Snowfall and snow cover, and related feedback mechanisms

E04

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1 Summary

Exploiting long-term satellite data and regional climate model (RCM) simulations in an observation-to-model & model-to-observation approach allows to answer:

- What are the seasonal dependent regional patterns of snowfall, snowfall-to-precipitation ratio, snow cover, and their changes?
- What are the relationships between snowfall changes and atmospheric conditions and sea-ice decline and do they trigger any regional feedback mechanisms?

Hypothesis

Changes in atmospheric conditions and sea-ice decline lead to consequences in regional snowfall patterns in the Arctic, which feed back to the sea ice.

2 Research rationale

Motivation

- Longer-term precipitation changes are supposed to be predominately driven by warming and the associated moistening, while changes in cyclones may have greater influence on shorter-term precipitation changes
- Reanalyses reveal only few regions with significant trends in precipitation though the spatial patterns are not consistent among different reanalyses (Fig. 1)

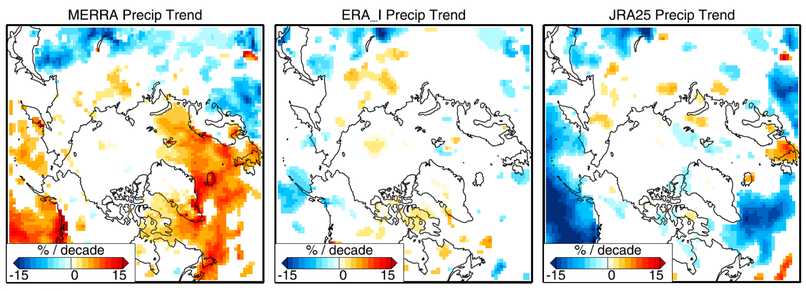


Fig. 1: Annual precipitation trends (%/decade) from three reanalyses (MERRA, ERA-Interim, JRA-25) for 1981-2010 expressed as fraction of mean annual precipitation. From Lindsay et al. (2014).

Challenges

- Feedback assessment of snow related processes is hindered by lack of observations covering snowfall, snow depth and coverage on land and sea ice
- Microwave radiances provide long-term data record, but disentangling surface
  and atmospheric signal is difficult (Fig. 2)
- Microwave signal depends on snow morphology (shape, size and density) both in the atmosphere and at the ground hampering retrievals

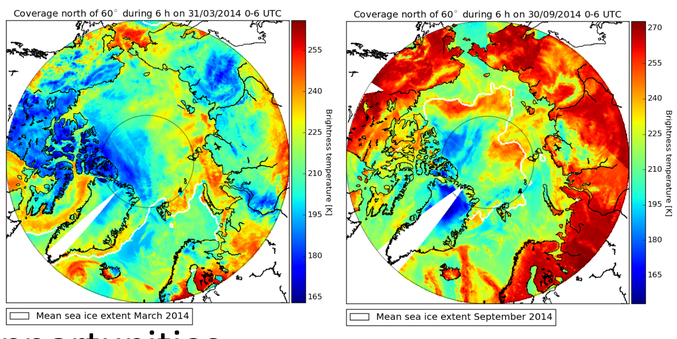


Fig. 2: Brightness temperatures at 90 GHz observed within 6 hours by operational weather satellites in March (left) and September (right), 2014. White line shows sea-ice extent.

Opportunities

- Comprehensive long-term and growing microwave satellite radiance observations available for more than a decade
- Improved techniques for model evaluation and feedback attribution
- Complementary expertise covering regional climate modelling (Rinke), atmospheric remote sensing (Crewell) and sea ice (Spreen)

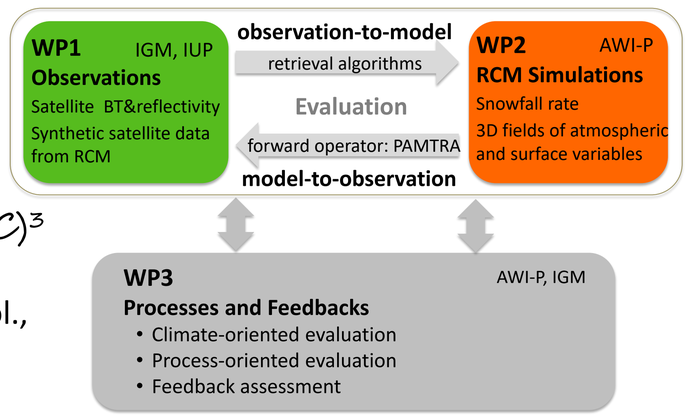
3 Research plan

WP1: Data compilation

- Long-term microwave radiances (2000+), CloudSat (2006+), GPM radar reflectiv.
- Coupling of forward operator PAMTRA to RCM output
- Improved surface emissivity in PAMTRA & consistency analysis (obs. trend)

WP2: RCM Simulations

- Multi-year present-day HIRHAM simulations (ctrl, improved clouds)
- Short-term simulations for (AC)³ campaigns, high-frequency output; sensitivity studies (resol., snowfall & cloud param.)
- Multi-year multi-model present-day climate simulations from the international Polar CORDEX project including two atmosphere-ice-ocean RCMs



