Sensitivity of Arctic climate change to changing land surface conditions

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REKLIM Helmholtz-Verbund Regionale Klimaänderungen

1 Introduction

- land surface conditions impact on atmospheric parameters, most importantly air temperature and mean sea level pressure
- the interaction and its complexity is investigated, using climate projections for the end of the 21st century as derived with the regional climate model HIRHAM
- presented is the sensitivity of projected climate change signals $(\bar{X}_{future} - \bar{X}_{present})$ over the Arctic to different land surface conditions (different model implementations)
- sensitivity $(\bar{X}_{future} - \bar{X}_{present})_{EXP} - (\bar{X}_{future} - \bar{X}_{present})_{CTRL}$ is derived by comparing the climate change signals of three experiment runs to the climate change signal of the control run

2 Experiment Setup

- for all four simulations, the control period 1980-1999 and a future time slice 2080-2099 were run
- the forcing, including sea ice, was identical for all experiment runs and taken from ECHAM5/ MPI-OM (SRES A1B scenario)
- the setup of the control run (HIRHAM with **LSM**, **MINERAL** soil and **FIXED** vegetation) differs from the various experiment runs in specific land surface conditions: simple versus advanced ground scheme (**HIR-LSM**), organic versus mineral soils (**ORGANIC-MINERAL**), varying versus fixed vegetation (**TRANSIENT-FIXED**)

HIR-LSM

Soil thermal properties	Phase changes	Ground moisture	Vegetation
LSM: seasonally & spatially varying	LSM: incl. by adding latent heat to heat capacity	LSM: moisture levels & transport	LSM: advanced vegetation
HIR: seasonally & spatially constant	HIR: no phase changes	HIR: bucket model	HIR: simple vegetation (fractions, LAI)

ORGANIC-MINERAL

improved representation of Arctic soils by included top organic soil layer:

(1) additional texture types (moss, peat, lichen)

(2) different texture is specified for each layer

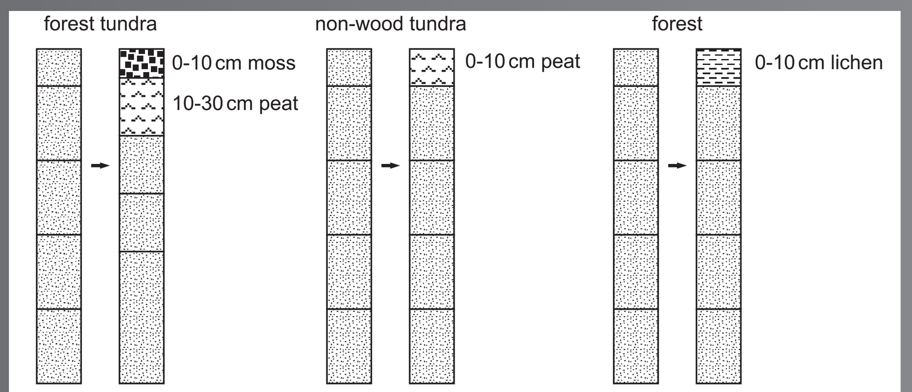

Fig 1: Representation of Arctic soils by inclusion of organic soil layers in the ground column

TRANSIENT-FIXED

- **FIXED** runs with constant present day vegetation distribution throughout the scenario
- **TRANSIENT** runs with transient vegetation as simulated by LPJ-GUESS

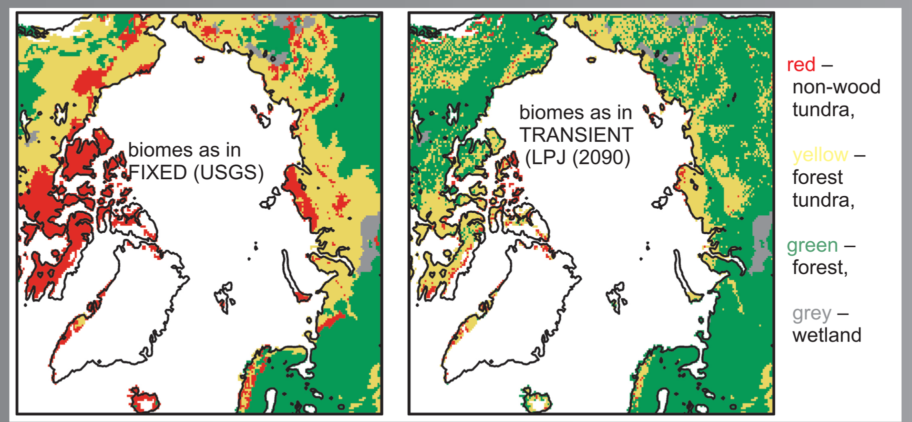

Fig 2: Biomes used for the **FIXED** (left panel) and **TRANSIENT** (right panel) vegetation runs

