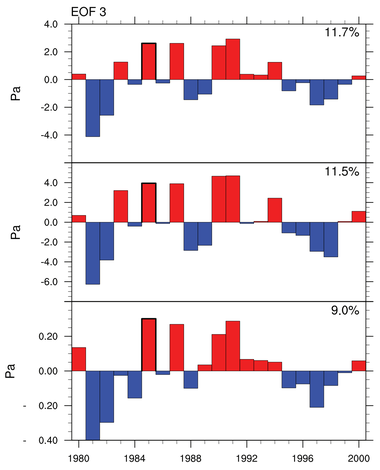

Fig 4: *From top to bottom, AD timeseries for ERA-Interim, ERA40 and 20th century Reanalysis at 700 hPa geopoential height level. Note that the AD appears to be the third EOF in this case. Also note that the effects of 1984 appear in the 1985 graph since ONDJFM is computed.*

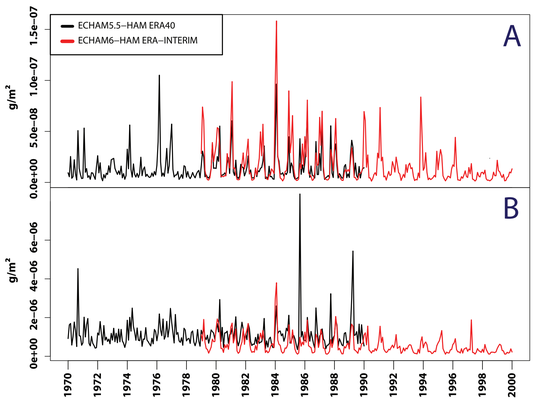

Fig 5: ***A)*** *Field average for accumulated dry deposition mass of coarse mode black carbon over 70-90°N in two aerosol datasets*
B) *The same as A) but for wet deposition*

Take Home Message

- An **intensification of the Arctic Dipole** pattern was found for the early warming period. This pattern shuffles warm air masses into the Arctic domain. This process is similar to what Overland et al. 2012 showed for the recent warming period.

- The Arctic Dipole is not always visible as **second leading EOF**, but depending on the dataset and time frame is also sometimes the **third EOF**

- The **case study of 1984** shows one of the strongest warming for the pre-Arctic Amplification era. It is accompanined by a positive AD, strong incoming heat flux over the European-Atlantic sector and an increase in aerosol transport from European source regions (as proposed by Grant et al. 2009 for the early warming)

- The 20CR (ensemble mean) appears to include strong **wind speed artifacts** stemming from erronous input data over the Canadian/Arctic domain

Data

- Microphysical **ECHAM5-HAM** and **ECHAM6-HAM** GCM with an attached aerosol and microphysics module nudged to ERA40 and ERA-INTERIM (2° x 2°)

- **Twentieth Century Reanalysis** (20CR) dataset covering 1871-2011 (2 °x 2°)

- **ERA40** and **ERA-INTERIM** dataset covering 1958 - 2013 (2 .5°x 2.5°, 1 .5°x 1.5°)

- CCC400 run, which is an **ECHAM5.4** Global Climate Model (GCM) run for the period from AD 1599 to 2005 with 30 ensemble members (2° x 2°)

- **Upper air, geopotential height reconstruction** produced by Griesser et al. 2010 for the period 1880 - 1957 (2 .5°x 2.5°)