Extreme winter air temperatures in the Arctic and mid-latitudes

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Arctic Climate and Weather Extremes: Detection, Attribution, and Future Projection
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Outlook

1. Mechanisms generating warm and cold extremes
2. Cold extremes in the Arctic and mid-latitudes
3. Warm extremes in the Arctic
4. Summary

1. Mechanisms generating warm and cold extremes in near-surface temperatures

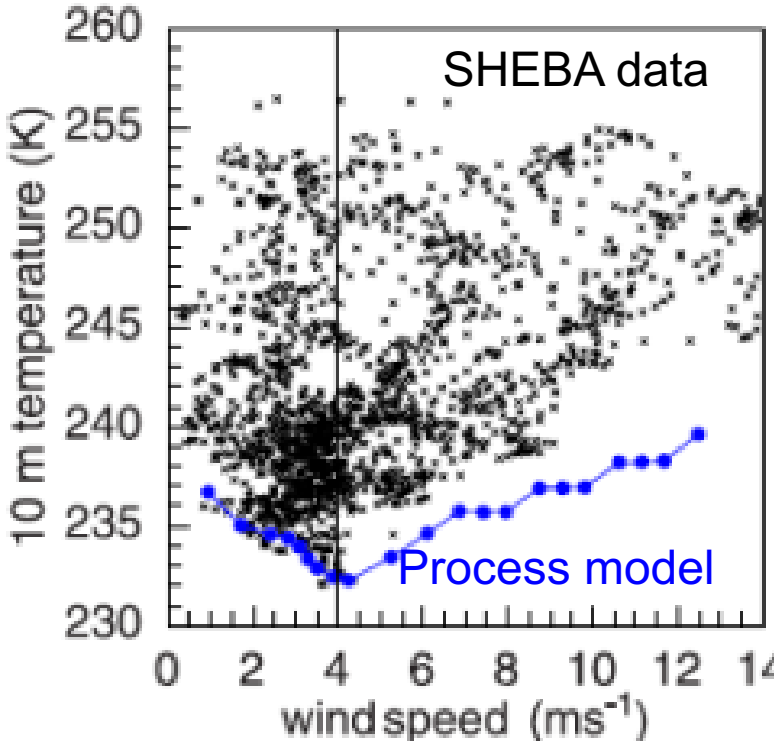
Cold extremes
- surface cooling (typically via longwave radiation or change in surface properties)
- cold-air advection

Warm extremes
- surface warming (typically via shortwave radiation or change in surface properties)
- warm-air advection and subsidence

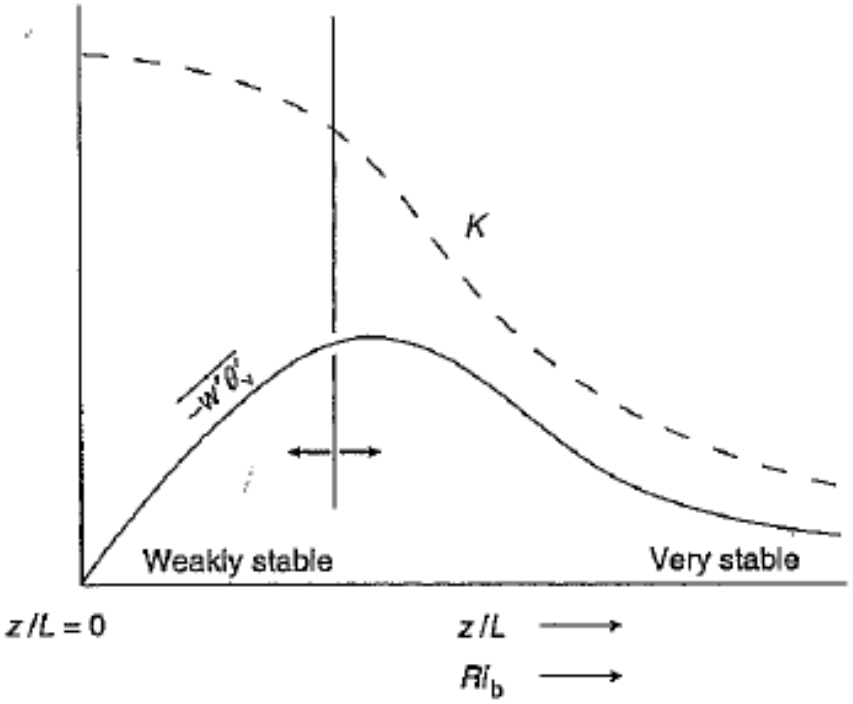
Major seasonal and regional differences in the importance of these mechanisms

Local generation of cold (and dry) extreme events

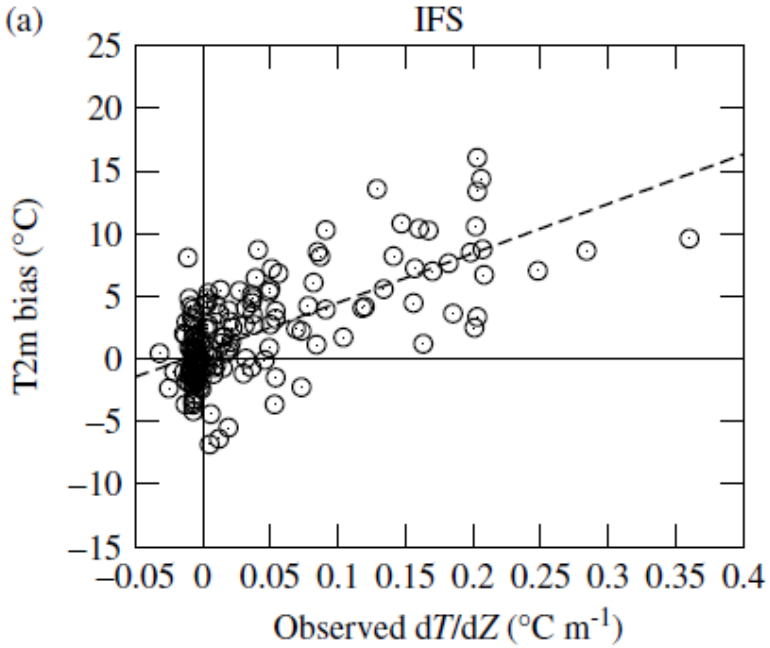
- Clear skies -> longvawe cooling of snow surface (low heat conductivity) -> stable boundary layer, but some wind, and little or no subsidence -> very low T2m



Lupkes et al. (2008)



