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Snow conditions in Northern Europe: the dynamics of interannual variability vs. projected long-term change

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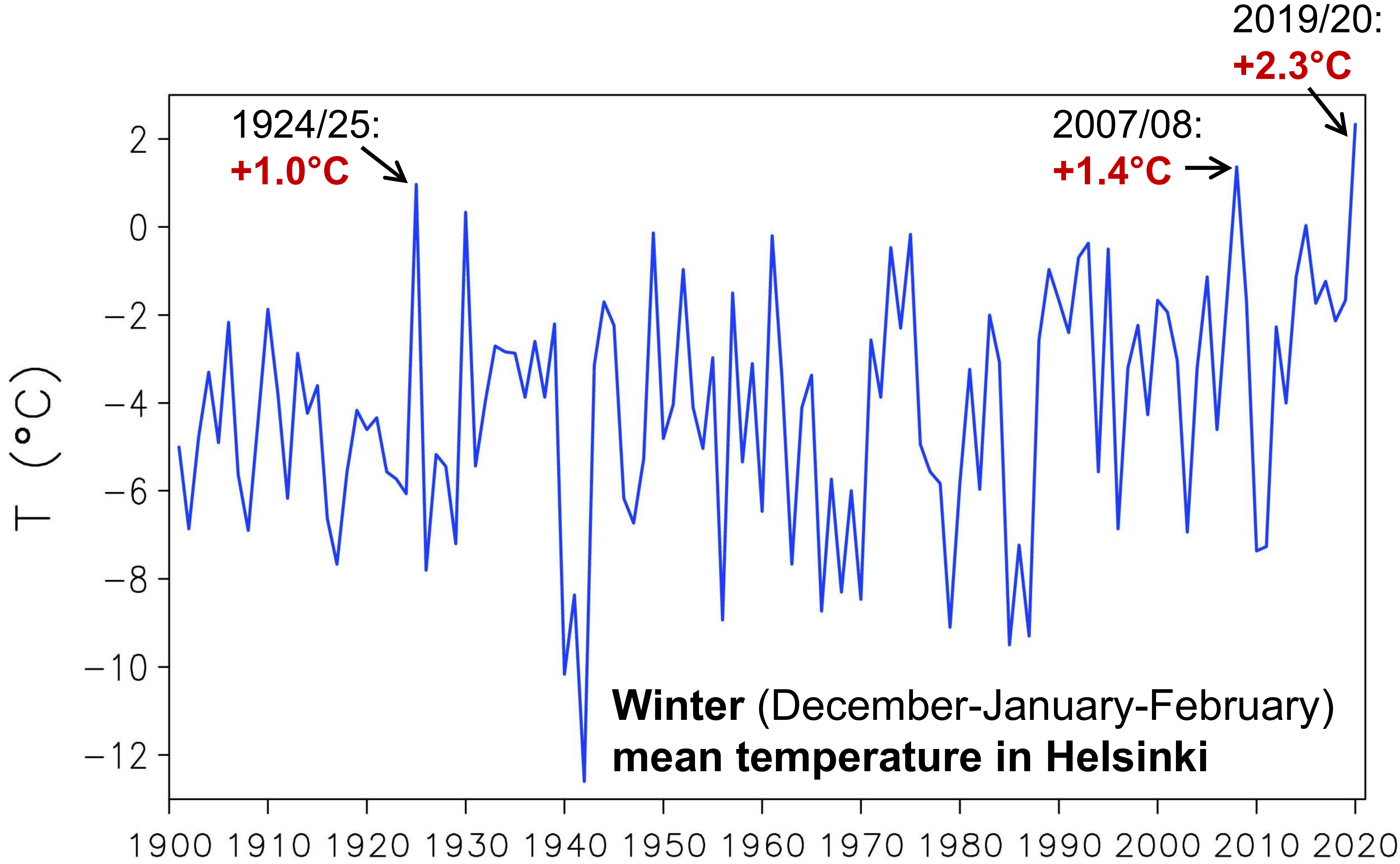
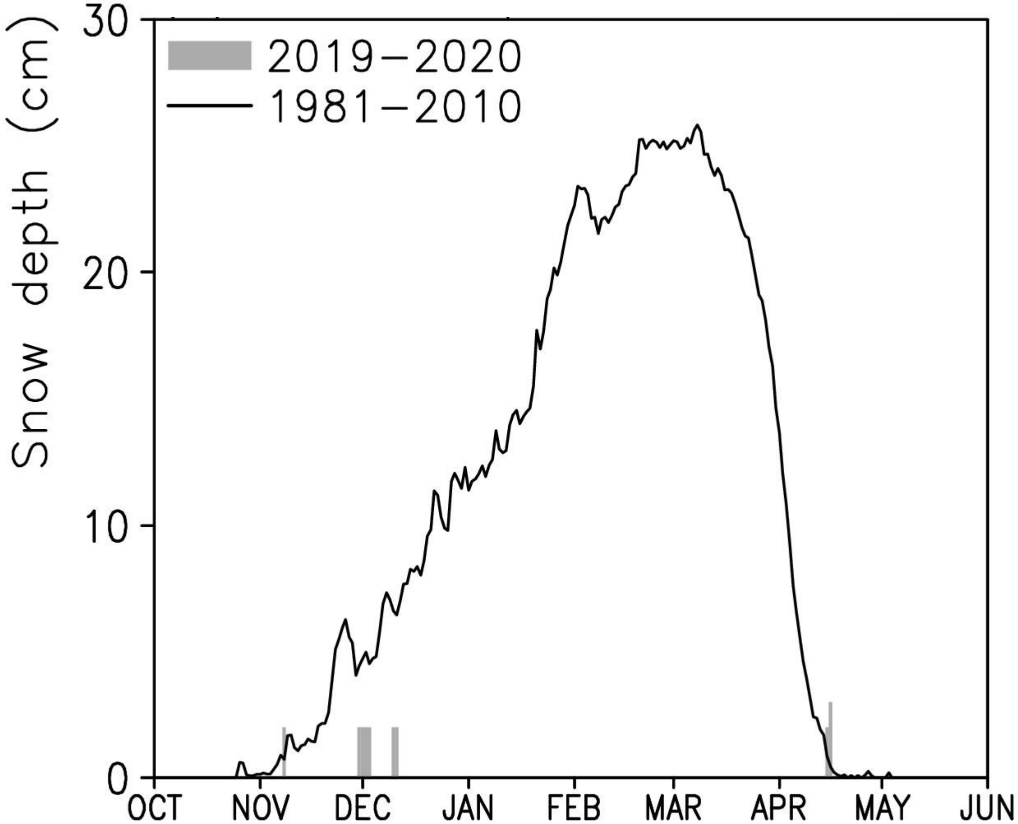
Winter 2019/20 was extremely mild in Finland …

