Future changes in mean and extreme snowfall in northern Europe

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Questions to be addressed

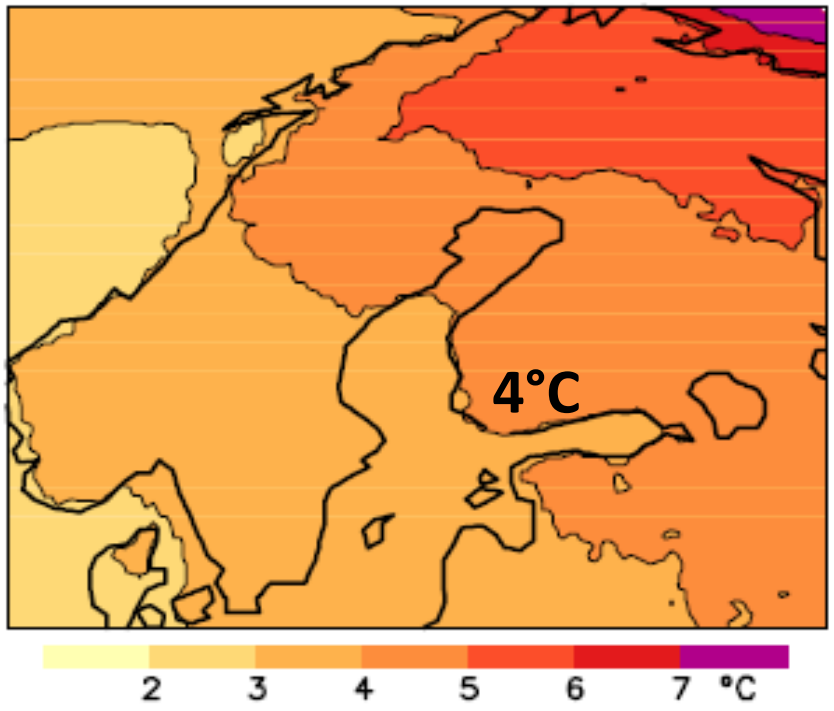
- How will climate change affect **mean annual snowfall** in Northern Europe?
- How will it affect **extremes of daily snowfall**?
- **Why** do mean and extreme snowfall change as they do?

ENSEMBLES RCM simulations

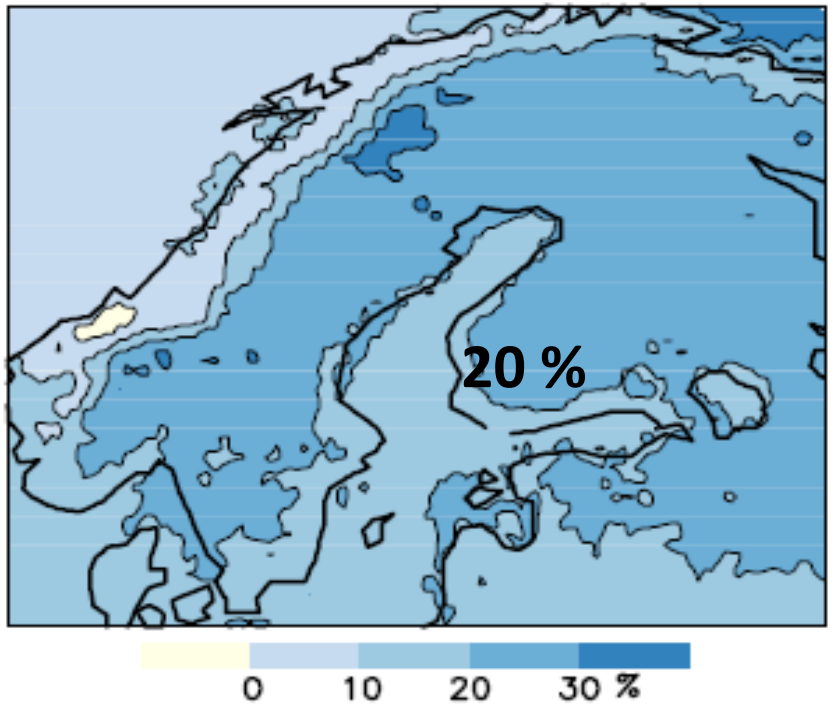
- **12** RCM simulations at **25 km** resolution
  - Not all independent regarding the GCMs/RCMs used
- SRES **A1B** scenario (700 ppm CO_2 in 2100)
- ”Present” = **1980-2010**
- Future = **2069-2099**
- Focus mostly on ensemble mean results (simple averaging of the 12 simulations)

Changes in extended winter (November-March) mean climate from 1980-2010 to 2069-2099

Temperature change



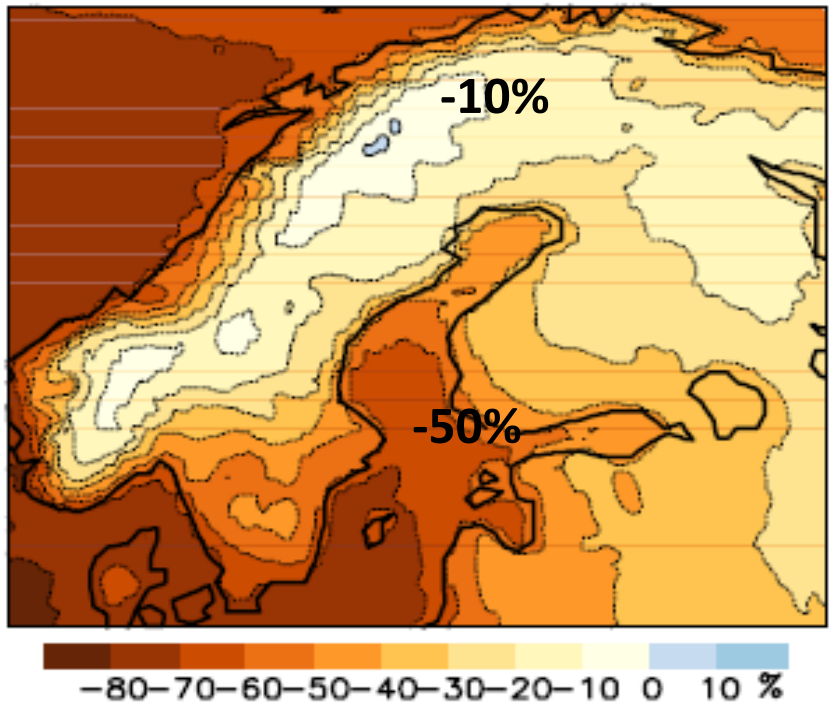
Precipitation change



= much warmer + more winter precipitation (as expected!)