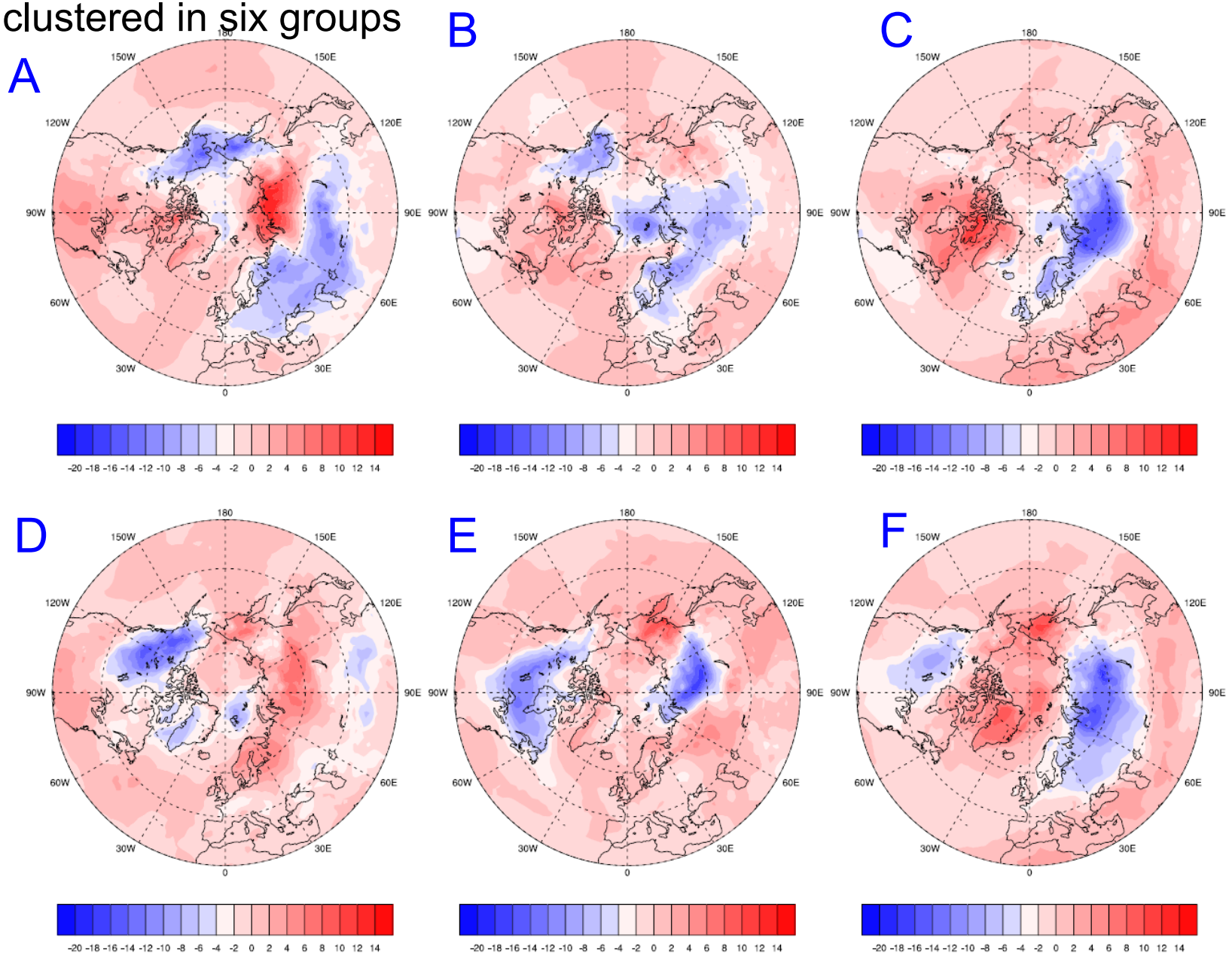
Mahrt (2002)

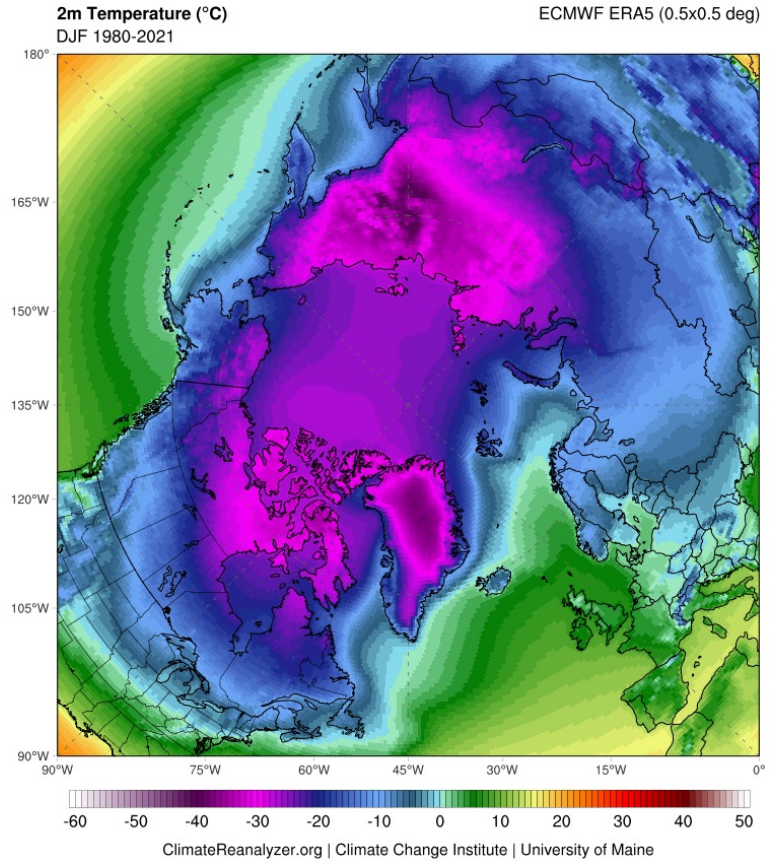


Atlaskin and Vihma (2012)

2. Cold Extremes in the Arctic and Mid-latitudes

100 coldest local T2m anomalies during winters 2006/07 – 2015/16 clustered in six groups



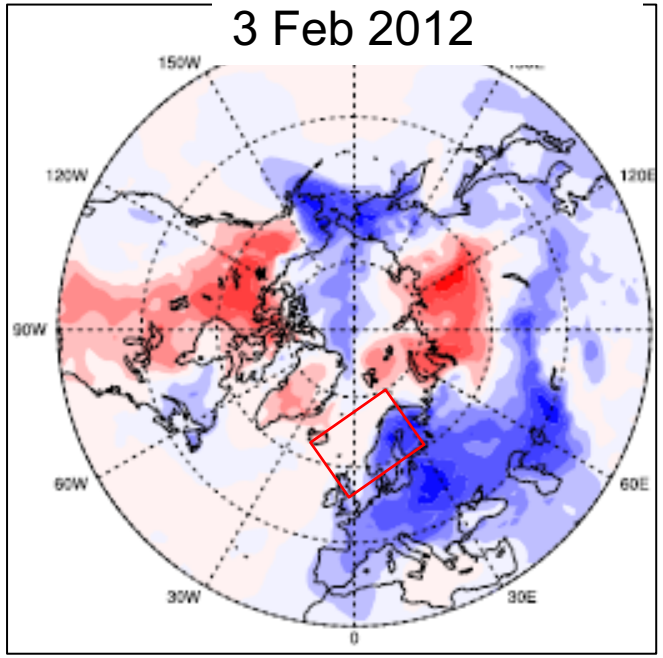


Cold anomalies in high-latitudes, above all in terrestrial Arctic and sub-Arctic, are typically locally generated,