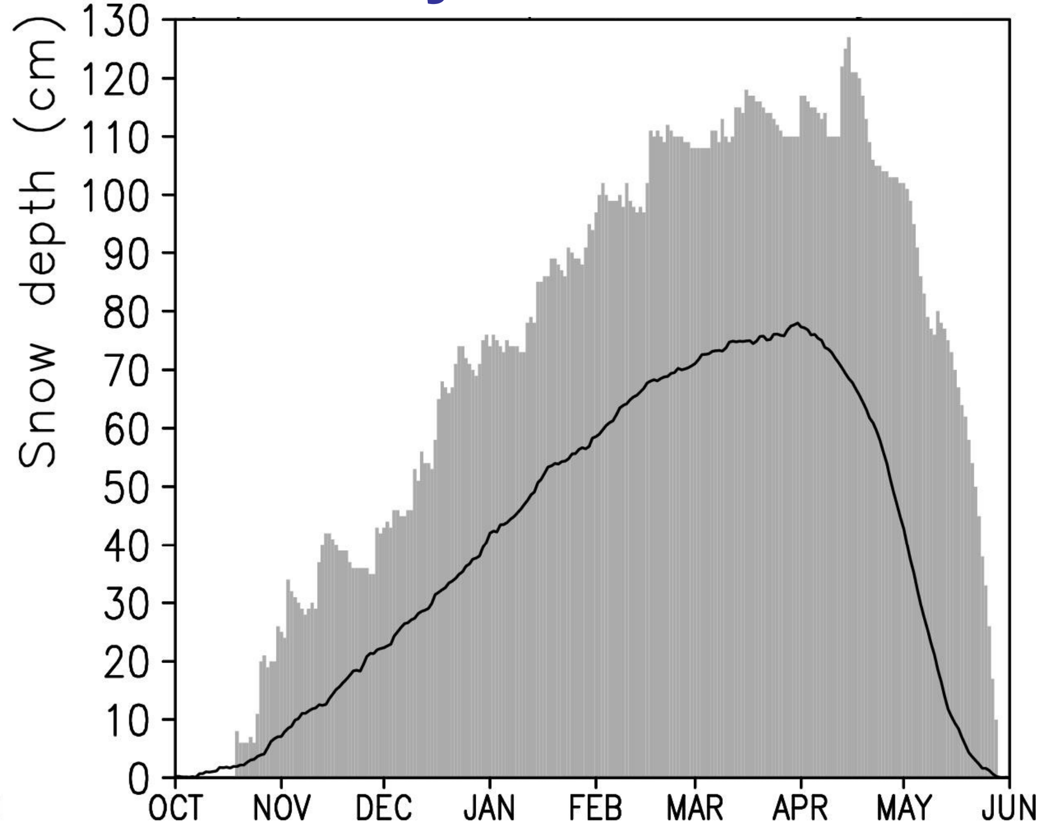


… and it also had unusual snow conditions

Helsinki Kaisaniemi



Sodankylä Tähtelä



- Maximun snow depth **3 cm**
- Only **9** days with measurable snow pack

- Maximun snow depth **127 cm** = all-time record

Questions

1. Were the snow conditions in 2019/20 typical to other mild winters?
2. Do they provide an analogy for future long-term climate change?
3. If the answers to (1) and (2) are different, why is this the case?