Changes in snowfall

Total annual snowfall

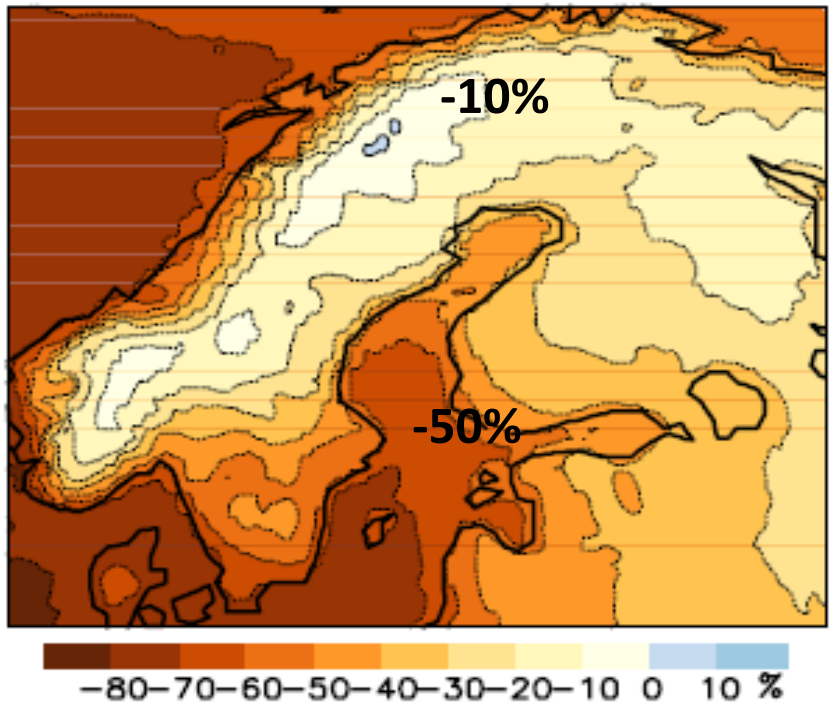


Generally less snowfall:

More precipitation in winter,
but much more of it in rain

Changes in snowfall

Total annual snowfall



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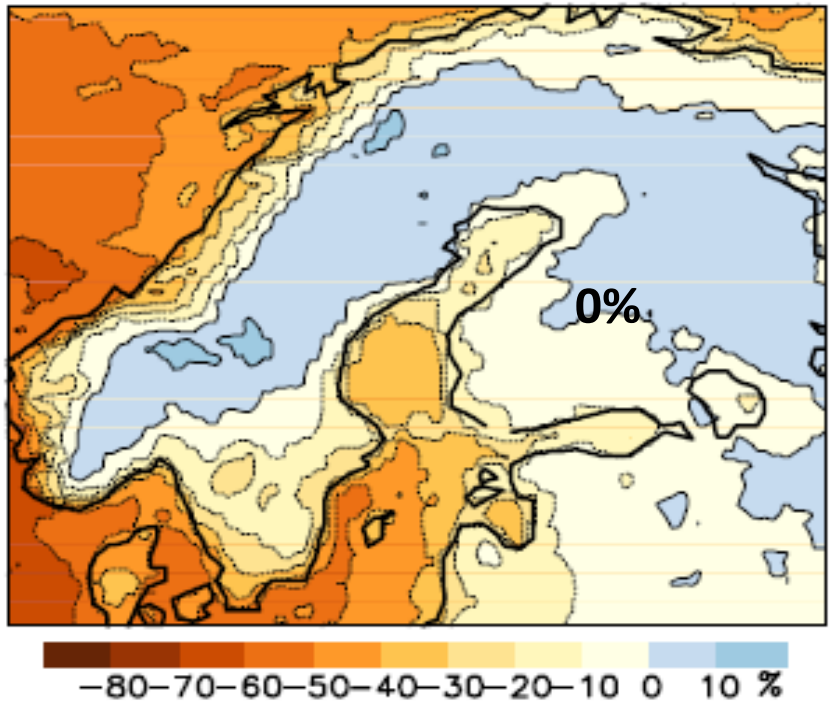
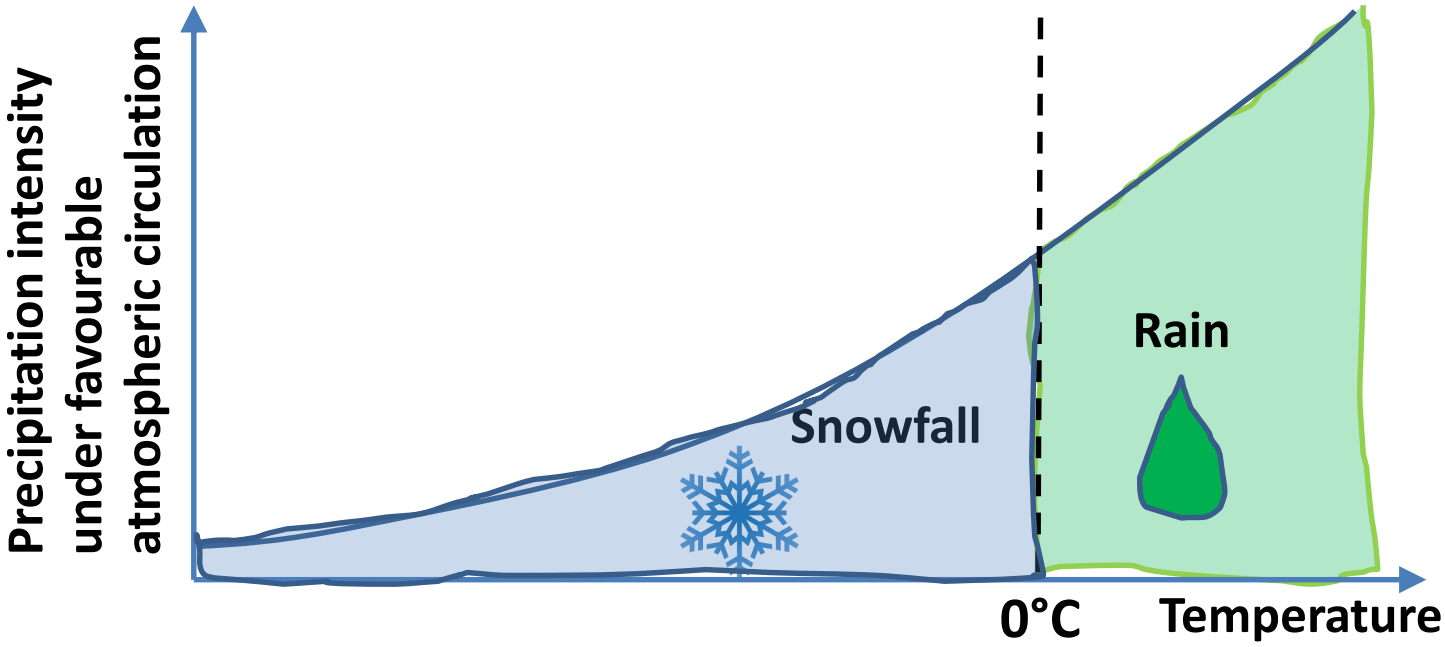
Annual one-day maximum