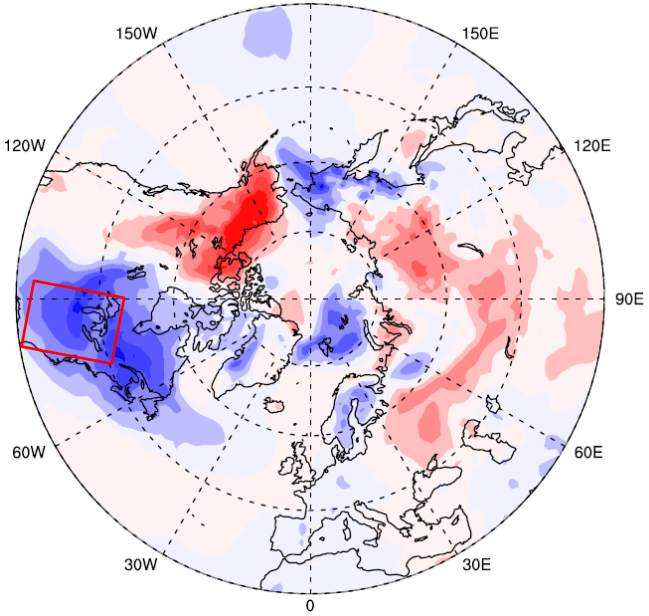
and colder than those occurring e.g in Europe, where cold-air advection plays a major role.

Coldest local T2m anomalies in Central Europe, North American East Cost and East Asia during winters 2006-2016

