Trends in snowmelt rates over Europe inferred from historical snow depth observations converted to SWE

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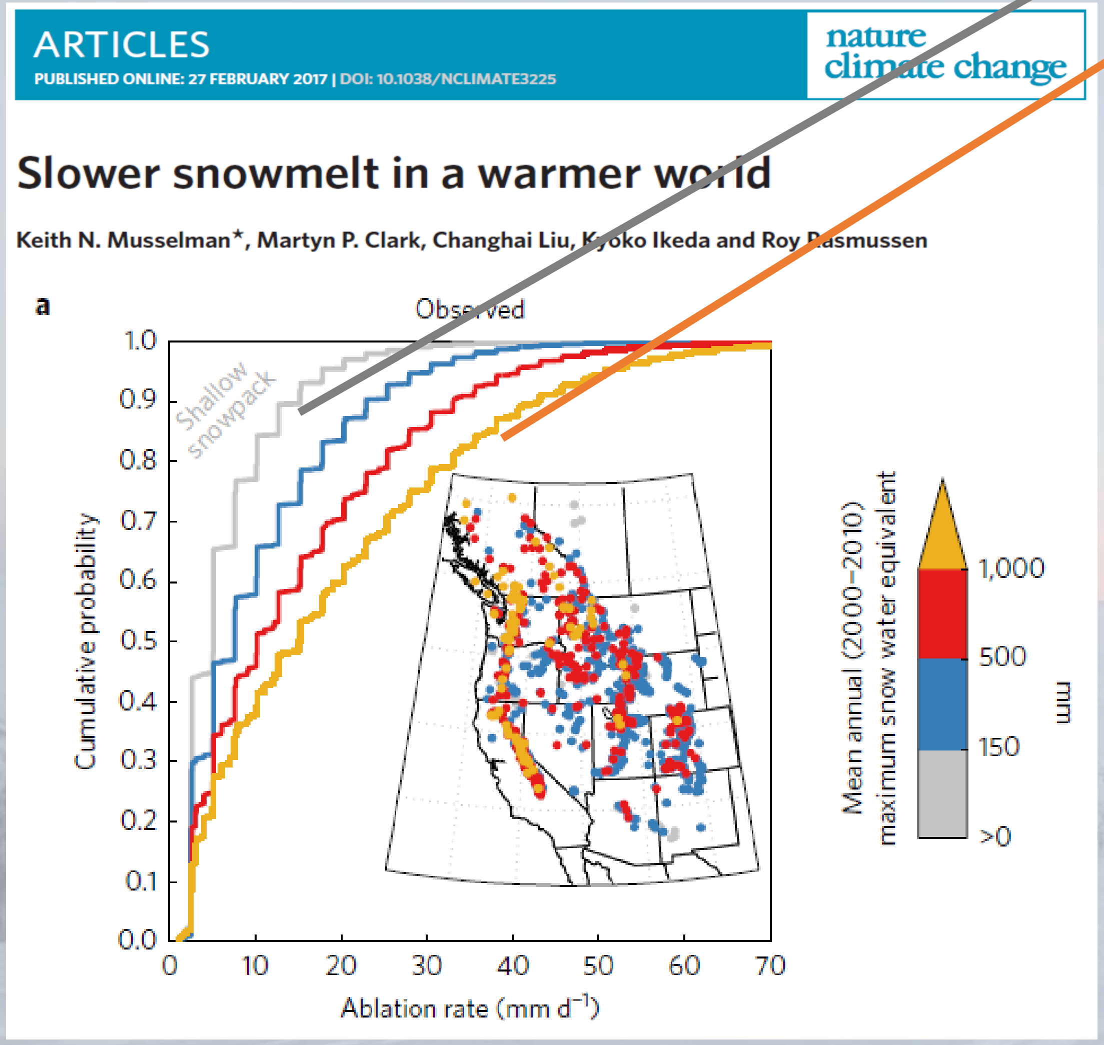
vEGU21 Session HS2.1.7: Snow and ice accumulation, melt, and runoff generation in catchment hydrology: monitoring and modelling (EGU21-12760)

Theoretical background:

Shallow snowpacks melt at <u>SLOWER</u> rates

Thick snowpacks melt at <u>FASTER</u> rates


ARTICLES

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nature climate change

Slower snowmelt in a warmer world

Keith N. Musselman*, Martyn P. Clark, Changhai Liu, Kyoko Ikeda and Roy Rasmussen

Slower melt ⟵⟶ Faster melt

Figure taken from Musselman et al. 2017

WHY?