Little change in extreme snowfall, despite the decrease in the annual total

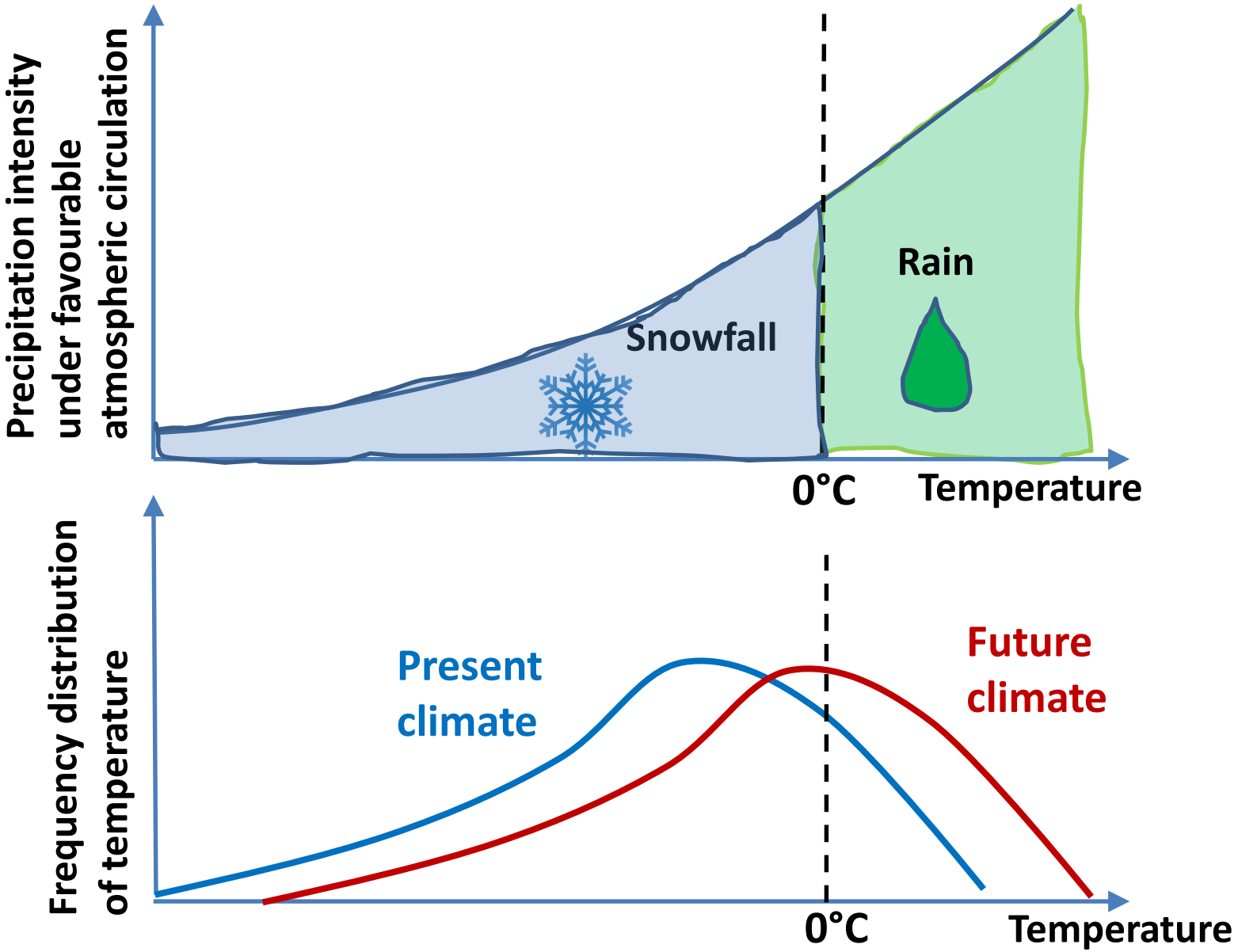
A schematic view on what happens



1. **Increase in precipitation intensity with increasing temperature** (due to increasing water vapour)

2. **Precipitation only falls as snow when it is cold enough** (<≈ 0°C)