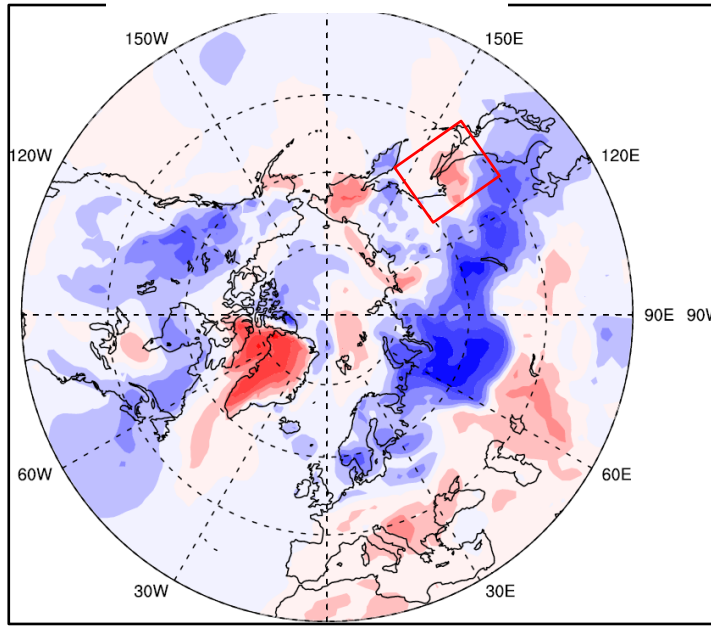
3 Feb 2012

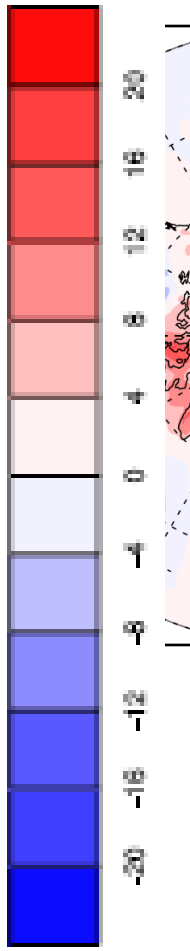


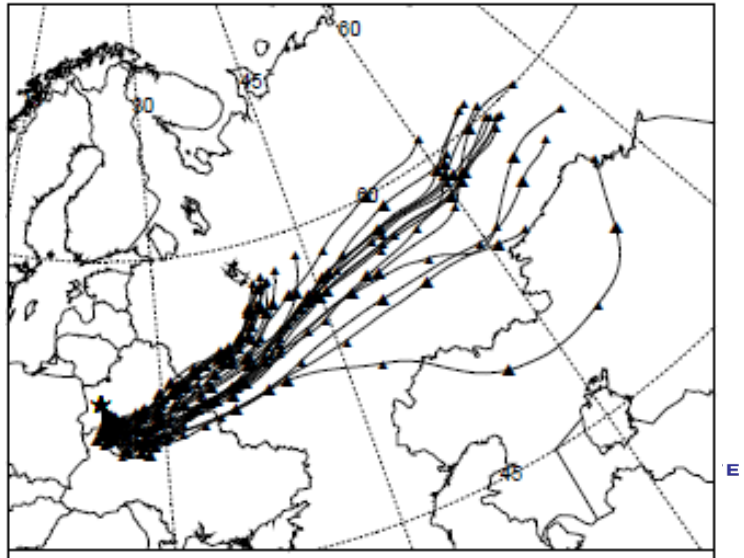
16 Jan 2009

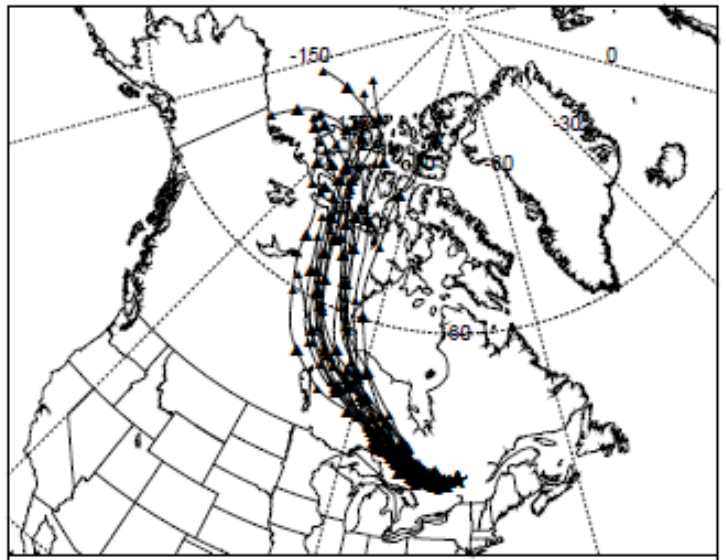


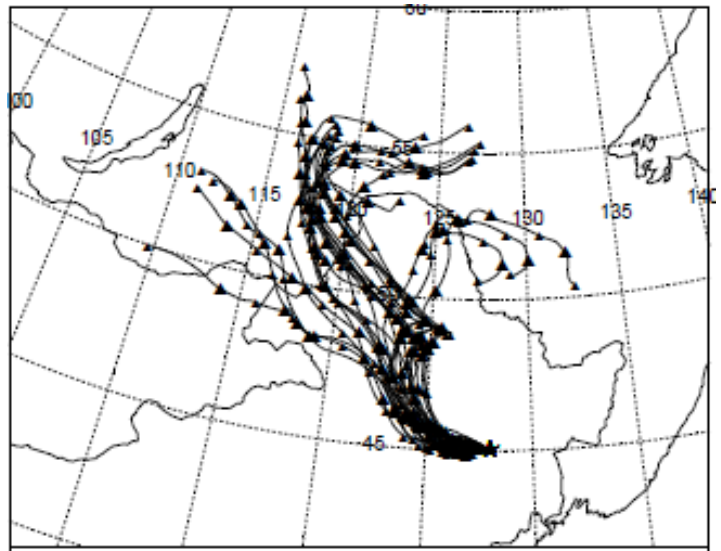
31 Dec 2009





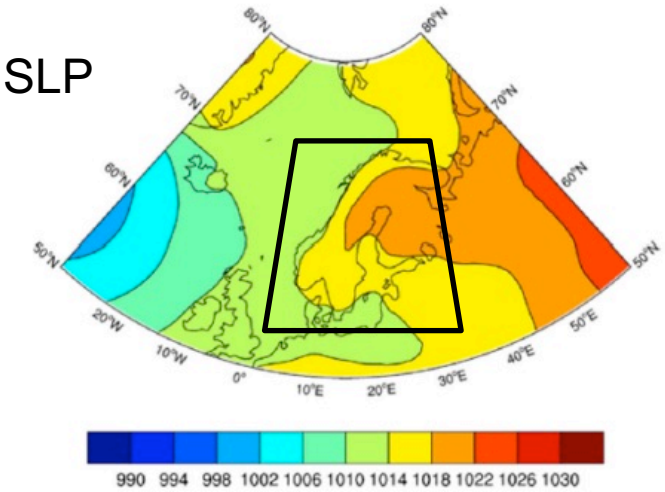




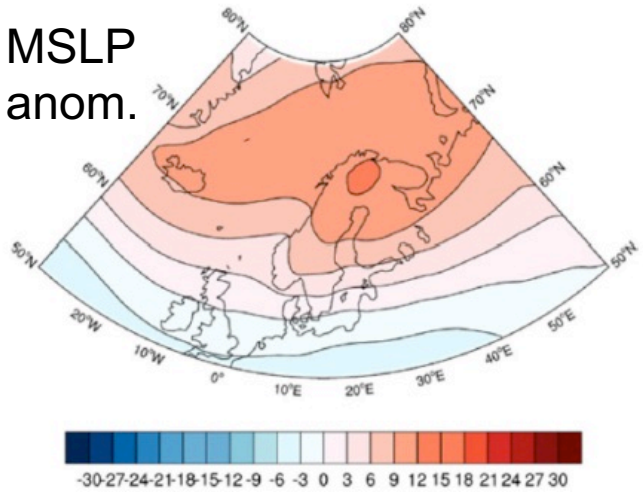


Cold extremes in northern Europe: composites of cases during winters 1979-2016

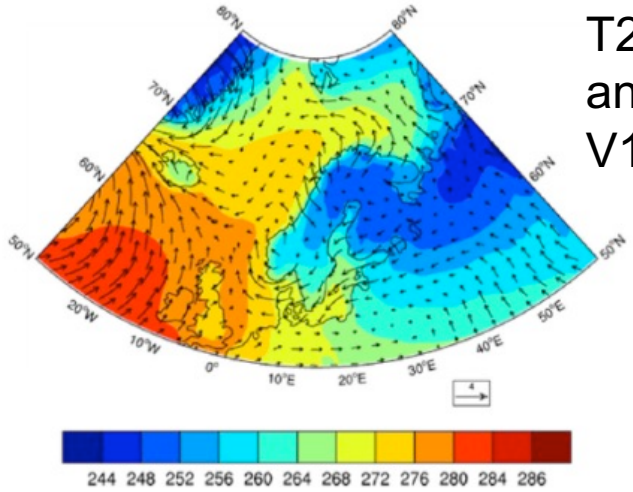
MSLP



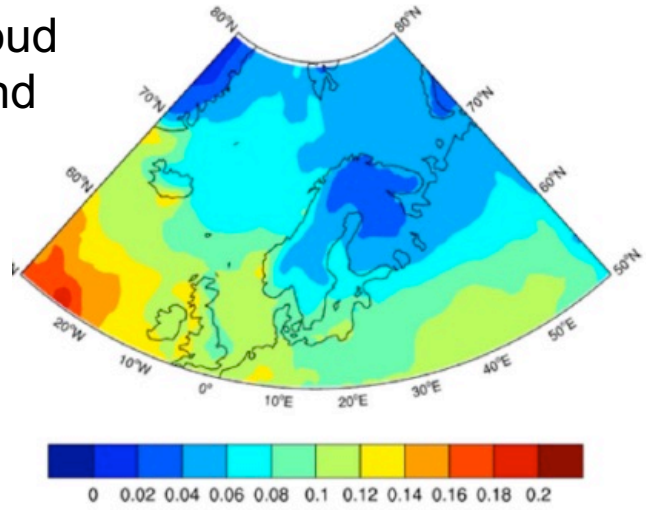
MSLP anom.



T2m and V10m



Cloud cond



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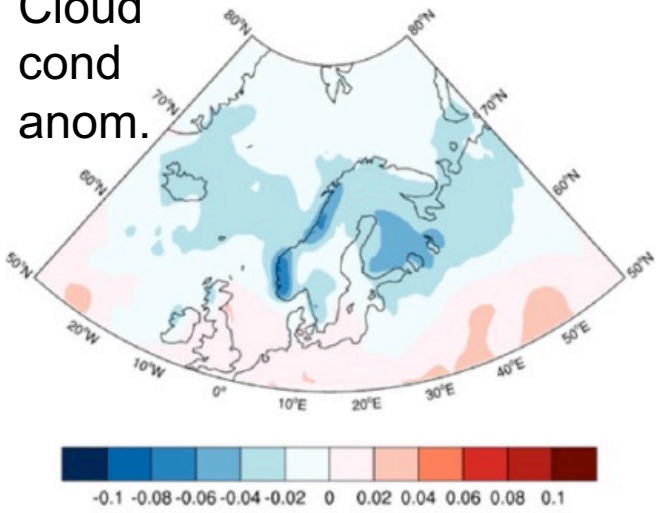