Shallow snowpacks become isothermal earlier and therefore melt earlier in spring, at a time when less energy is available for melt (lower temperature and lower solar radiation)

Thick snowpacks take longer to become isothermal and melt later in spring, when higher temperature and higher solar radiation favour faster melt rates

Therefore….

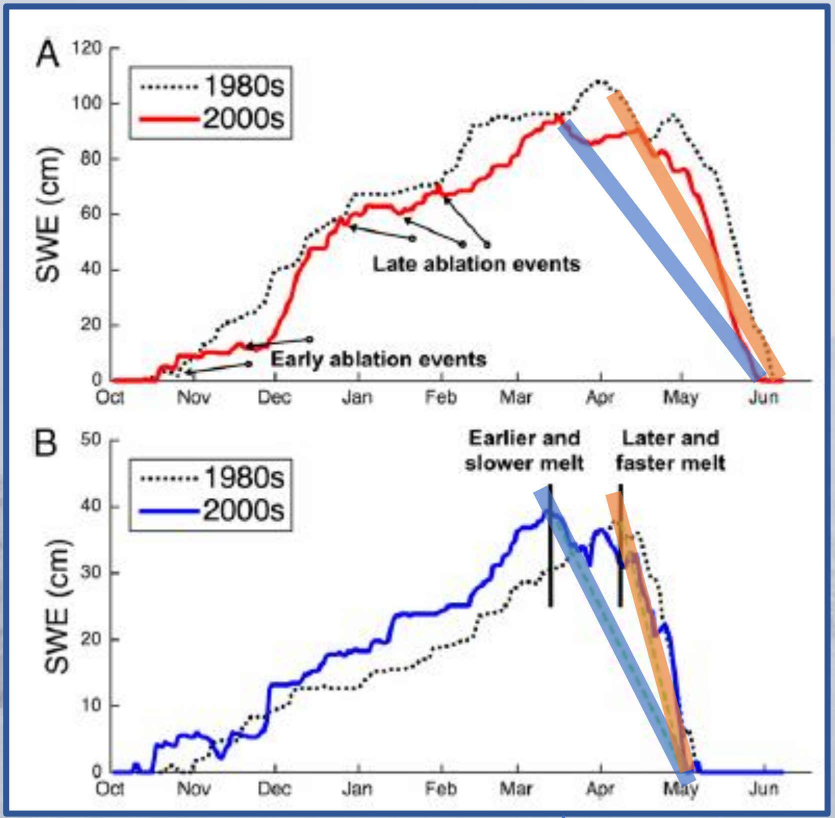
In a warmer world with <u>thinner snowpacks</u>, melt rates will be slower

Theoretical background: an example

Two examples of:

