Assessment of Arctic feedback processes in climate models

E01

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1 Summary

Quantification and evaluation of feedback processes

- Quantify feedback parameters in Arctic from CMIP5/6 multi-model ensemble and new simulations with the ICON GCM using partial-radiative-perturbation method
- Process-oriented evaluation of the cloud feedback using large-eddy simulations, campaign observations and ground-based remote sensing
- Climate-oriented evaluation of feedback mechanisms using satellite-derived trends and model sensitivity studies

Hypothesis

We can quantitatively identify the important physical climate feedback mechanisms in the Arctic using state–of–the–art GCMs.

2 Research rationale

Feedback quantification from models

- Climate models include relevant processes
- Techniques have been developed for quantification
- Partial-radiative-perturbation most reliable and allows for cloud feedback assessment

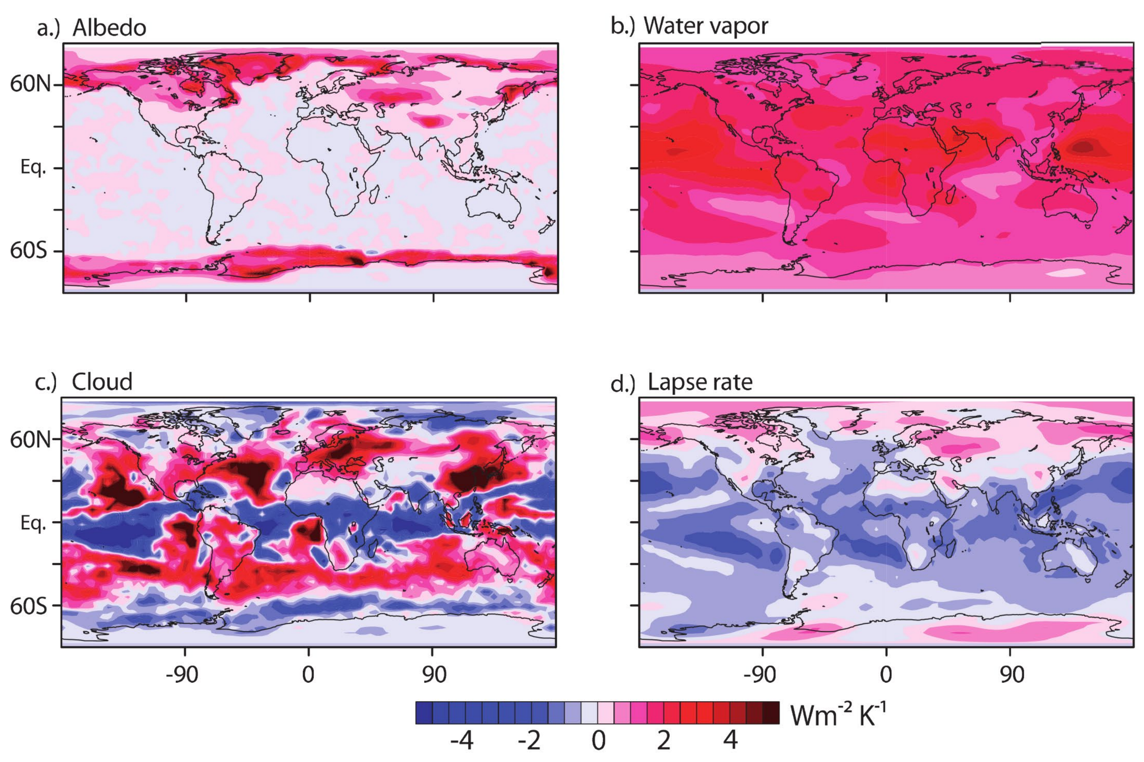


Fig. 1: Geographical distribution of the feedback strength for the (a) surface albedo (b) water vapour, (c) cloud and (d) lapse rate feedback, from a six–year simulation with the MPI–ESM. From Klocke, Quaas and Stevens (Clim. Dyn. 2013).