A schematic view on what happens



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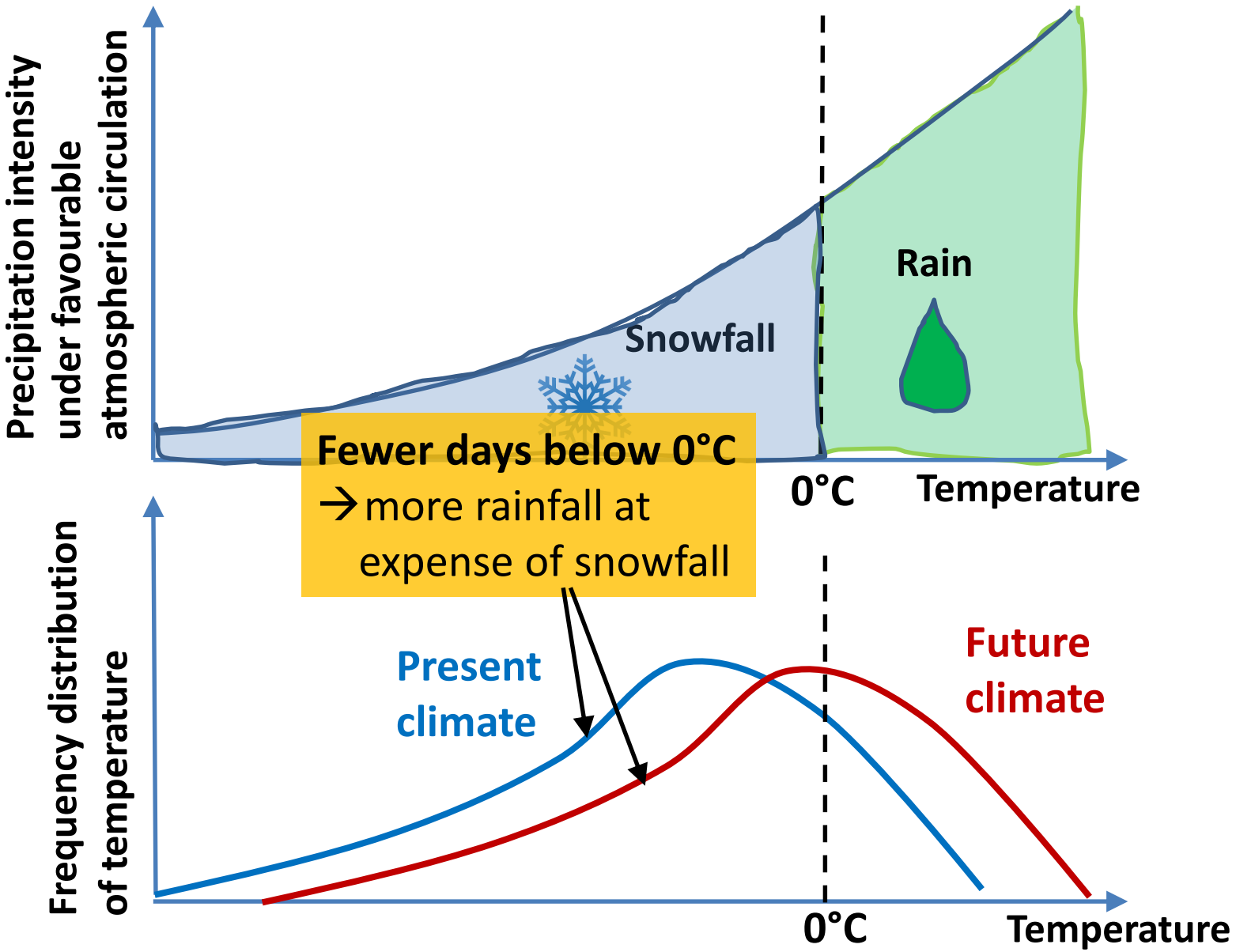
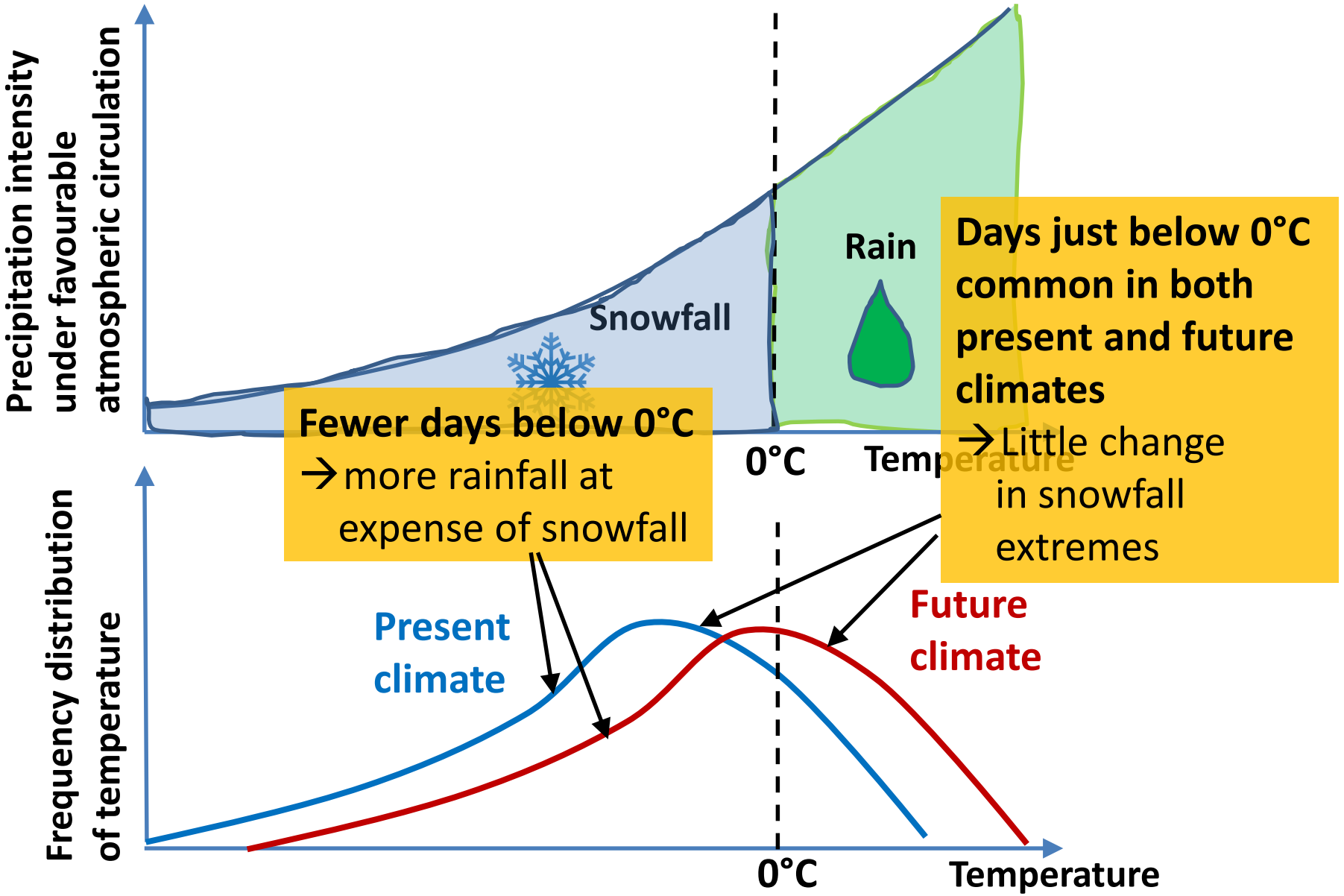