WP3: Evaluation of processes and feedback mechanisms

- Climate-oriented evaluation multi-year present-day RCM simulations
  - **Observation-to-Model Approach**
    using CloudSat snowfall, terrestrial snow cover and snow water equivalent from GlobSnow, snow depth on sea ice (D03)
  - **Model-to-Observation Approach** (forward operator; Fig. 3)
    for microwave radiances, radar reflectivities at atm. observatories & CloudSat

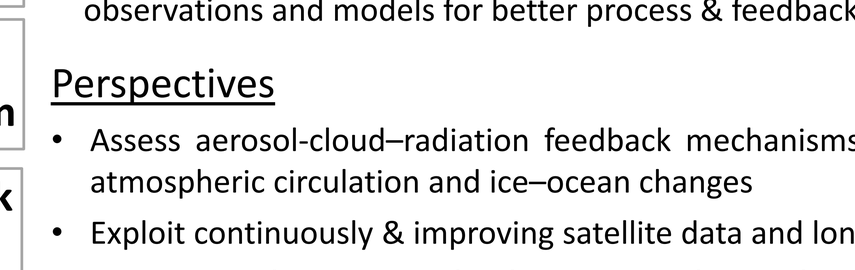
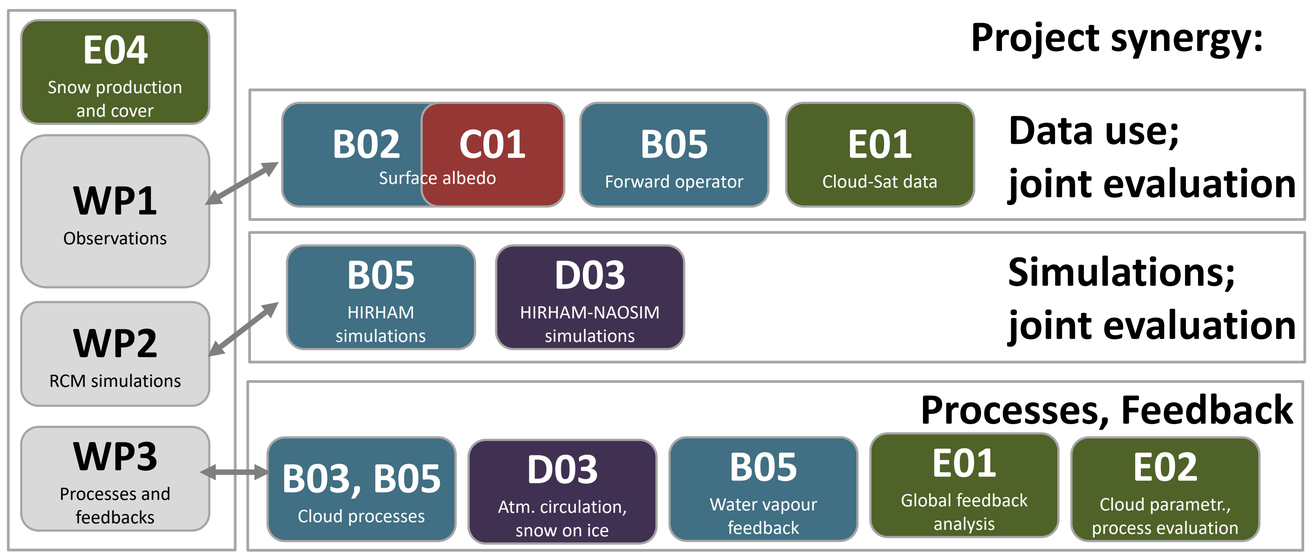


Fig. 3: Joint histograms of radar reflectivity Z and temperature from CloudSat (left) and calculated from GCM output (right). From Reitter et al. (2011).

- Process-oriented evaluation investigating histograms of liquid/frozen precip. in dependence on environmental parameters, regions and seasons
- **Temperature–stratification–clouds–snowfall** feedback assessment
  composites of low & high pressure; snowfall-atmosph. thermodyn. structure
- **Sea ice–moisture–clouds–snowfall** feedback assessment
  composites of low & high sea-ice extent and low & high snowfall (or snow cover)

4 Role within (AC)³ & perspectives



Collaborations within (AC)³

- Detailed investigations of clouds (B–Cluster) and surface (C–Cluster) processes as well as role of atmospheric circulation (Cluster D) are used for the integrative assessment of snow characteristics in the Arctic
- RCM simulations and data base of microwave radiances are shared with B05
- Close collaboration with all projects of the E cluster on the integration of observations and models for better process & feedback understanding

Perspectives

- Assess aerosol-cloud–radiation feedback mechanisms and their links with atmospheric circulation and ice–ocean changes
- Exploit continuously & improving satellite data and long–term profiling data
- Derive cumulative snow depth on sea ice by combining snow precipitation data with satellite sea-ice drift and area data

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