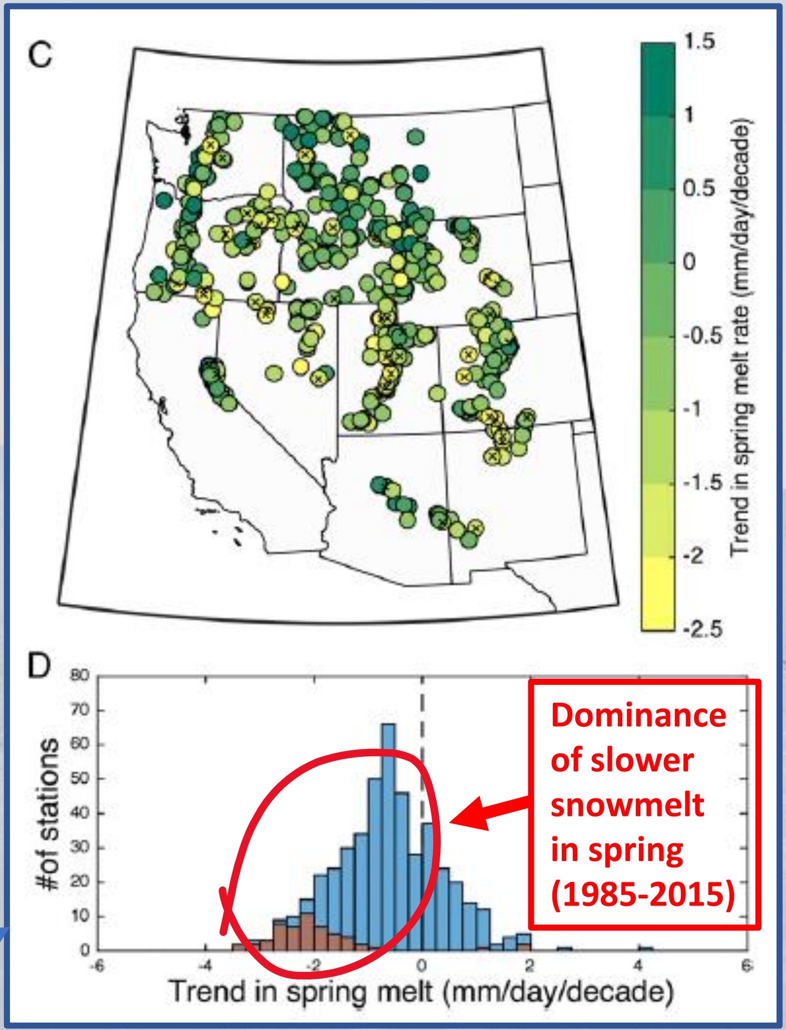
Earlier and slower melt in the 2000s vs.

Later and faster melt in the 1980s



Taken from Harpold and Brooks, 2018

Trends in spring melt rate over the SNOTEL dataset



HOWEVER…

- Trends spatially inhomogeneous
- Some locations show increasing trends
- Climatic/geographic drivers not assessed
- Most research done over the U.S.A SNOTEL dataset
- Theory slightly oversimplified:

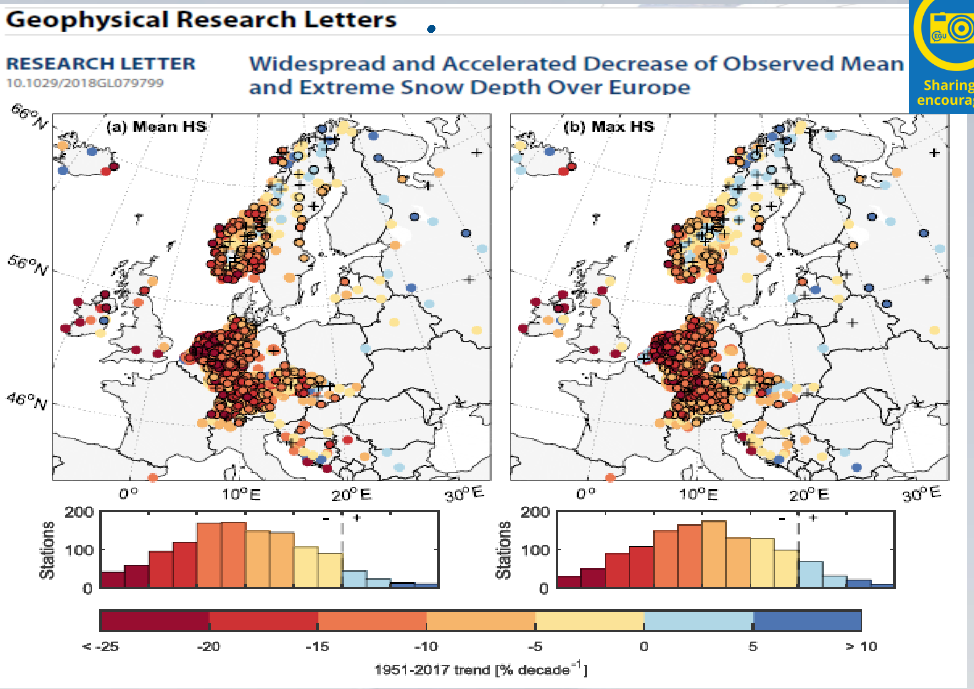
assumes snowpacks become thinner, melt earlier, and less energy is available at the time of melt