Question 1

1. Were the snow conditions in 2019/20 typical to other mild winters?

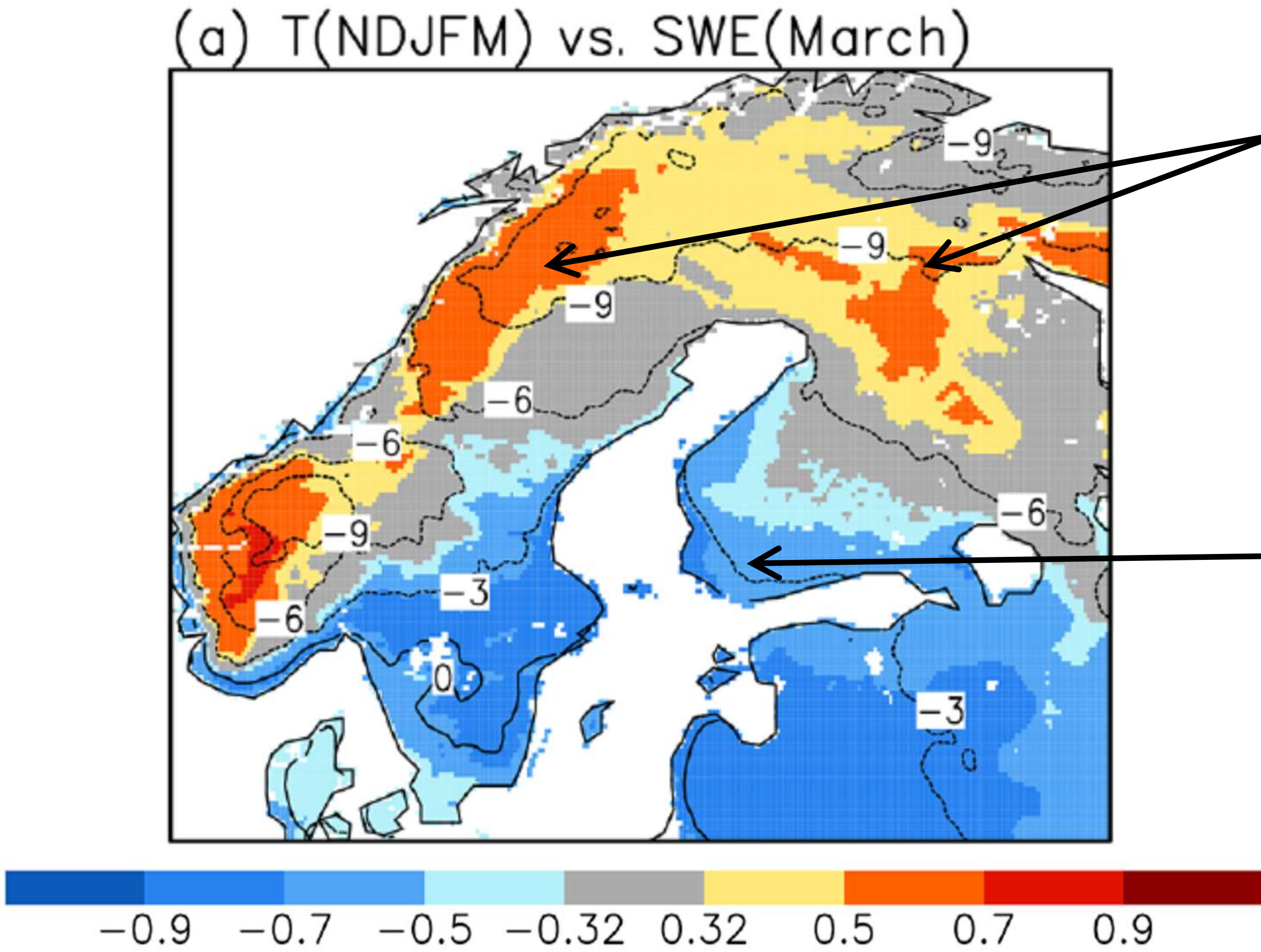
In the next slide, this is answered by calculating the interannual correlation between

- Extended winter (November-March) mean temperature

and

- March mean Snow Water Equivalent (SWE)

in the **ERA5-Land** data set for winters 1981/82 – 2019/20



Positive correlation in the North and over the Scandiavian mountains

Negative correlation in the South

→ **Yes. The conditions in winter 2019/20 (little snow in southern Finland but a lot of snow in Lappland) were qualitatively typical for a mild winter, although the correlation between T and SWE is moderate only.**