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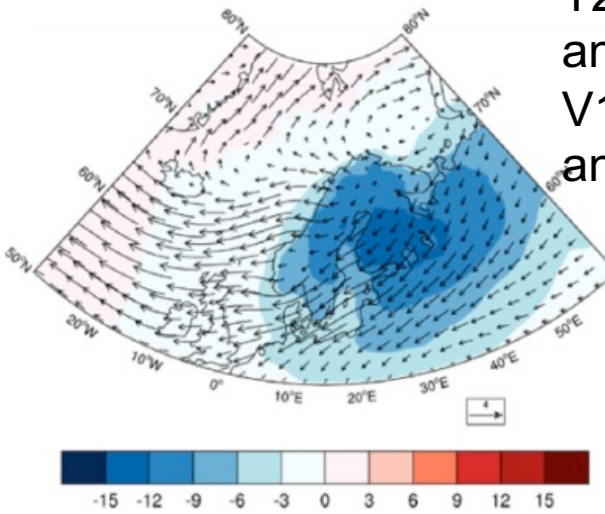
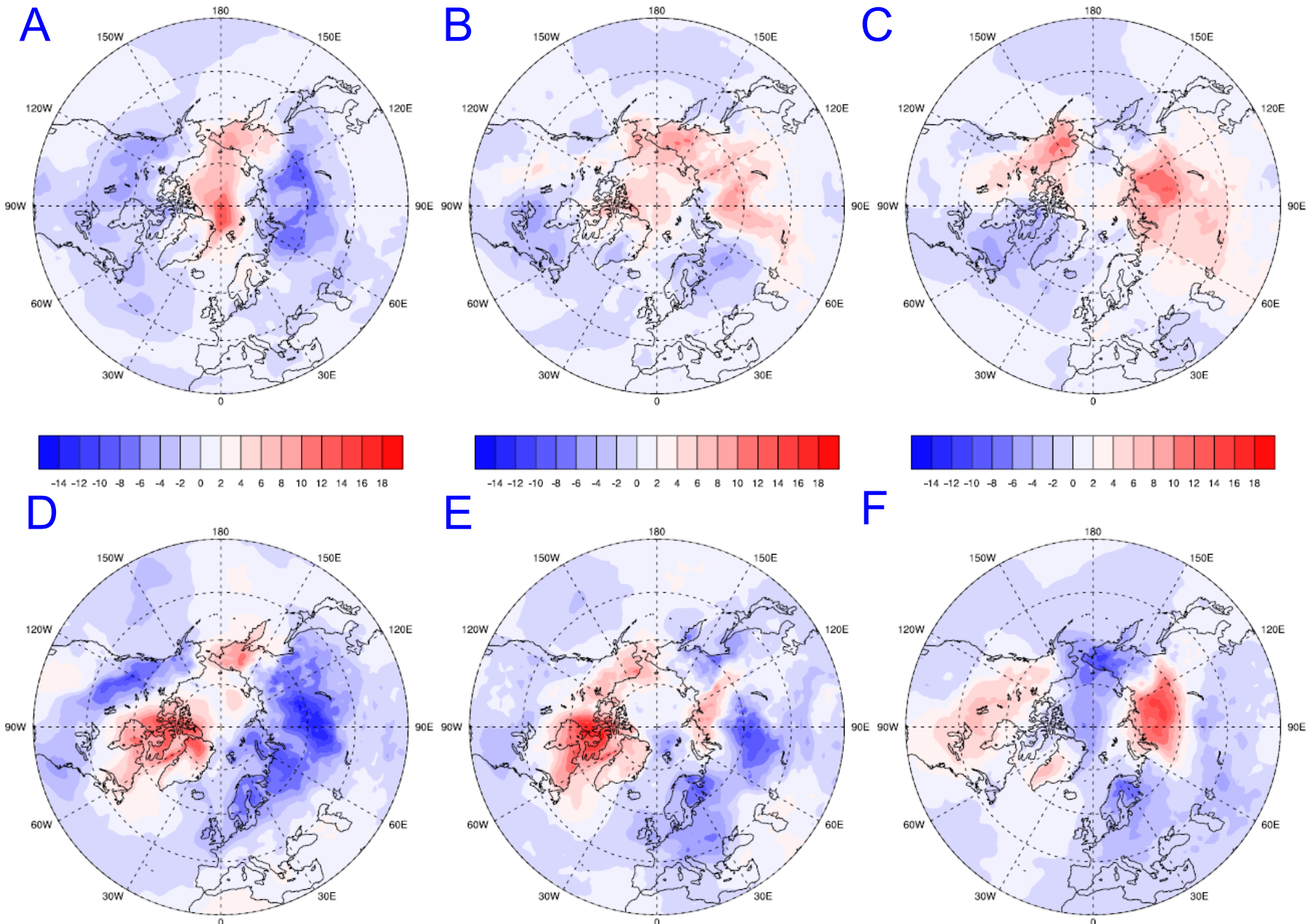


Sui, Yu, and Vihma (2020), Tellus

Combination of local generation and weak easterly cold-air advection

3.Warm Extremes in the Arctic and Mid-latitudes

100 warmest local T2m anomalies during winters 2006/07 – 2015/16 clustered (SOM) in six groups