Taken from Fontrodona-Bach et al 2018

Research questions:

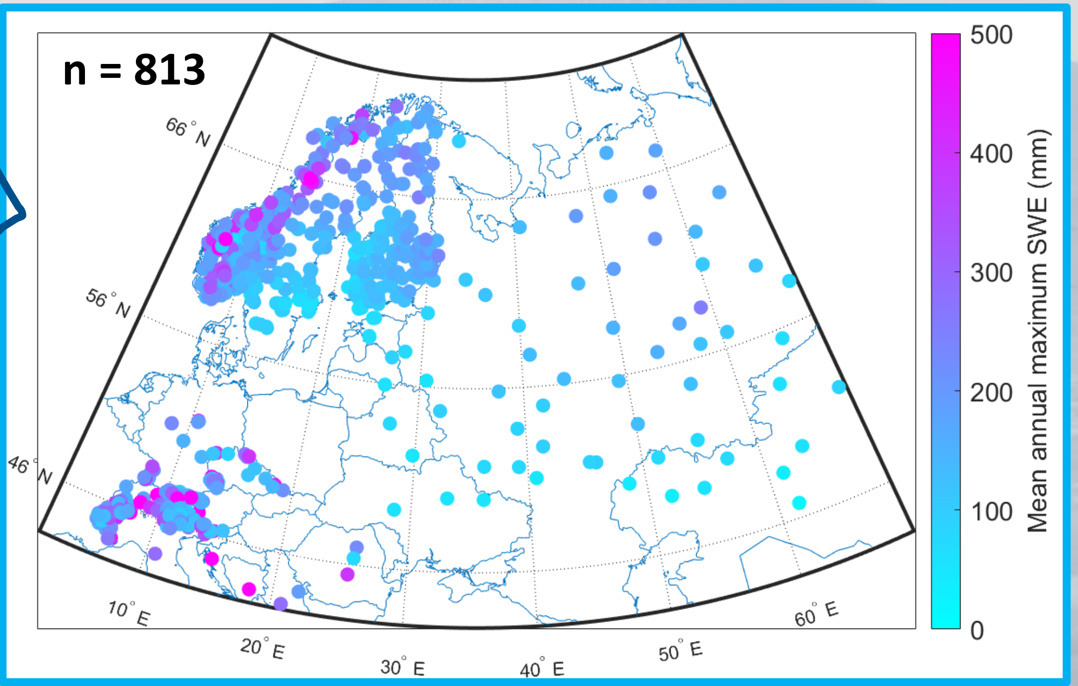
Over heavily depleted European snowpacks:

1. How are snowmelt rates changing? Is melt slower?
2. What climatic or geographic drivers can be identified?



Snow depth data (all open data):