Question 2

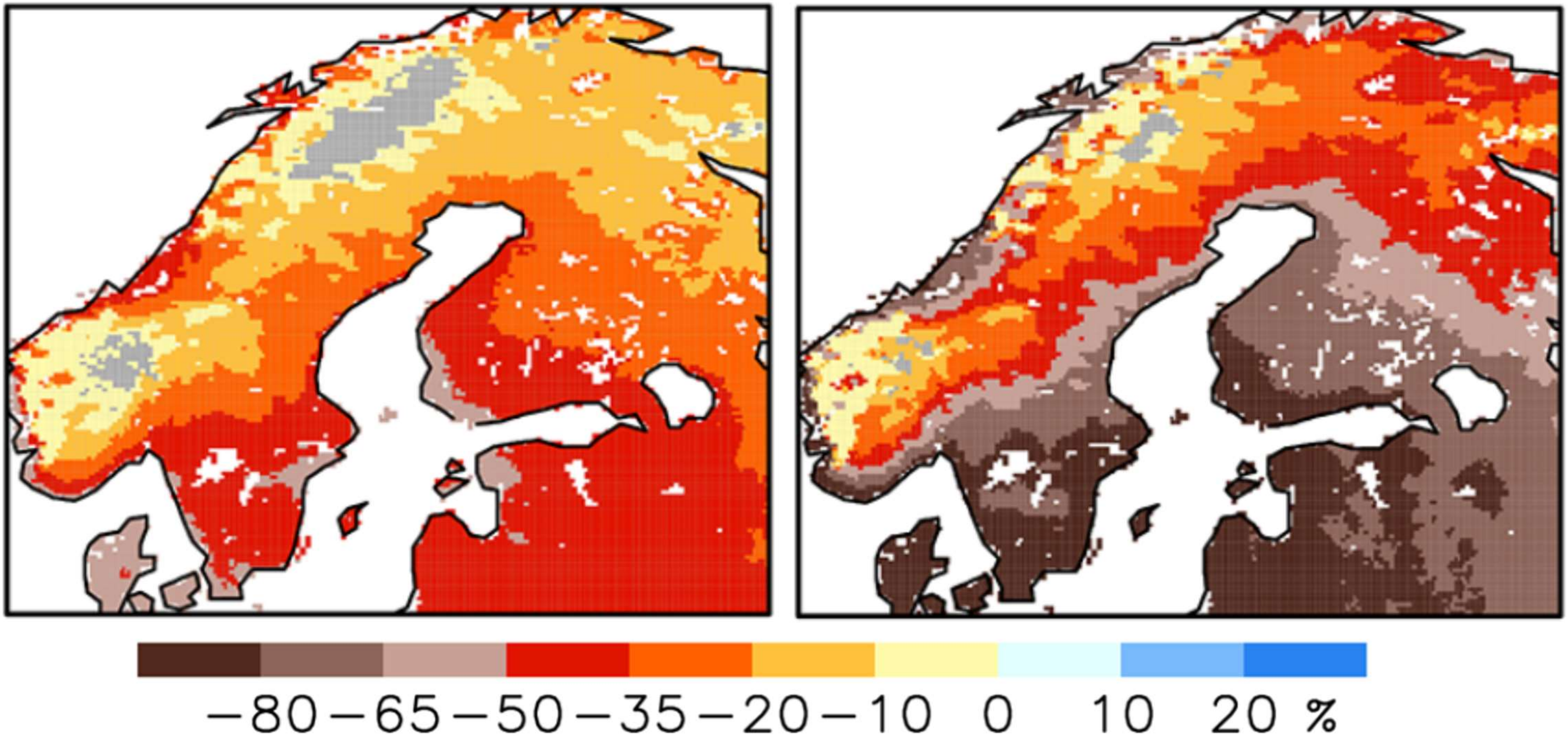
2. Do they (the snow conditions in 2019/20) provide an analogy for future long-term climate change (i.e. what happens to the amount of snow in a warming climate)?

This is studied by calculating the changes in SWE in the **EURO-CORDEX** regional climate model (RCM) simulations

- **12.5 km** horizontal resolution
- Baseline period **1981/82-2019/20**
- Two future periods: **2020/21-2058/59** and **2059/60-2097/98**
- **RCP8.5** (worst-case!) scenario
- Results from **17** RCM simulations averaged

Relative (%) change in March mean SWE

1982-2020 to 2021-2059 1982-2020 to 2060-2098



- Snow reduced dramatically in the south (as in individual mild winters)
- Snow also reduced in the north (in contrast to individual mild winters!)

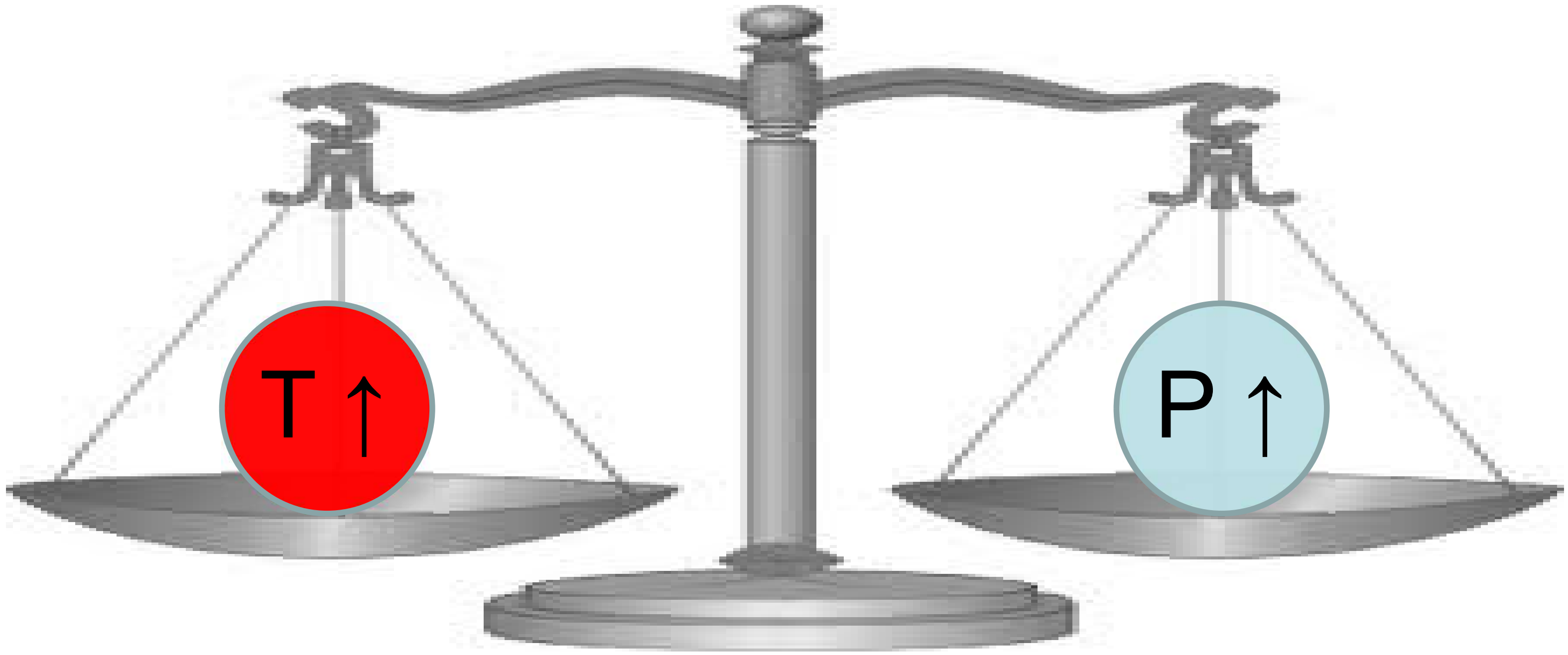
Question 3 (rephrased)