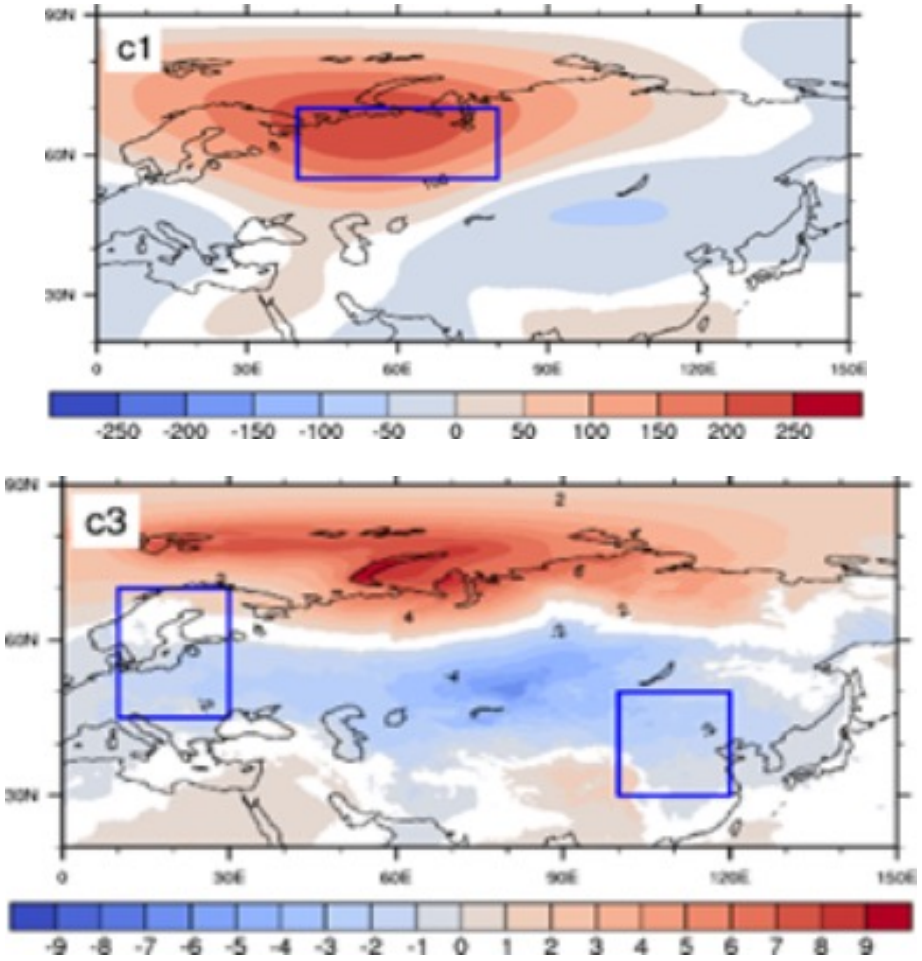


Strongest warm anomalies orccur in regios that are climatologically cold

Warm and moist advection plays a major role

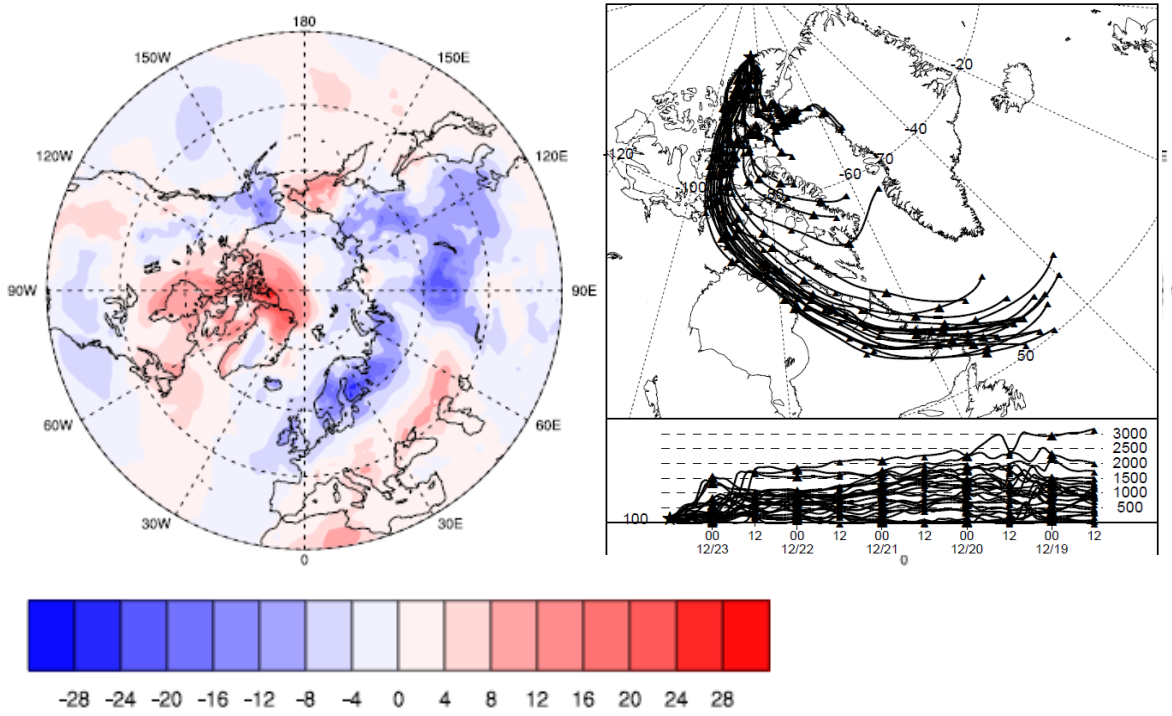
Drivers of warm-air intrusions to the Arctic: Blocking anticyclones

Ural blocking



Z500 (above) and T2m (below) anomalies in conditions of Ural blocking (Sui, Karpechko, Vihma, Yu and Feng, 2022, J. Climate)

Greenland/Baffin blocking 23 Dec 2010



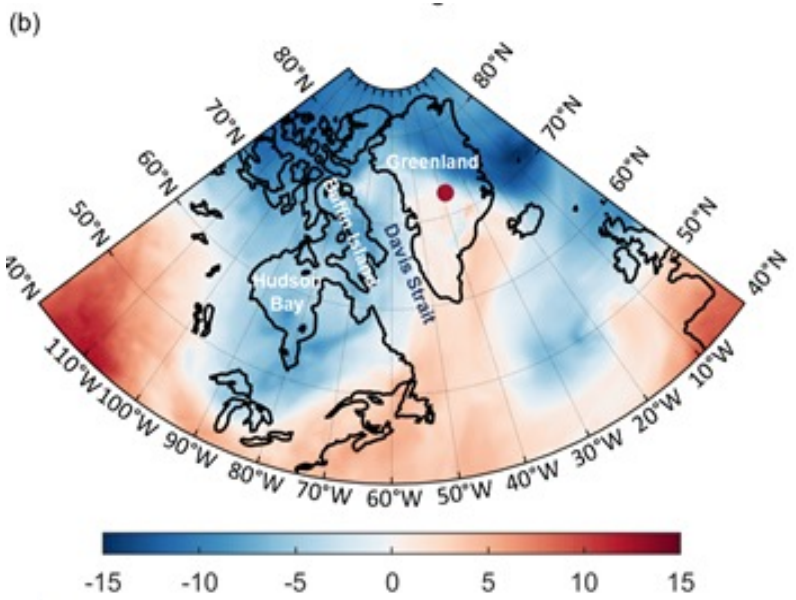
T2m anomaly

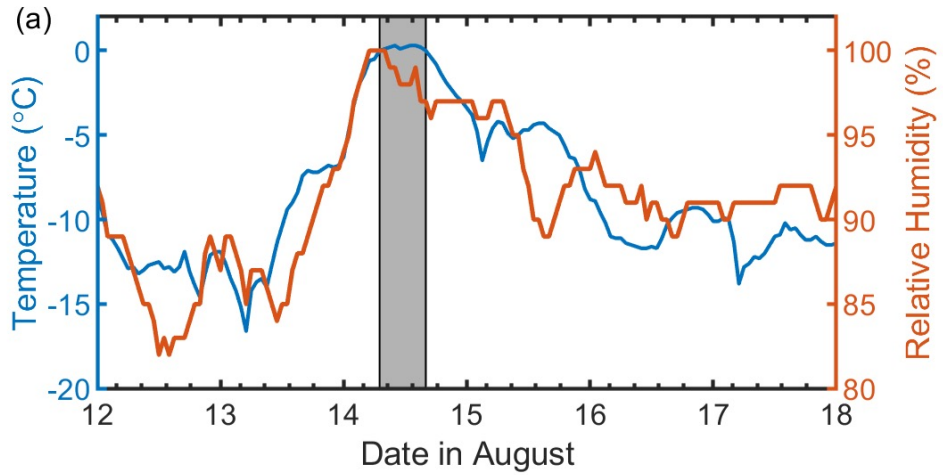
GBI = 5371 m, exceeds December mean by 2 x std