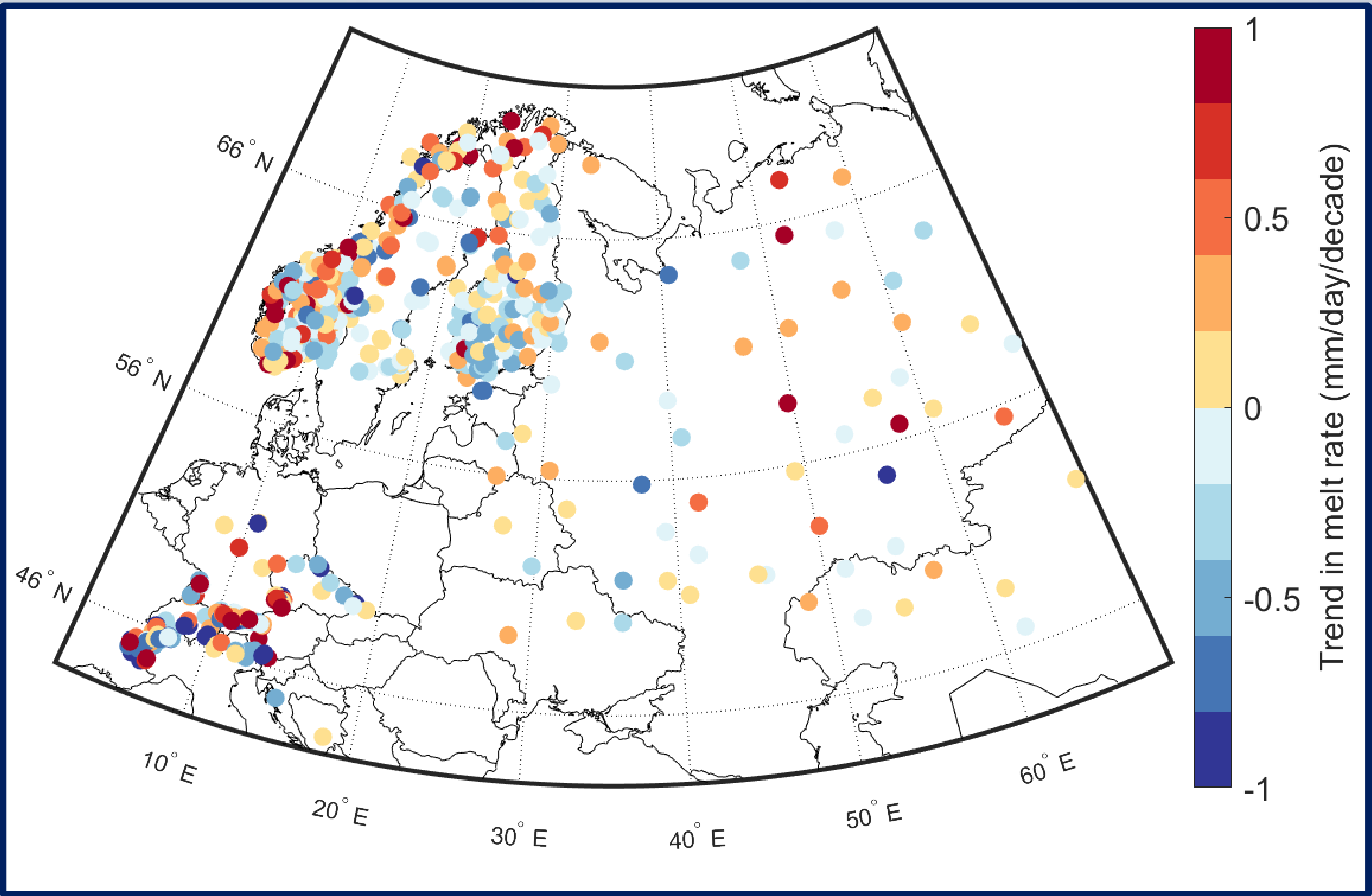
- ECA&D Daily Snow Depth Dataset (as used in Fontrodona-Bach et al., 2018)
- Finnish Meteorological Institute available observations
- European Alps time series (from Matiu et al., 2021)
- E-OBS dataset for daily Temperature and Precipitation



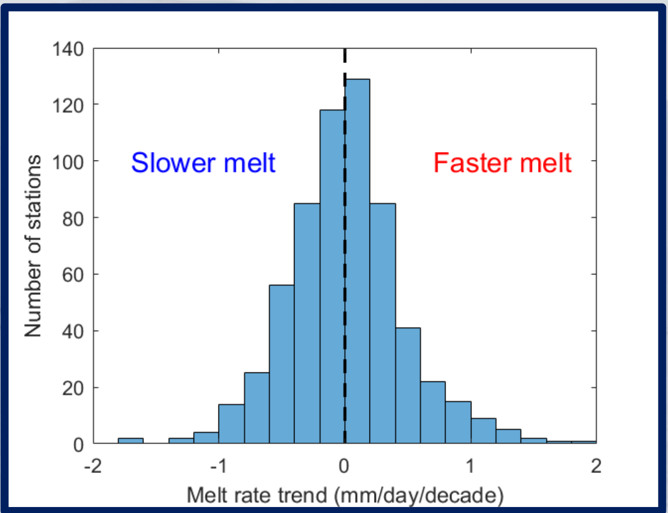
Methods

- Converting snow depth to SWE (Combining the models of Hill et al. 2019 and Winkler et al. 2021)
- Selecting only seasonal snow sites
- Yearly mean melt rates as: $\boxed{\textit{Melt rate} = \dfrac{\textit{peak SWE}}{\textit{melt season length}}}$
- Long-term linear trends (1951-2017)