3 Thermal Response

- sensitivity in the 2 m air temperature over land shows the direct thermal impact of changes in land surface conditions

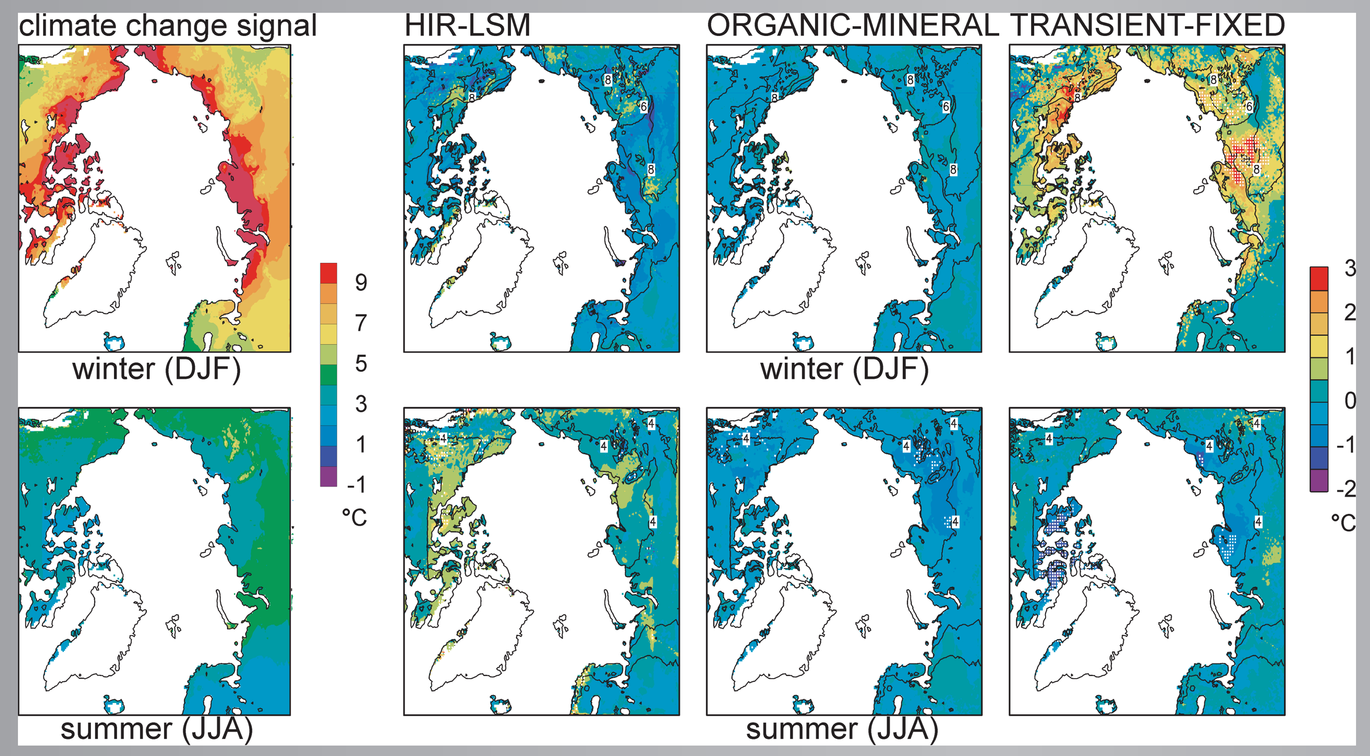

Fig 3: left panel: climate change signal of the control run; other panels: spatial distribution of the sensitivity (isolines: climate change signal of the control run)

ORGANIC-MINERAL:

- signal smaller than for both other comparisons (±1°C)
- strongest negative signal at the coastal area east of Taymir Peninsula

TRANSIENT-FIXED:

- in winter, dominantly positive signal (up to 3°C)
- small negative signals in summer in coastal areas
- changes mainly due to albedo shift in snow covered areas

HIR-LSM:

- signal between -2 and 1°C
- slighlty smaller warming over Eastern Siberia winter, larger warming over Alaska and Canada in summer
- complex changes in model, difficult to allocate to a specific process, most probable reason: change in snow (snow fraction, period of snow cover)