A schematic view on what happens



Two refinements to the schematic view

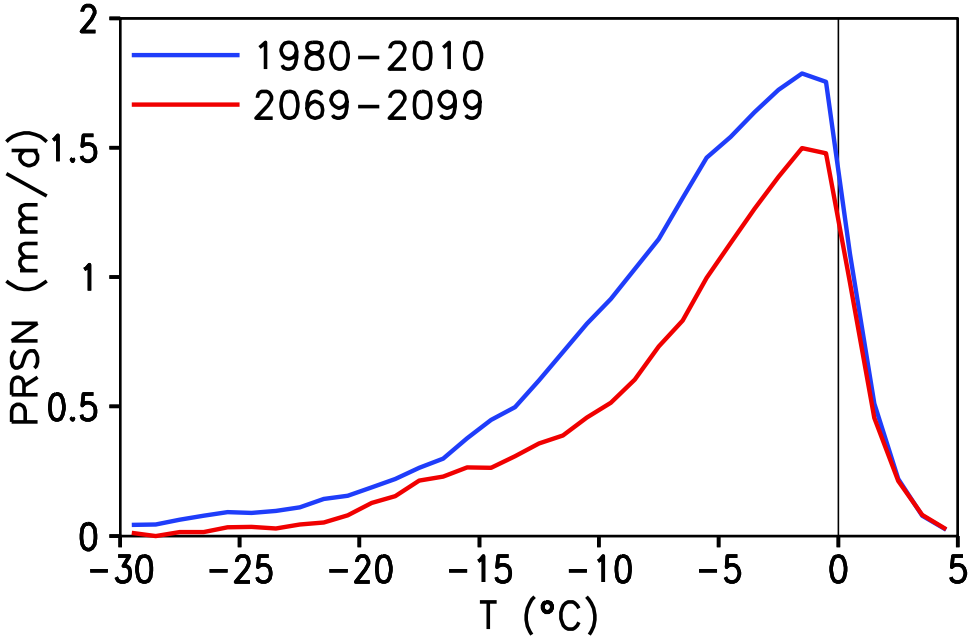
1. **Snowfall not a function of temperature alone:** atmospheric circulation also matters
   - **In a warmer climate, ”cold” temperatures require more anticyclonic circulation** which is less favourable for snowfall

2. **How much rainfall increases at expense of snowfall strongly dependent on the baseline temperature climate**

   → Larger decrease in snowfall in mild than in cold areas

Mean snowfall as a function of daily mean temperature in Southern Finland (< 61°N)

Less snowfall for the same temperature in the future …



Mean snowfall as a function of daily mean temperature in Southern Finland (< 61°N)