Results – Melt rate trends (1951-2017)



- Trends are weaker in magnitude than reported over the SNOTEL dataset (Harpold and Brooks, 2018)
- Trends are highly spatially inhomogenous
- NO DOMINANCE OF SLOWER OR FASTER MELT



BUT WHY?

Results – Melt rate trends (1951-2017)

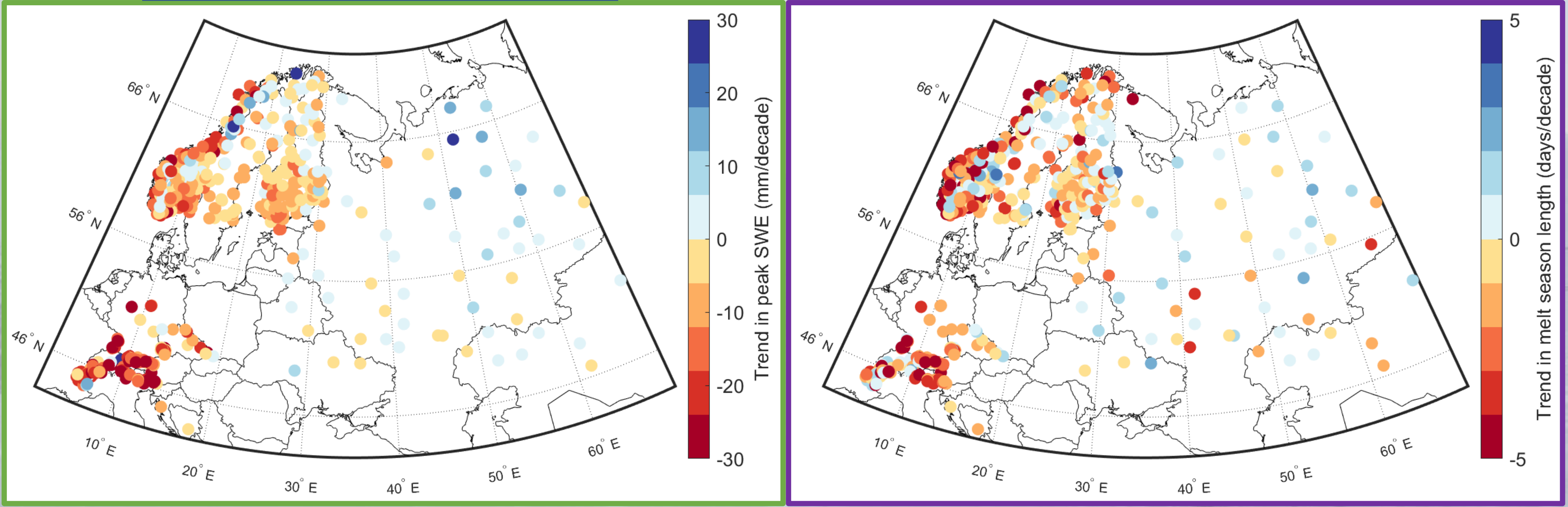
Why such variability in melt rate change?
Melt rate depends on the change in max snow accumulation, and the change in length of the melt season →

$$\Delta\, \mathit{Melt\ rate} = \frac{\Delta\, \mathit{peak\ SWE}}{\Delta\, \mathit{melt\ season\ length}}$$

So how are peak SWE and melt season length changing?

$\Delta\, \mathit{peak\ SWE}$ (*per decade*)

$\Delta\, \mathit{melt\ season\ length}$ (*per decade*)



BOTH PEAK SWE AND LENGTH OF THE MELT SEASON ARE WIDELY AND LARGELY DECREASING!