4 Uncertainties

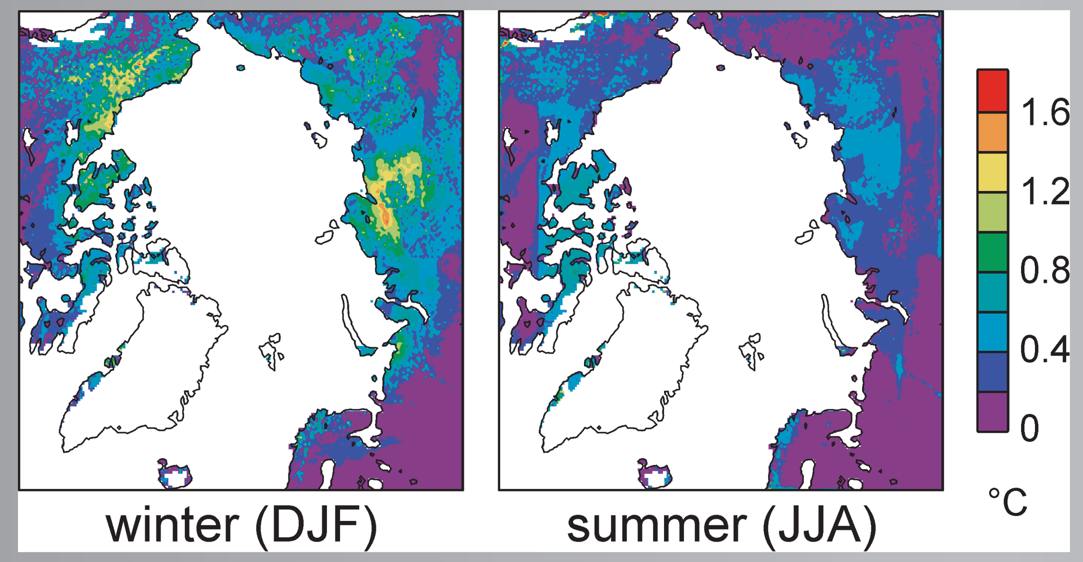

Fig 4: across-ensemble scatter (standard deviation, over all four runs) of the climate change signal in the 2m air temperature

- scatter across the projections of the different runs is high (0.1–1.8°C), particularly over tundra regions (up to 1.8°C)
- in tundra regions, projection uncertainty is high, so that one realization of the model is not enough to describe potential changes
- uncertainty is higher in summer (uncertainty of up to 0.8°C for a climate change signal of up to 4°C) than in winter (uncertainty of up to 1.4°C for a climate change signal of up to 10°C)
- areas of high uncertainty are associated with vegetation shifts

5 Dynamical Response

- sensitivity of the climate change signal of mean sea level pressure (mslp) shows the dynamical response of the atmosphere to changes in land surface conditions
- vertical temperature profile shows propagation of response with height
- these responses are triggered by the non-linear feedbacks within the atmospheric system

mean sea level pressure

ORGANIC-MINERAL:

- very small signal in t2m, but signal in pressure similar in magnitude as in other runs --> strong dynamical feedback
- patterns different from those in other experiments

HIR-LSM:

- small differences in t2m, still considerable differences in pressure patterns
- signal strong over ocean --> dynamical feedback