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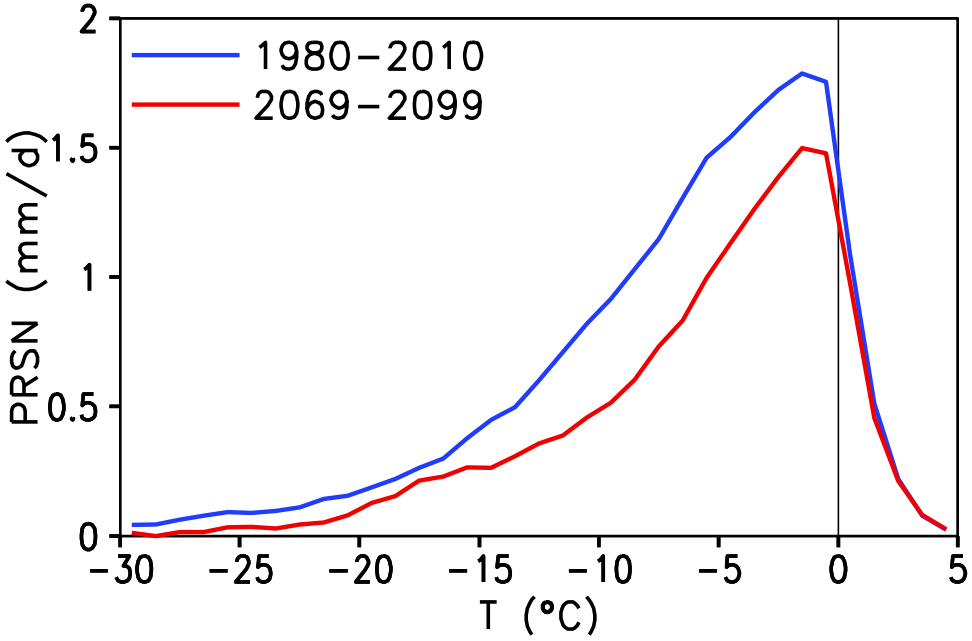
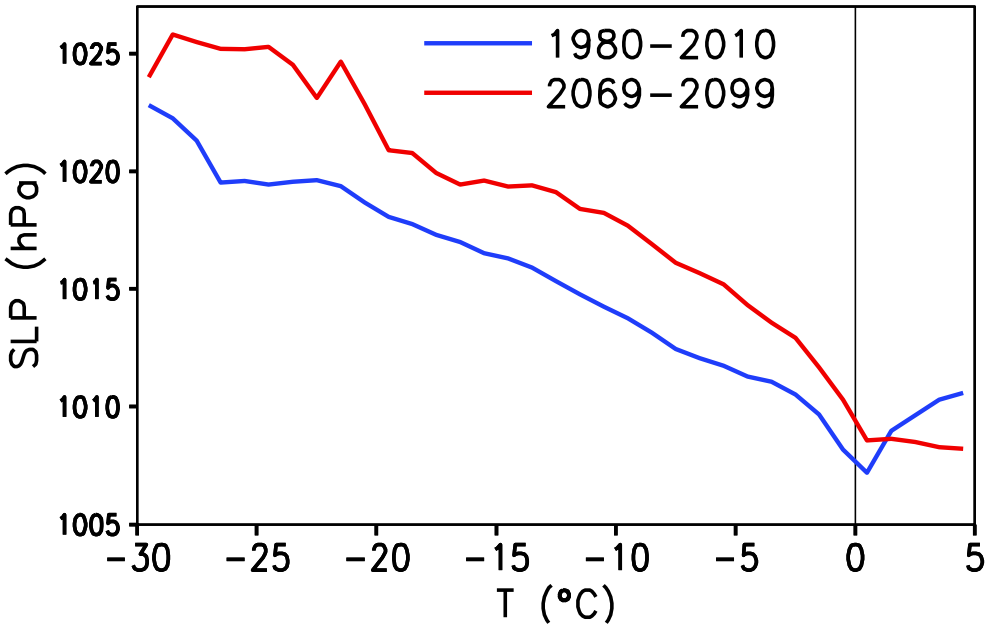
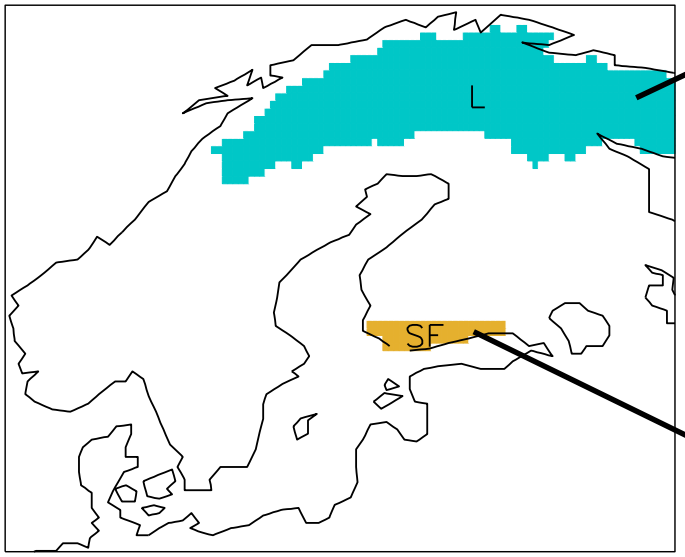


Mean sea level pressure as a function of daily mean T in Southern Finland (< 61°N)

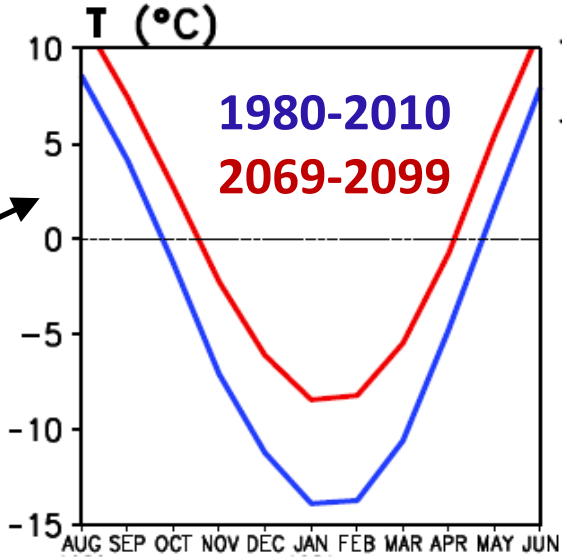
… because low temperatures require more anticyclonic conditions in a warmer climate



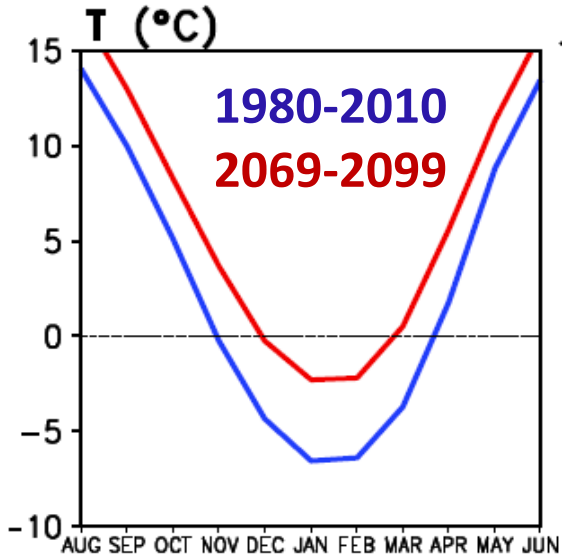
Seasonal cycle of ensemble mean temperature (August → June)



"Lapland"