Cloud feedback dominates uncertainty

- Most variable feedback
- Particularly challenging in the Arctic
- Especially low-level, mixed-phase clouds are challenging and need improved parameterisations

Climate modelling as integrative tool

- General circulation models simulate interaction of processes with others, and of processes with the general circulation in ocean and atmosphere
- May be used for long-term integrations and climate projections
- Help detection and attribution, hypothesis development

3 Research plan

WP1 Arctic feedback quantification from climate models

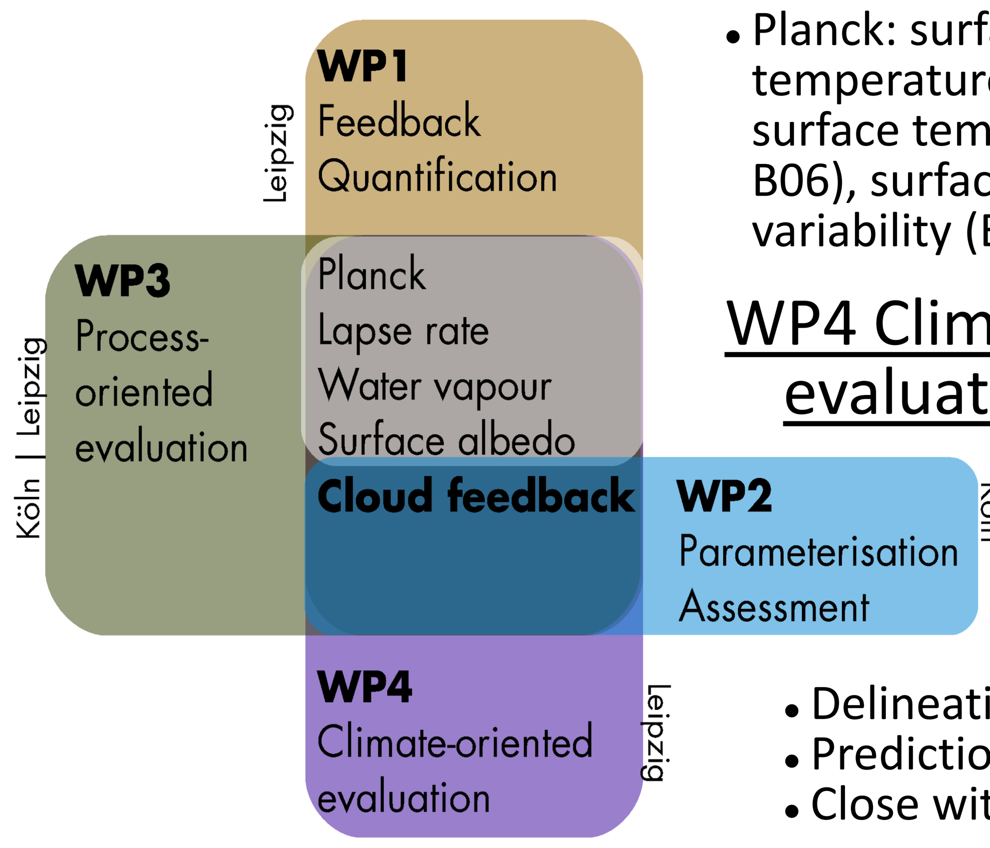
- Use partial-radiative-perturbation to quantify feedback strength in the Arctic from CMIP5 multi-model ensemble
- Planck, lapse-rate, water vapour, surface albedo and cloud (disentangle components from fraction, height, optical thickness) feedback processes
- Idealised 4xCO_2 simulations, and period 1990 – 2019 from historical + RCP8.5
- Inter-model spread and methodological uncertainty

WP2 Cloud parameterisation assessment for Arctic

- Analyse different cloud parameterisations in ICON and HIRHAM simulations
- Model ensemble ICON R2B04 (~127 km), sensitivity study with two-way nest over Arctic to R2B06 (~40 km) for 2006 – 2015 period
- Two microphysics and three cloud parameterisations explored
- Evaluation with E02 column data at supersites and with E03 LES simulations
- Parameterisation improvement and test

WP3 Process-oriented feedback evaluation

- Apply climate modelling community satellite simulator (COSP)
- Cloud feedback: Contoured frequency-altitude diagrams pre-industrial vs. present-day; comparison to satellite data for present-day



- Planck: surface temperature vs. OLR, lapse rate: temperature profiles (B05), water vapour: surface temperature vs. vapour profile (B05, B06), surface albedo: snow- and sea ice cover variability (E04)