3. Why are individual mild winters an imperfect analogy to future climate change (in terms of the temperature-snow relationship)?

To answer this question, we must study the two main factors that determine the amount of snow

- Temperature (T)
- Precipitation (P)

Effects of climate change **and** interannual climate variability **on snow conditions**

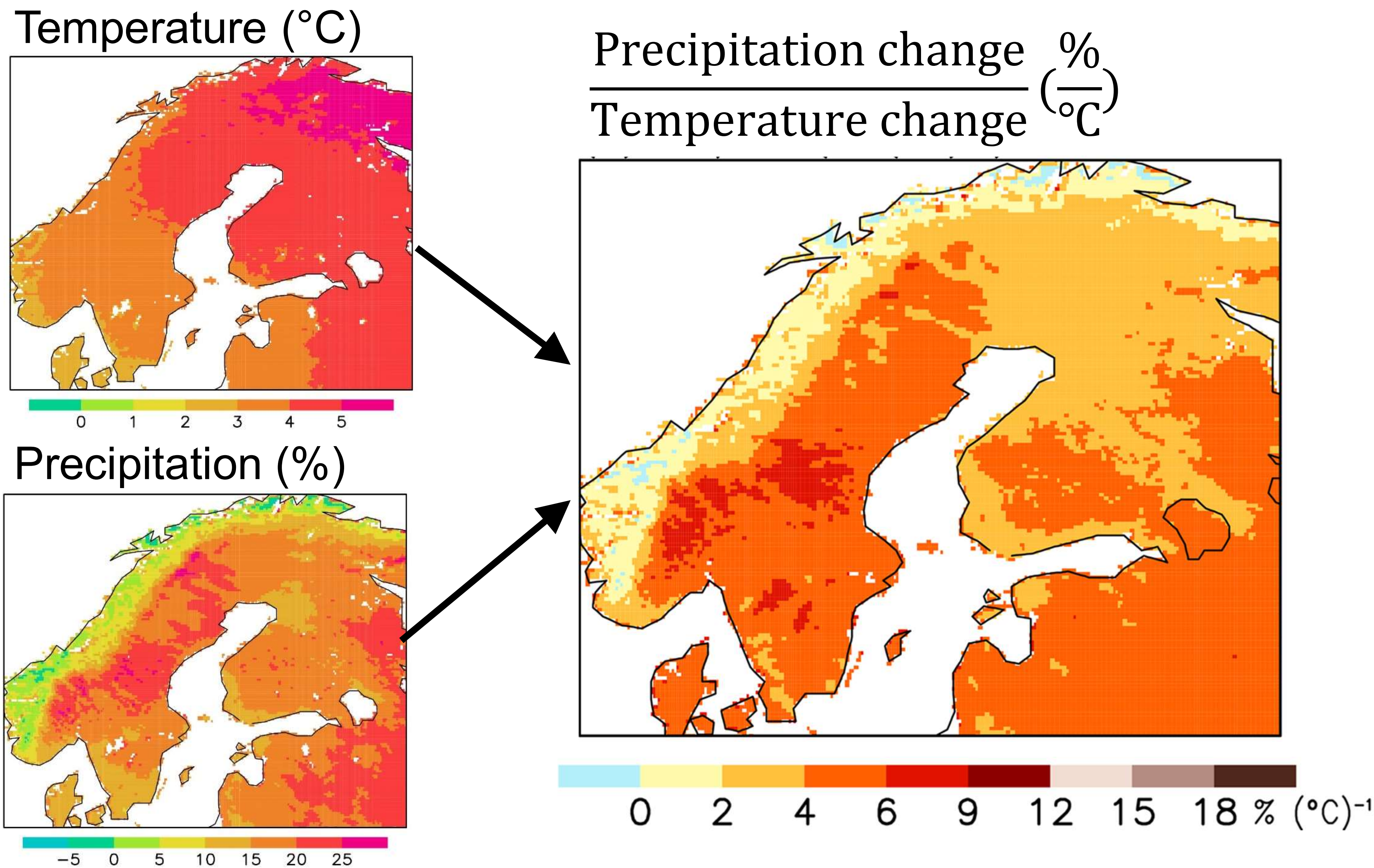


- More rainfall at expense of snowfall
- More snowmelt

- Potentially more snowfall and snow, if increase in P large enough to dominate over the increase in T

How does this balance differ between interannual variability and long-term climate change?