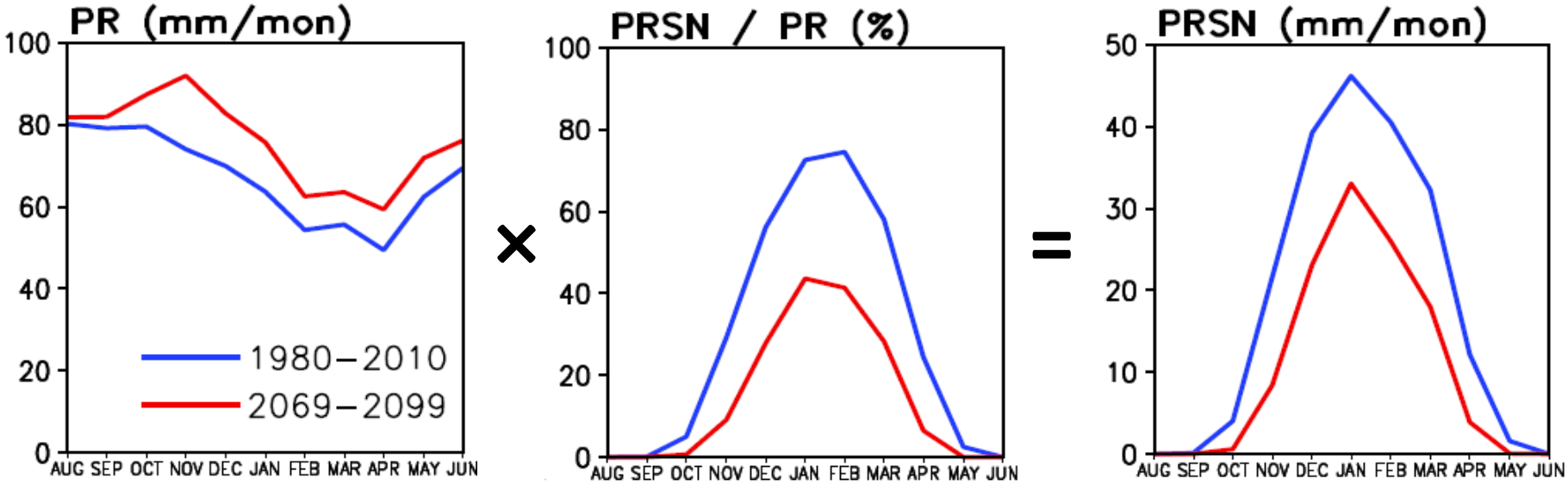


"Southern Finland"



Proper winters in the north
(but not in the south)
even in the end of the century

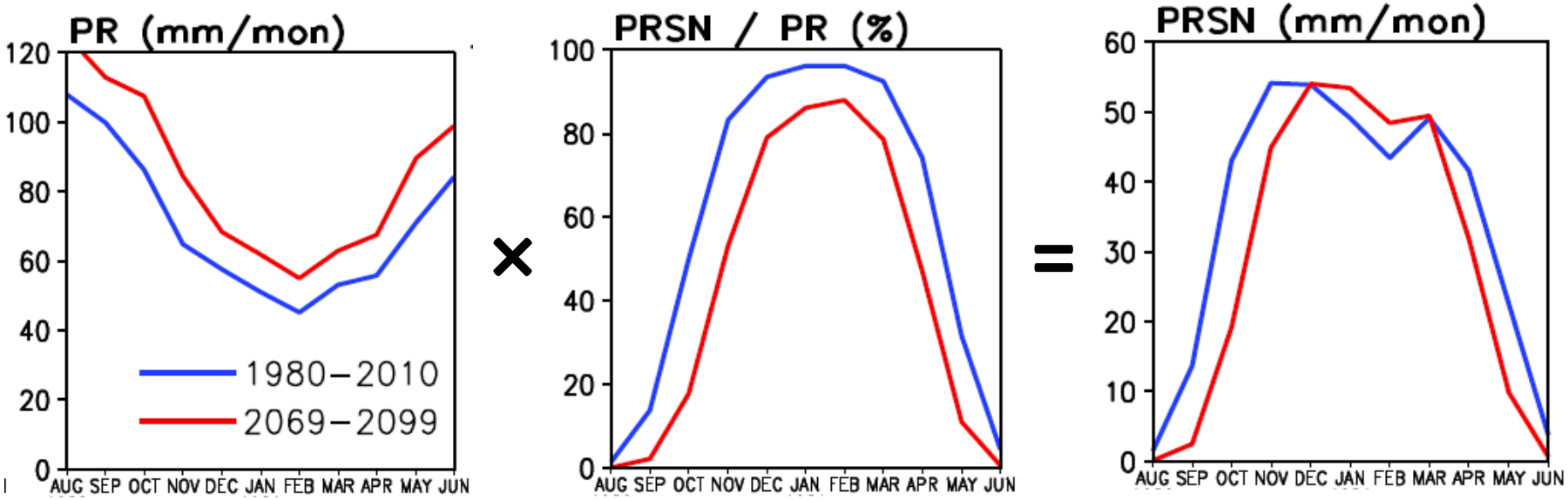
Seasonal cycles in Southern Finland (August → June)



Total precipitation × Snowfall / Tot. precip. = Snowfall

In southern Finland, snowfall decreases througout the winter because the decrease in the fraction of solid precipitation edominates over the increase in total precipitation

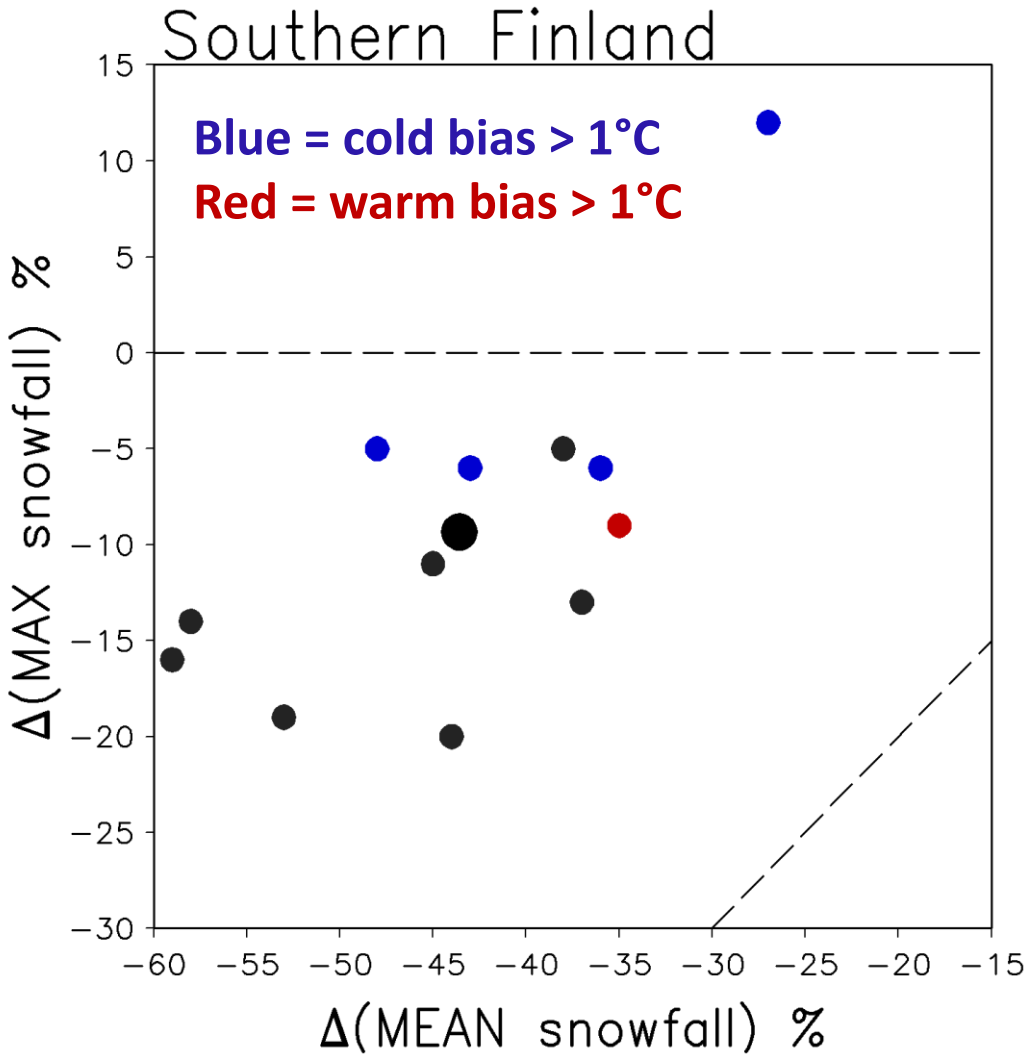
Seasonal cycles in ”Lapland” (August → June)



