Past and Future snow conditions in Europe calculated by the EURO-CORDEX regional climate model ensemble

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The future evolution of snow is relevant…..

Future snow projections are relevant for numerous sectors:

- Important natural water resource: hydropower, water supply …Water management
- Agriculture (length of snow cover)
- Ecology
- High importance for tourism and recreation in many regions
- Road maintenance
- Surface energy balance (e.g. snow-albedo feedback)

Validierung 1989-2008:
Assess the ability of state of the art RCMs to reproduce observed snow cover

Analysis of 21st century RCM snow cover projections
Simulations, variables and European analysis domain

- **EURO-CORDEX** RCM ensemble at 12 km resolution EUR-11: Reanalysis- and GCM-driven simulations
- Variable: surface snow water equivalent (SWE) and snow depth (SND) (if not available: surface snow depth; conversion by constant density rough estimate of 333 Kg/m³)
- Snow cover day has the threshold of 3 cm snow depth
- European analysis domain with focus on Scandinavia and Alps
Evaluation

• 10 ERA-Interim driven EURO-CORDEX RCMs: ALADIN, CLM, HIRHAM, RACMO, RCA4, RegCM, REMO, WRF

• Datasets: ERA5, GLDAS, UERRA-MESCAN, NSIDC
Mean snow cover duration 1989 - 2008

- Differences in representation of present day snow cover duration
Alps: Snow cover extent [%] 1998 -2008

Observations:
ERA5, GLDAS, UERRA MS, NSIDC
Scandinavia: Snow cover extent [%] 1998 -2008
1989-2008 Temperature and precipitation bias of individual RCMs compared to EOBS (November-April)
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Climate Scenario Simulations
# Climate scenario simulations

<table>
<thead>
<tr>
<th>GCM/RCM (realisation)</th>
<th>RCA</th>
<th>CLM</th>
<th>REMO</th>
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- **RCM**: 9
- **GCM**: 12
- **rcp26**: 18
- **rcp45**: 12
- **rcp85**: 31
Study Focus Regions

Scandinavia

Alps
Alps: Historical snow cover extent [%] 1989-2008 (snow day=3 cm snd)
Snow water equivalent [mm] 1971-2000 (November-April)
Snow water equivalent [mm] 2021-2050 (November-April)
Snow water equivalent [mm] 2070-2099 (November-April)
Snow water equivalent: relative change to 1971-2000 [%]
Scandinavia, 30-year running mean

- **RCP2.6**
  - 0-500 m: -5 to -50 %
  - 500-1000 m: 0 to -45 %
  - 1000-1500 m: 0 to -45 %
  - 1500-2000 m: +5 to -35 % (-65%)

- **RCP4.5**
  - 0-500 m: -30 to -55 %
  - 500-1000 m: -25 to -50 %
  - 1000-1500 m: 0 to -45 %
  - 1500-2000 m: -15 to -65 %

- **RCP8.5**
  - 0-500 m: -55 to -85 %
  - 500-1000 m: -40 to -80 %
  - 1000-1500 m: -25 to -70 %
  - 1500-2000 m: -15 to -70 %

Relative change by 2070-2099

(numbers:)

- Snow water equivalent: relative change to 1971-2000 [%]
  - Scandinavian, 30-year running mean

(Charts showing relative changes for different regions and time periods for RCP2.6, RCP4.5, and RCP8.5 scenarios.)
Snow water equivalent: relative change to 1971-2000 [%]
Scandinavia, 30-year running mean

Relative change by 2070-2099

<table>
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<tr>
<th>Height Range</th>
<th>RCP2.6</th>
<th>RCP4.5</th>
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- **Percentage loss**
- **0 to -45 %**
- **-30 to -55 %**
- **-55 to -85 %**
- **+5 to -35 % (-65%)**
- **-15 to -65 %**
- **-15 to -70 %**
Snow water equivalent: relative change to 1971-2000 [%]  
Alps, 30-year running mean  

RCP2.6  
-20 to -55 %  
-10 to -55 %  
-5 to -40 %  
0 to -30 %  

RCP4.5  
-45 to -75 %  
-25 to -65 %  
-25 to -55 %  
-15 to -45 %  

RCP8.5  
-60 to -90 %  
-65 to -90 %  
-60 to -85 %  
-40 to -70 %
Annual cycle of snow water equivalent [mm]
Alps 1500-2000 m, RCP8.5

1971-2000

2070-2099

no snow left in July, August, September
Annual cycle of snow water equivalent [mm]
Scandinavia 500-1000 m, RCP8.5

1971-2000

2070-2099

no snow left in July, August, September
Summary and outlook:

- RCM-simulated snow cover is overall realistic.
- Climate scenarios indicate **important reduction of European snow cover** by end of 21st Century, even for RCP2.6
- Scandinavia/Alps: **strong loss (55%-90%)** at low elevations for RCP8.5
- Scandinavia/Alps: strong reduction of snow cover duration at low elevations for RCP8.5

- Snow atmosphere feedbacks
- Complete study of climate scenario simulations
Mean snow cover duration 1998 -2008