Sensitivity of Present Day Arctic Climate Simulations to Snow

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Motivation

- snow covers Arctic land areas between 6 and 9 months of the year, it acts as a mediator between atmospheric and ground conditions
- snow melt impacts hydrology (availability of water, summer temperatures) with longterm effects
- surface conditions impacted by snow interact via feedback mechanisms with atmosphere

Questions:

1. **To what snow properties are the simulations of atmosphere and ground sensitive? What do those sensitivities look like?**
2. **Are there remote impacts on the atmosphere, or are all effects only local? What are possible feedbacks?**

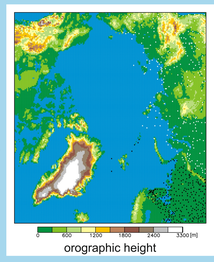
Conclusions

- **impact of changing optical properties of snow or grid cell are relatively small and mostly not statistically significant**
- **snow albedo changes associated with snow aging change the ground significantly via changes in snow melt**
- **impacts on the atmosphere are most prominently remote, not statistically significant**
- **statistically significant differences in cyclone tracks are found, which can be associated with air temperature differences, especially in winter snd summer**

Model and experiment setup

model: regional Arctic climate model HIRHAM5-CLM4SP[1]

- run with 60 vertical levels and 25km horizontal resolution, the domain roughly covers the area north of 60°N
- ERAInterim data are used as lower and lateral boundary conditions, the runs cover 10 yrs (2005-2014)
- 6 model runs for sensitivity study
- all experiments were run with identical initial conditions

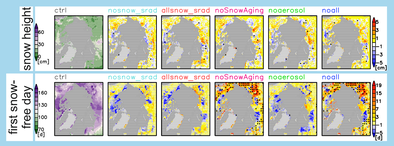


orographic height

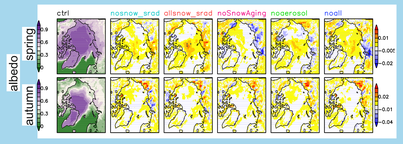
sensitivity experiments

- **ctrl**: standard CLM snow scheme
- **allsnow_srad**: if there is snow, the canopy is always completely covered by snow (approximation of no snow masking by vege-tation)
  → higher albedo
- **nosnow_srad**: there never is snow on the canopy (approximation of maximum possible snow masking by vegetation)
  → lower albedo
- **noaerosol**: aerosol deposition on the snow was switched off
  → higher albedo
- **noSnowAging**: changes of albedo due to snow aging are switched off
  → higher albedo
- **noall**: maximization of snow dependent albedo, combination of **allsnow_srad**, **noaerosol** and **noSnowAging**
  → highest albedo

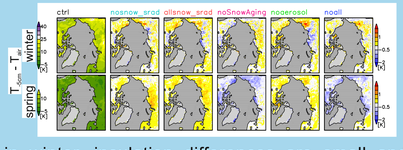
Changes in snow and its properties



- snow height shows positive and negative changes of similar magnitude in all experiments, the differences are not statistically significant
- first snow free day shows significant positive differences (up to 15 days) for **noSnowAging** and **noall**

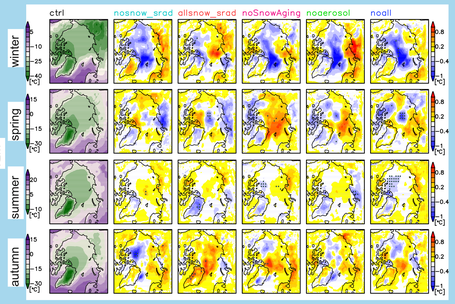


- albedo differences are small and inhomogeneous
- in autumn, differences are similar between runs
- in spring, there are similar patterns of negative albedo differences for **noSnowAging** and **noall** related to later snow melt



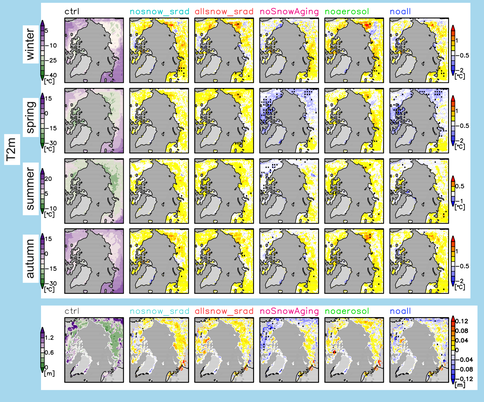
- in winter, insulation differences are small and inhomogeneous over the domain
- spring differences are similarly positive around 1K and homogeneous for the whole domain for **nosnow_srad**, **allsnow_srad** and **noaerosol**
- **noSnowAging** and **noall** show negative insulation differences in spring related to later snow melt

Sensitivity of 2m air temperature



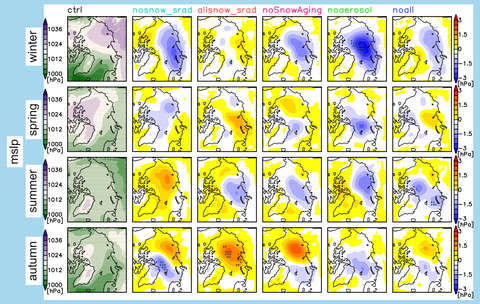
- differences are small (+-1K) and mostly not statistically significant for all runs and seasons
- most prominent differences occur over the ocean (remote)
- winter and summer patterns are similar among runs
- in spring, four runs show similar patterns (**noaerosol**, **nosnow_srad**, **allsnow_srad**, **noall**), while **noSnowAging** looks different

Sensitivity of 20 cm soil temperature and active layer thickness

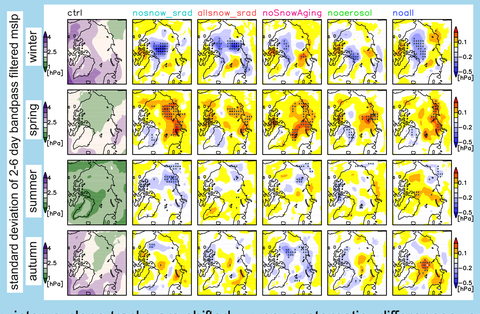


- soil temperature differences are in the same range as air temperature differences
- significant negative differences of up to 1.5K occur for **noSnowAging** and **noall** in spring
- smaller negative significant differences occur for **noSnowAging** in summer (accordance with later snow melt and partly with air temperature)
- longer snow presence in spring leads to lower active layer thickness (ALT) for **noall** and **noSnowAging**

Remote impact: atm. circulation



- differences in mean sea level pressure (mslp) are small (±3hPa) and mostly not statistically significant for all runs and seasons
- most prominent differences occur over the ocean (remote impact)
- no systematic differences between the runs are apparant



- in winter, cyclone tracks are shifted from north of Greenland towards the Barents and Kara seas for all runs
- in spring, all runs show an intensification of cyclones along the Siberian coast
- no systematic differences occur between the runs, within one season, all patterns have strong similarities
- air temperature patterns are associated with shifts in cyclone tracks in winter (differences with same sign) and summer (differences of opposite sign)

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[1] Matthes, H. , Rinke, A., Zhou, X. and Dethloff, K. (2017): Uncertainties in coupled regional Arctic climate simulations associated with the used land surface model, Journal of Geophysical Research Atmospheres, https://doi.org/10.1002/2016JD026213.

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