Total precipitation × Snowfall / Tot. precip. = Snowfall

In ”Lapland” snowfall dominates over rainfall in the middle of the winter even in late 21st century → mid-winter snowfall increases slightly (but snowfall in autumn and spring decreases!)

Variation between models / Southern Finland

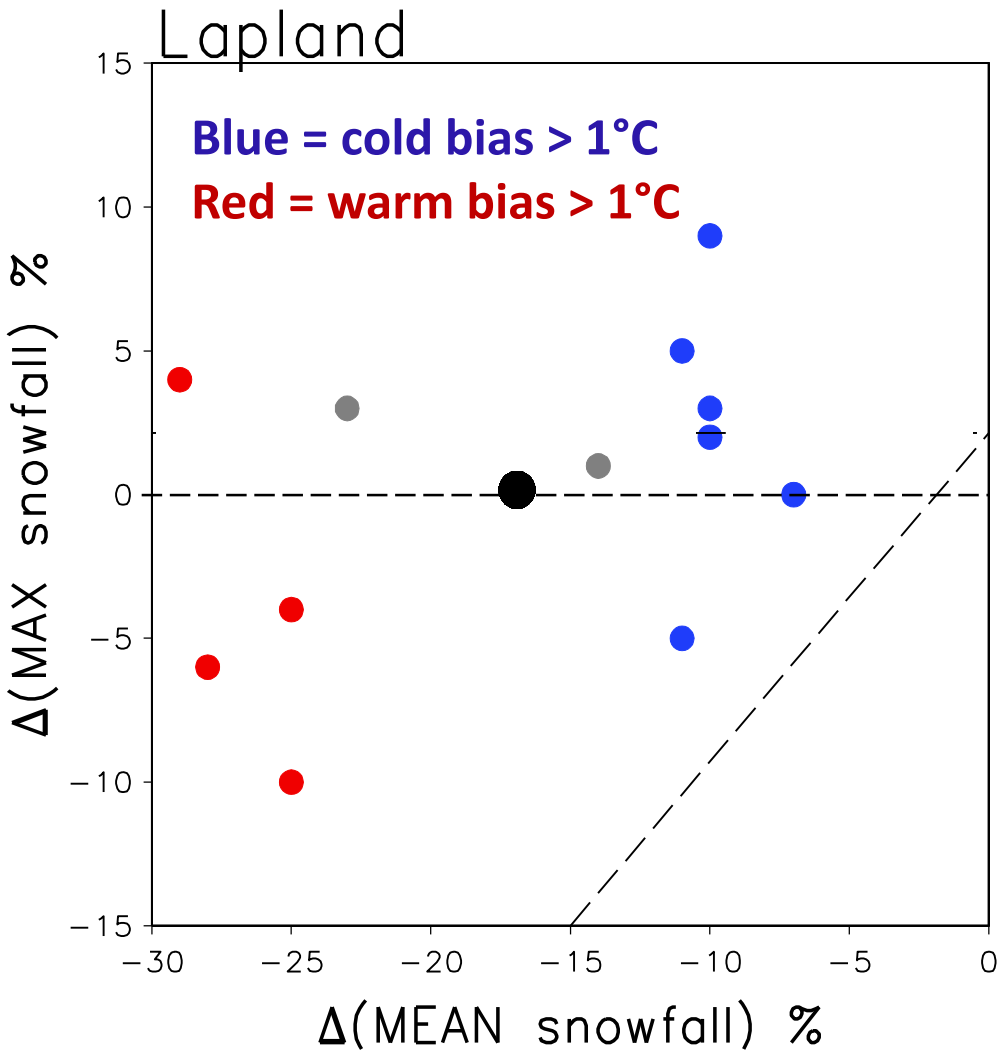


Change in mean snowfall:
-27% … -59%

Change in annual maximum snowfall: -20% … +12%

Less negative changes in models with colder winters in the baseline period (1980-2010)

Variation between models / Lapland



Change in mean snowfall:
-7% … -29%

Change in annual maximum snowfall: -10% … +9%

Less negative changes in models with colder winters in the baseline period (1980-2010)

Conclusions

- **There will be less snowfall overall in a warmer future climate in Finland,** particularly in the south

- **Despite this, high extremes of daily snowfall will more or less maintain their current intensity**

Further reading

- **Räisänen, J. (2014):** 21st century changes in snowfall climate in Northern Europe in ENSEMBLES regional climate models. Climate Dynamics, doi: 10.1007/s00382-015-2587-0.

- **O'Gorman, P.J. (2014):** Contrasting responses of mean and extreme snowfall to climate change. Nature 512, 416-418.