Changes in November-to-March mean climate from 1981/82-2019/20 to 2059/60-2097/98

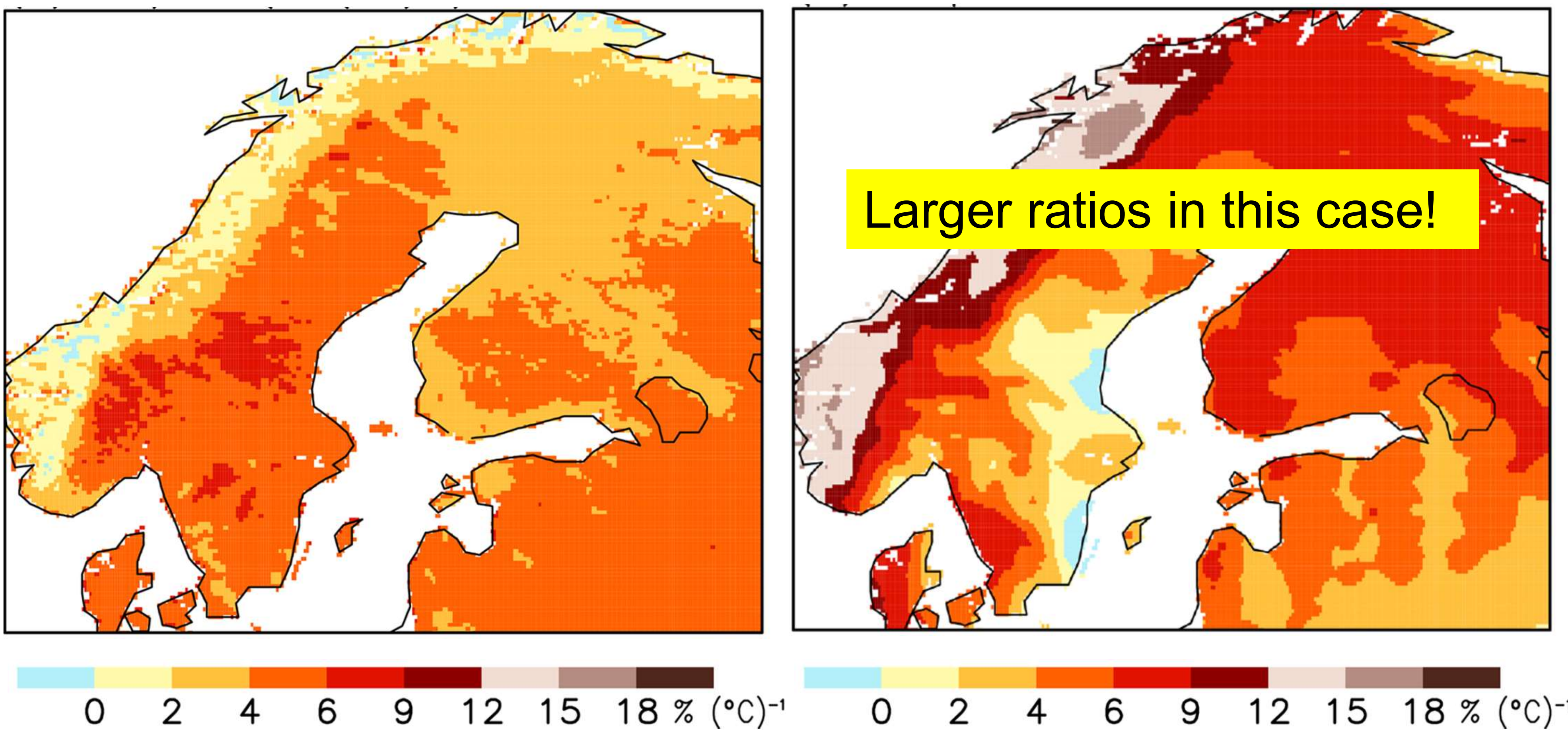


Ratio between NDJFM precipitation and temperature anomalies

Long-term change in EURO-CORDEX simulations

Ratio for interannual variability, as *slope b* from linear regression

$$P = a + \boldsymbol{b}T$$



Conclusions (this far)

- **The EURO-CORDEX simulations indicate a future decrease in snow amount in Finland**
  - **Larger decrease in the south**: milder climate → phase of winter precipitation and frequency of mid-winter melt events more sensitive to warming
  - **Snow also decreases in the north**: increase in winter precipitation too small to compensate the warming
- **On the interannual time scale**
  - **Mild winters** typically have little snow in the south, but (in contrast to the long-term warming) **a lot of snow in the north**
- **Cause of the difference**
  - *For the same anomaly in temperature, the increase in precipitation is larger on the interannual than the climate change time scale*