Results – Melt rate trends (1951-2017)

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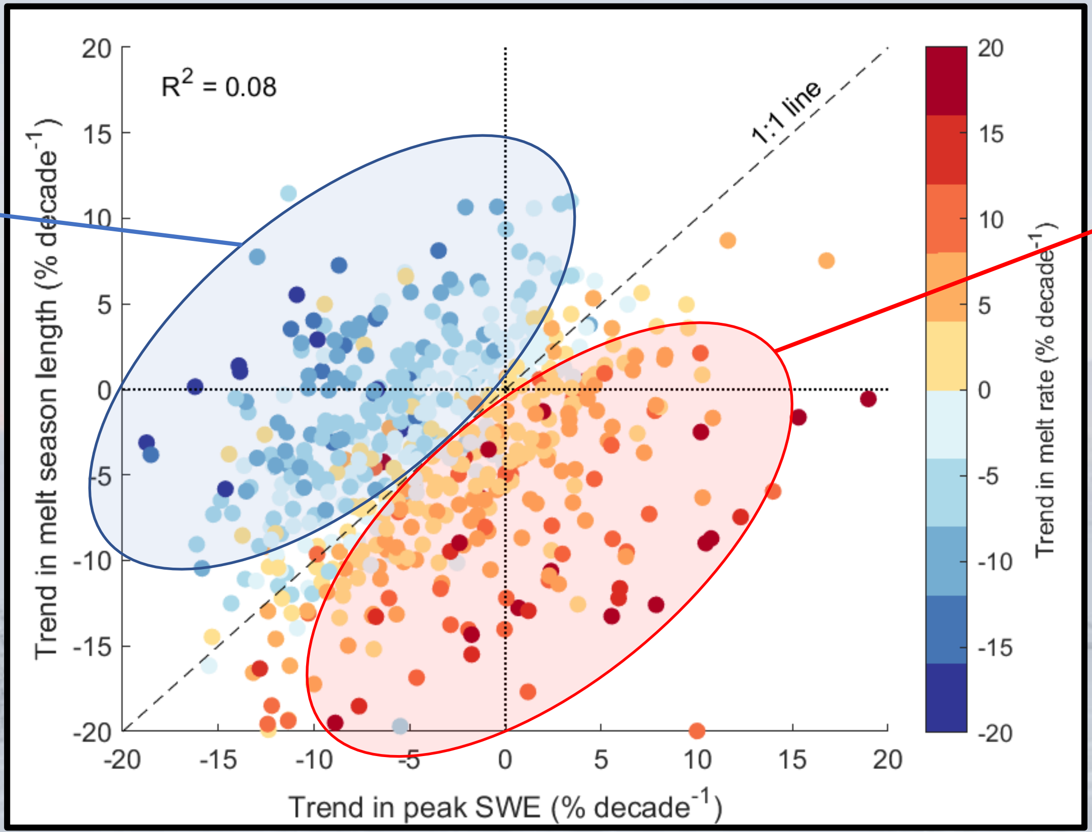
$$\Delta\, \boldsymbol{Melt\ rate} = \frac{\Delta\, \boldsymbol{peak\ SWE}}{\Delta\, \boldsymbol{melt\ season\ length}}$$

Above the 1:1 line:
the decrease (or increase) in peak SWE dominates over a smaller proportional reduction in melt season length

Slower melt



Below the 1:1 line:
the decrease in melt season length dominates over a smaller proportional reduction (or an increase) in peak SWE

Faster melt

- **The balance between change in peak SWE and change in melt season length determines the change in melt rate.**
- **But what is controlling this balance? Why is it not spatially consistent?**
- **Peak SWE is more sensitive to variability in precipitation, melt season length is more sensitive to temperature variability**