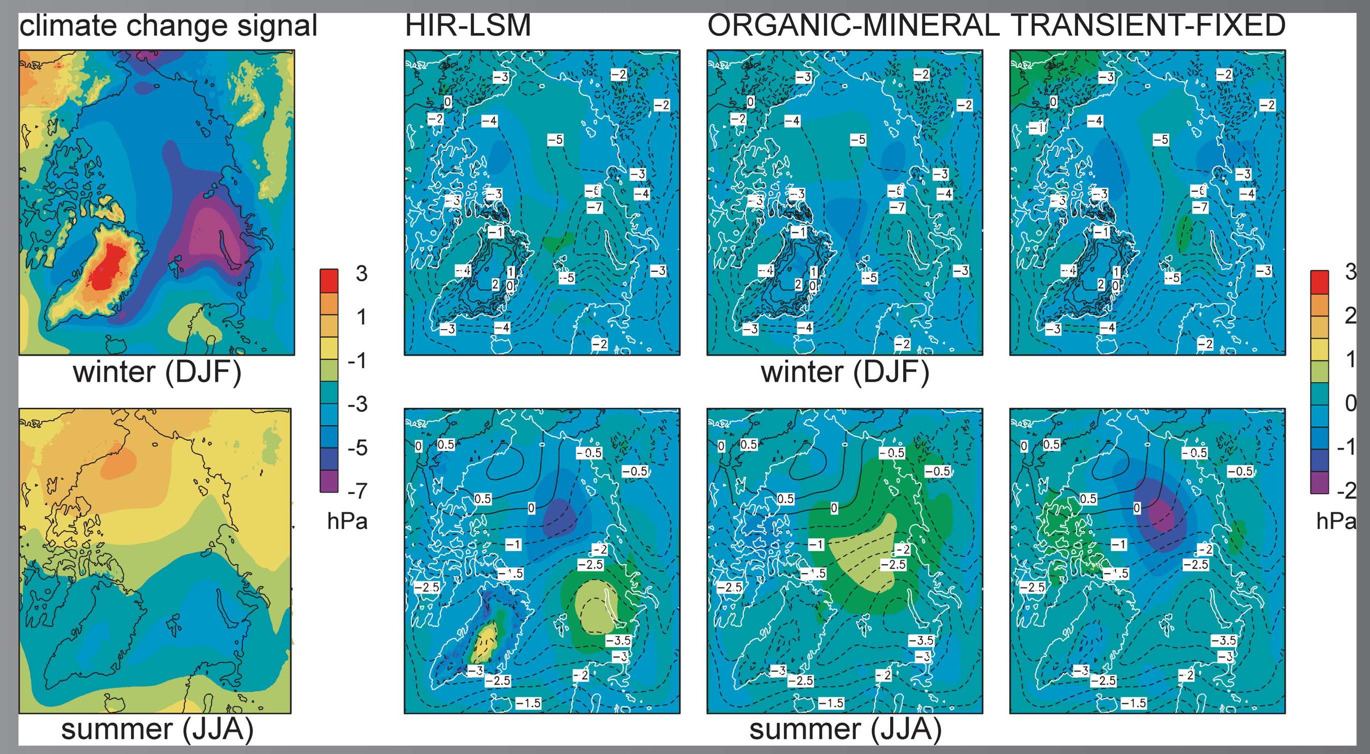

Fig 5: left panel: climate change signal of the control run; other panels: spatial distribution of the sensitivity (isoline: climate change signal of the control run)

TRANSIENT-FIXED:

- patterns are similar to HIR-LSM, but with differences in expression of signal
- the signal is stronger in summer compared to winter

vertical temperature profiles

- surface inversion strength is diminished in future time period for all experiments and biomes
- especially strong effect for experiment **TRANSIENT** (eg inersion strength for non-wood tundra decreases from 5°C to 1.9°C compared to FIXED with decrease from 5°C to 2.2°C)
- sensitivity decreases with height

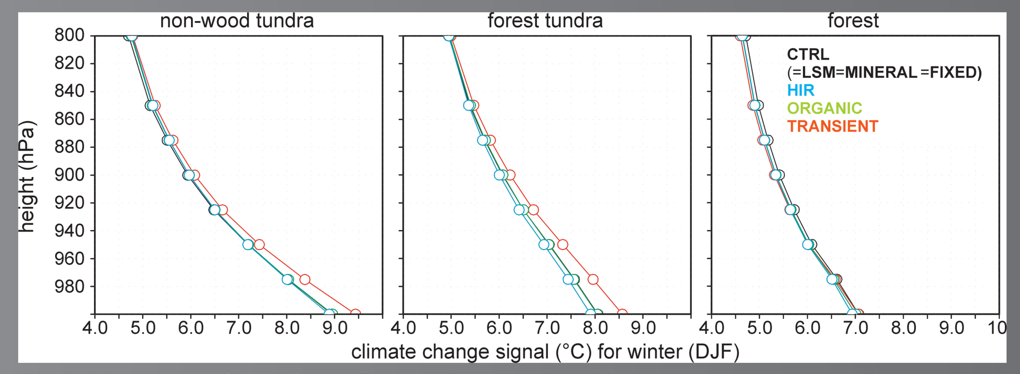

Fig 6: Vertical profiles of the climate change signal in temperature, spatially averaged over the different biomes for each experiment run and the control run

6 Conclusions

- the climate change signal is sensitive to land surface conditions, all experiment runs show sensitivity signals
- changing land cover has strongest influence on near surface climate (eg 2m air temperature and turbulent heat fluxes)
- highest uncertainties in tundra regions (0.5 to 1.5°C for climate change signal: 3 to 10 °C)
- alongside the regional thermal effects in near surface climate, changes in the land surface condition result in large-scale dynamical effects

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