The first case ever when rain was observed at Summit (14 August, 2021) was due to a ridge south of Greenland

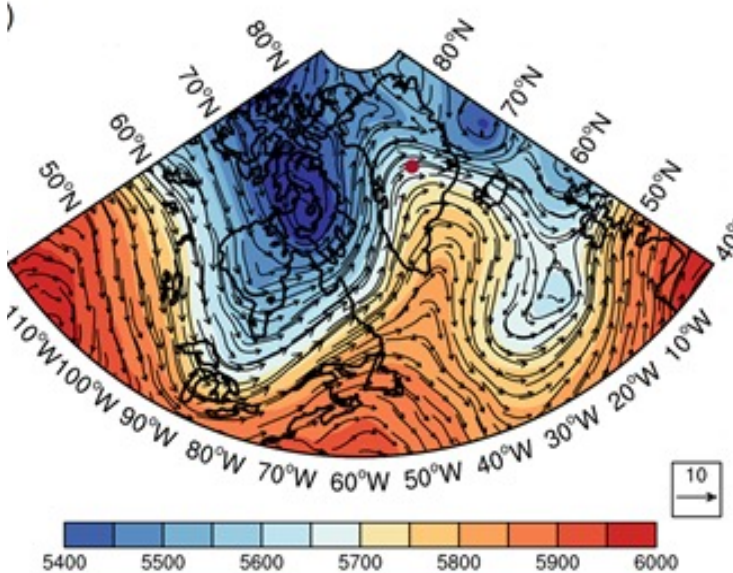
(Xu, Yang, Hu, Liang and Vihma, 2022, Env. Res. Lett.)

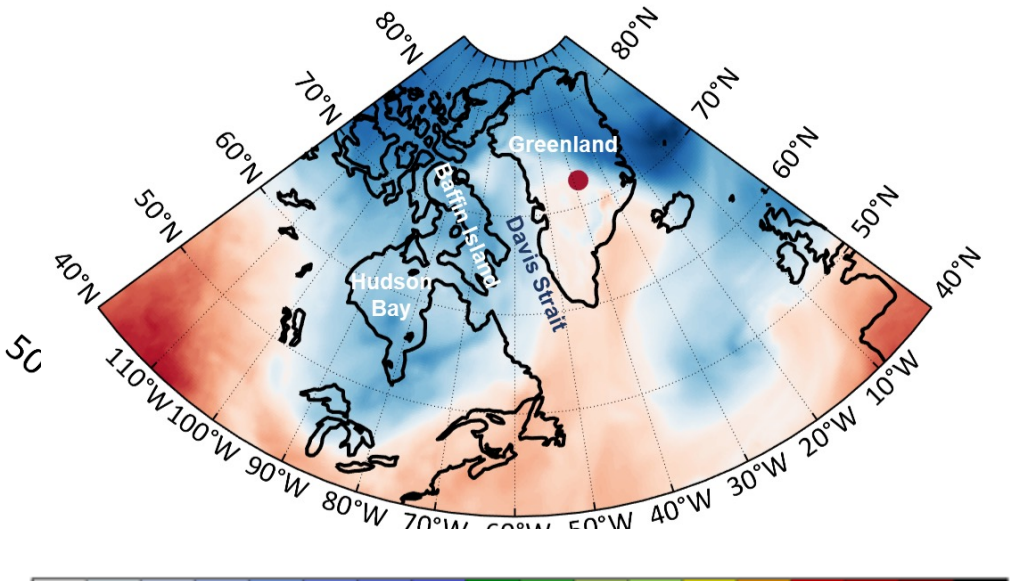
T650





Z500
UV500

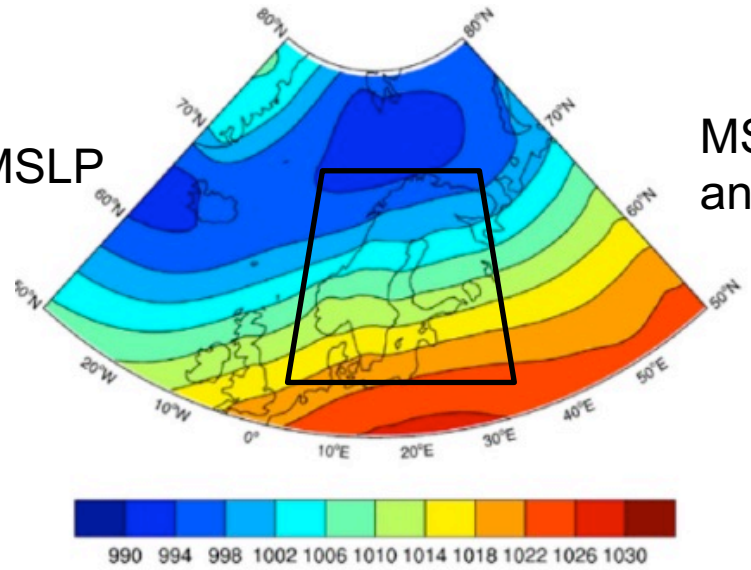




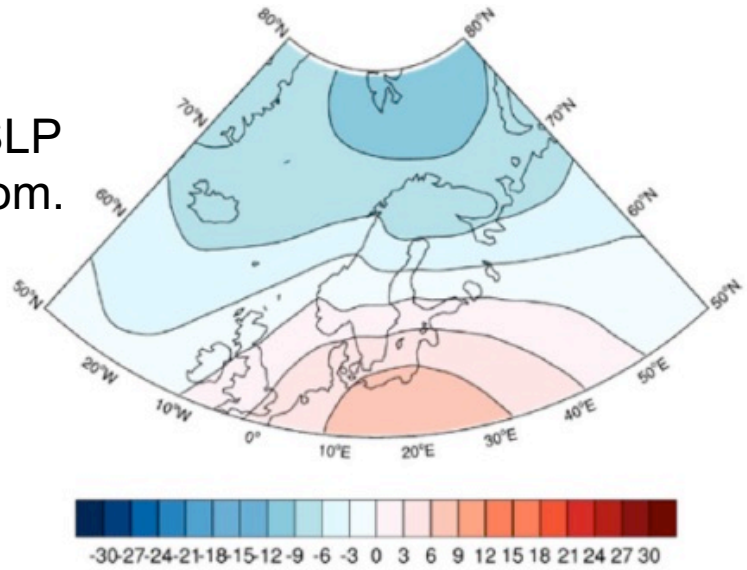
Vertically integrated water vapour transport ($kg\ m^{-1}\ s^{-1}$)