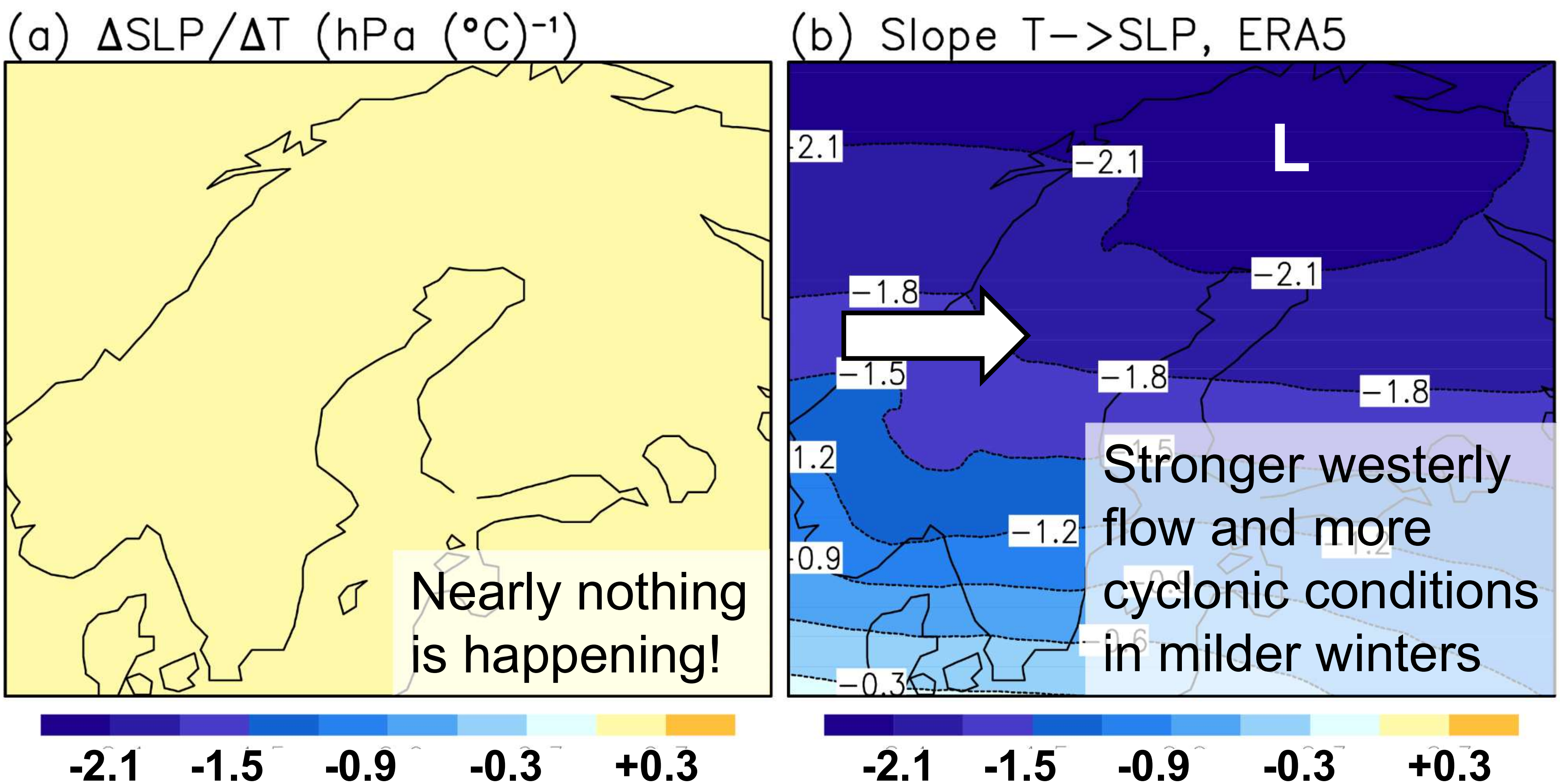
… which has, of course, something to do with the atmospheric circulation!