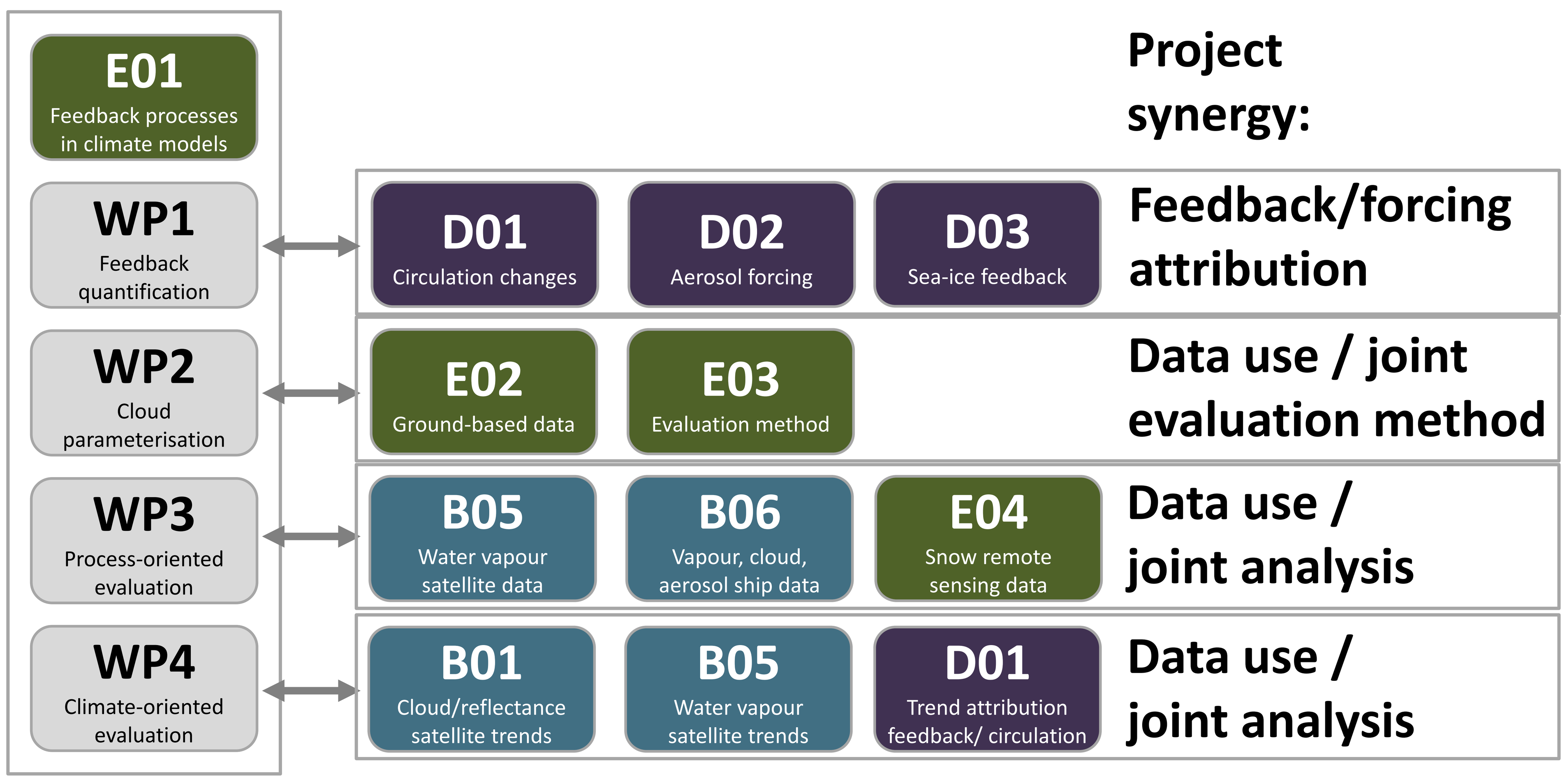
WP4 Climate-oriented feedback evaluation

- Historical and RCP8.5-simulation
  → temporal evolution of surface temperatures and sea ice
  → plus cloud, water vapour, radiation (B01, B05)
- Delineation from circulation changes (D01)
- Prediction of future evolution
- Close with WP1-3 for new simulations

4 Role within (AC)³ & perspectives

Collaboration within (AC)³

- E01 provides large-scale context and modelling framework for feedback processes
- E01 relies on data from (AC)³ for process- and climate-oriented evaluation



Perspectives

- New parameterisations
  → Test new and revised parameterisations from (AC)³ in the ICON GCM
- More interactions
  → New, additional focus on ocean circulation
  → Intensified collaboration on sea-ice and snow interactions
- Deepen model evaluation using (AC)³ data
  → More detailed process-oriented evaluation
  → Comprehensive climate-oriented evaluation
  → using long (AC)³ time-series
  → Use upcoming EarthCARE observations
- International cooperation
  → Make use of and contribute to upcoming 6th Coupled Model Intercomparison Project (IPCC 6th Assessment Report)

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