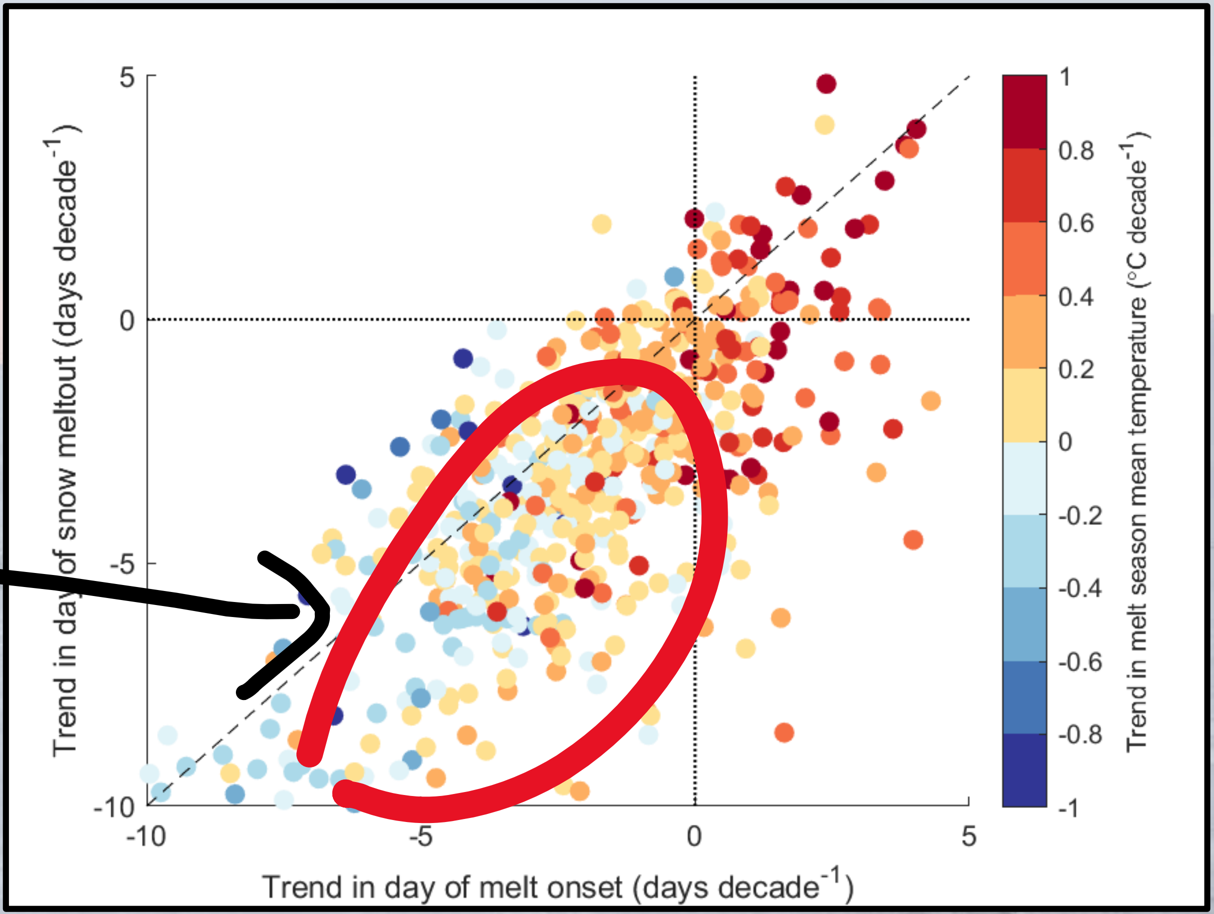
Discussion/Conclusion – Melt rate trends (1951-2017)

- The dominance of change in peak SWE or change in melt season length is not spatially consistent and probably needs to be explained by other climatic, geographic, or local factors. This needs further investigation
- A deeper analysis of precipitation and temperature variability needs to be performed to further understand the variability in melt rate change

Also: The assumption of thinner snowpacks melting earlier and slower due to less energy available at the time of melt might be oversimplified and is challenged here:

Earlier melt onset (x-axis), earlier meltout (y-axis), and shorter melt season (below 1:1 line)

But also warmer temperatures (red dots), compensating for less solar radiation? This could explain the lack of consistent "slower snowmelt" despite earlier melt



Thank you for your attention!

Happy to receive feedback, comments, or more data!

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