Composites for wintertime warm extremes in Northern Europe in 1979-2016

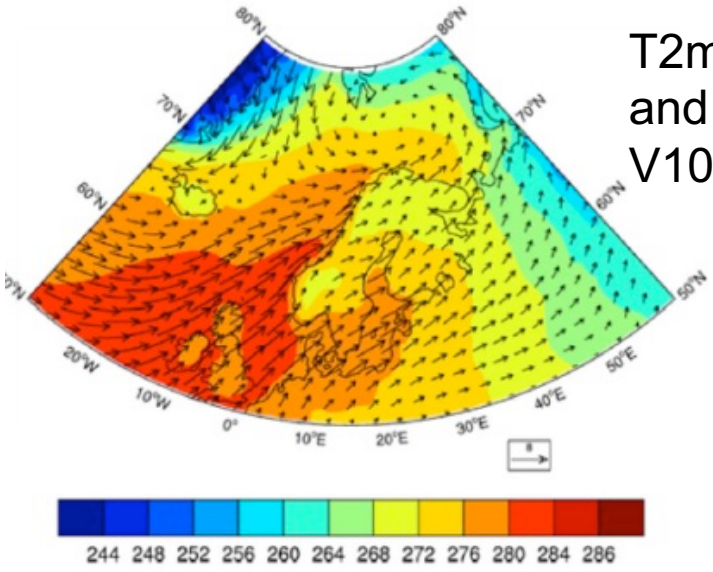
MSLP



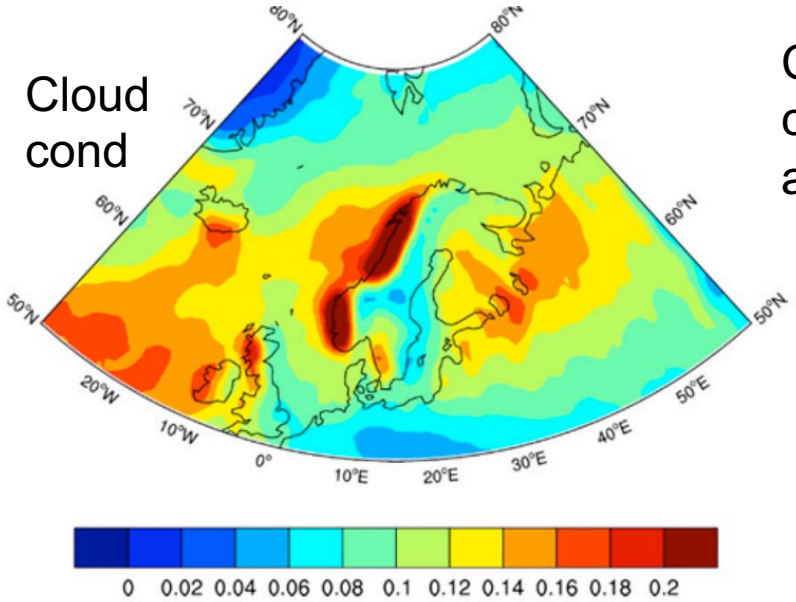
MSLP anom.



T2m and V10m



Cloud cond



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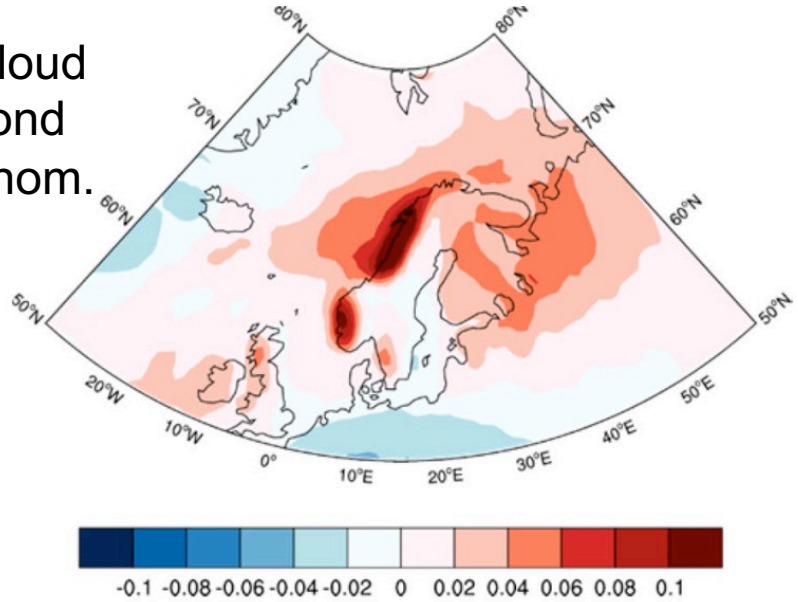

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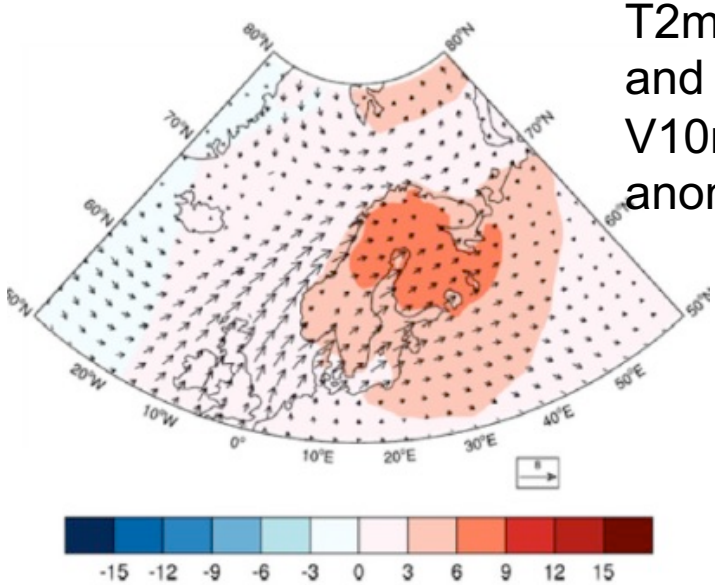

Barents Sea low -> southerly airmasses directed to Northern Fennoscandia -> Föhn contribues to warming

Summary

Cold T2m anomalies in terrestrial Arctic and sub-Arctic are typically locally generated and colder than those occurring in Europe, although cold-air advection plays a major role only for the latter.

Coldest T2m anomalies in central Europe due to cold-air advection from the East
in North American East Cost due to strong cold-air advection from the North
in East Asia due to local generation and weak advection from the North

Warm anomalies in the Arctic clearly larger than those in mid-latitudes, and due to advection of warm (and moist) air advection from the south and subsidence heating

Accordingly, strongest warm and cold T2m anomalies occur in regions that are climatologically cold. Also related to the small heat capacity of SBL.

Ural Blocking / Scandinavian Pattern and Greenland blocking important for warm anomalies in the Arctic and cold anomalies in northern and eastern Europe