Ratio between NDJFM sea level pressure and temperature anomalies

Long-term change in EURO-CORDEX simulations

Ratio for interannual variability, as *slope b* from linear regression

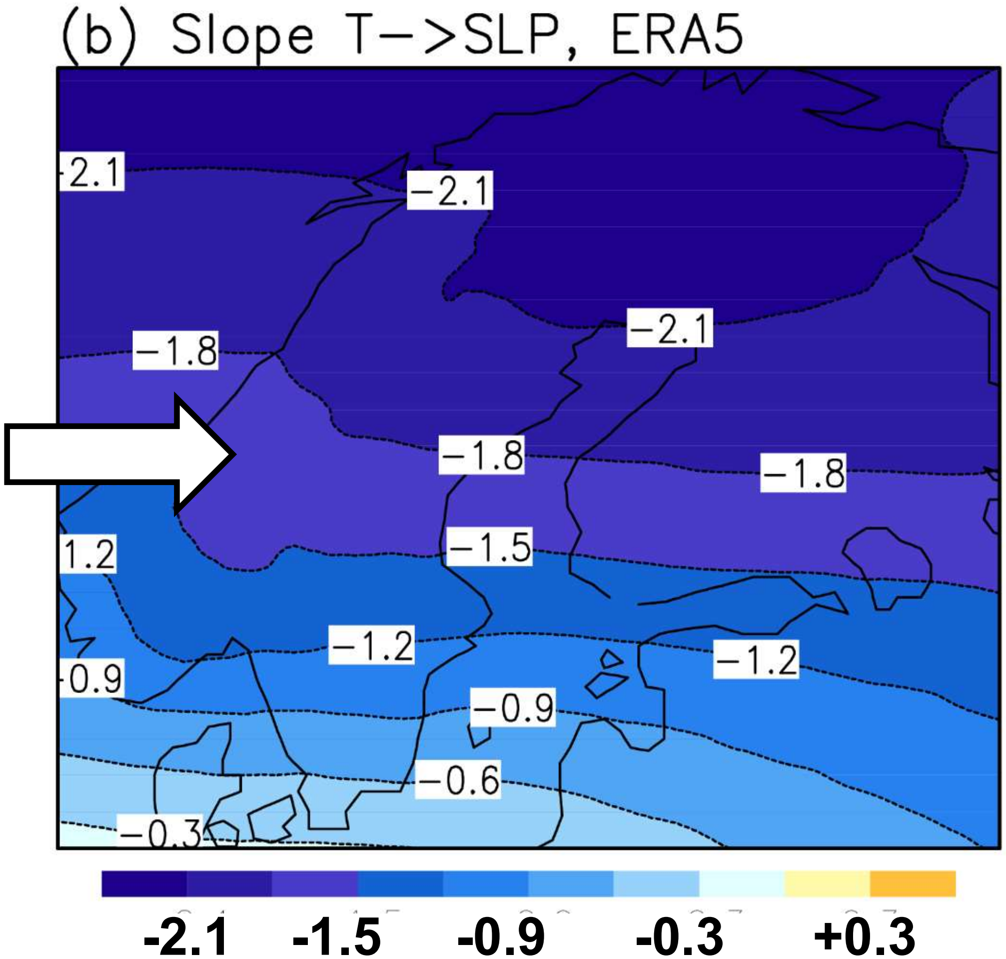
$$SLP = a + bT$$

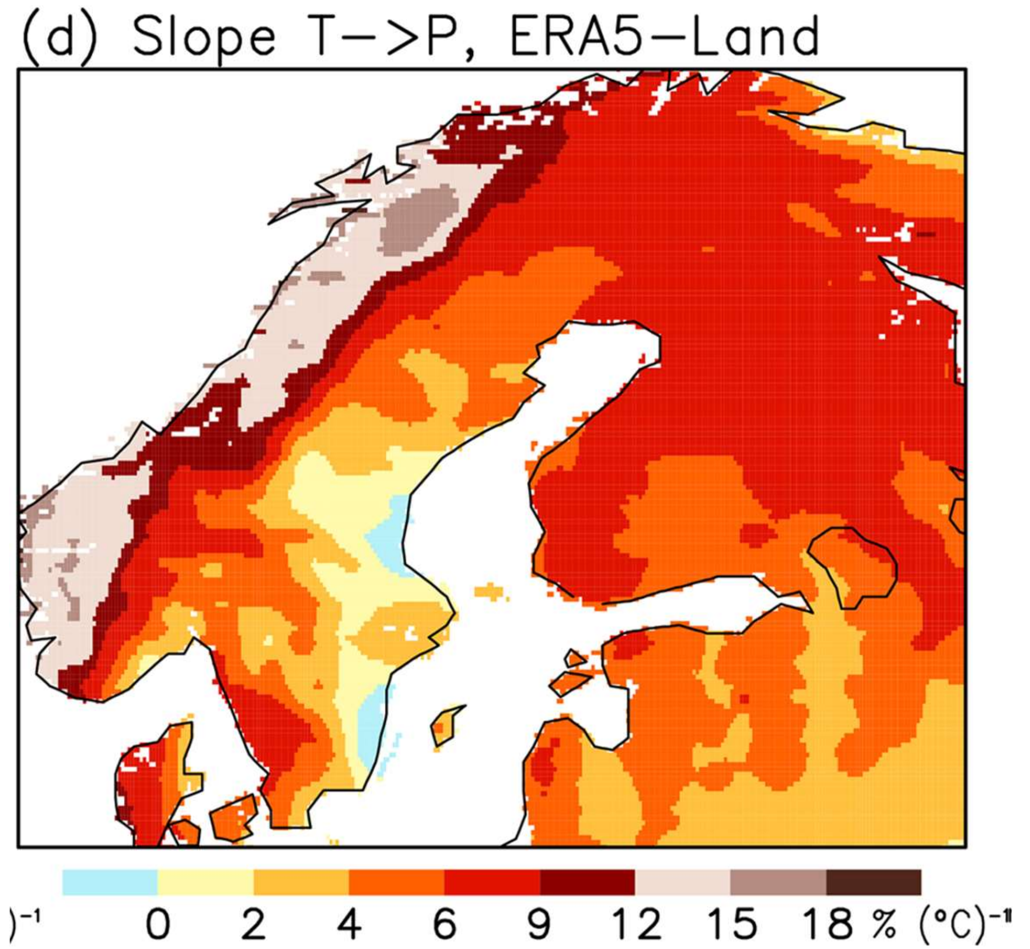


Long-term warming vs. individual mild winters

- **Long-term warming**
  - Mainly of thermodynamic origin (increase in greenhouse gases)
  - Increase in precipitation due to increased water vapour in a warmer atmosphere
- **Individual mild winters**
  - Mainly due to anomalous atmospheric circulation
  - Stronger westerlies → larger heat and moisture transport from Atlantic Ocean
  - Larger moisture transport + more cyclonic conditions → increase in precipitation larger than expected from mild temperatures alone

Effect of circulation modulated by orography (western Norway vs. Eastern Sweden!)





More in this article …

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Questions?