Interactions between atmosphere and sea ice in the Arctic

D03

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1 Summary

Evaluation and quantification of atmosphere-sea ice interactions

- **What are the mechanisms for the rapid Arctic sea-ice loss?**
- **Which are the involved key regional atmosphere–sea ice feedback mechanisms?**
- **Are they appropriately described in climate models and how can they improved?**

→ Application of a high-resolution coupled atmosphere-ice-ocean Arctic RCM
→ Development of high-resolution and combined sea-ice data sets from satellite

Hypothesis

Regional feedback processes arising from (a) interactions between atmosphere and sea ice-ocean and (b) changes in the large-scale atmospheric circulation patterns are critical mechanisms for the Arctic Amplification.

2 Research rationale

Problem

- System–level understanding of critical Arctic processes and feedbacks is still lacking
- Need for better understanding of past, present and future Arctic sea ice changes
- Synthesis of Regional Climate Model (RCM) simulations with integrated observations

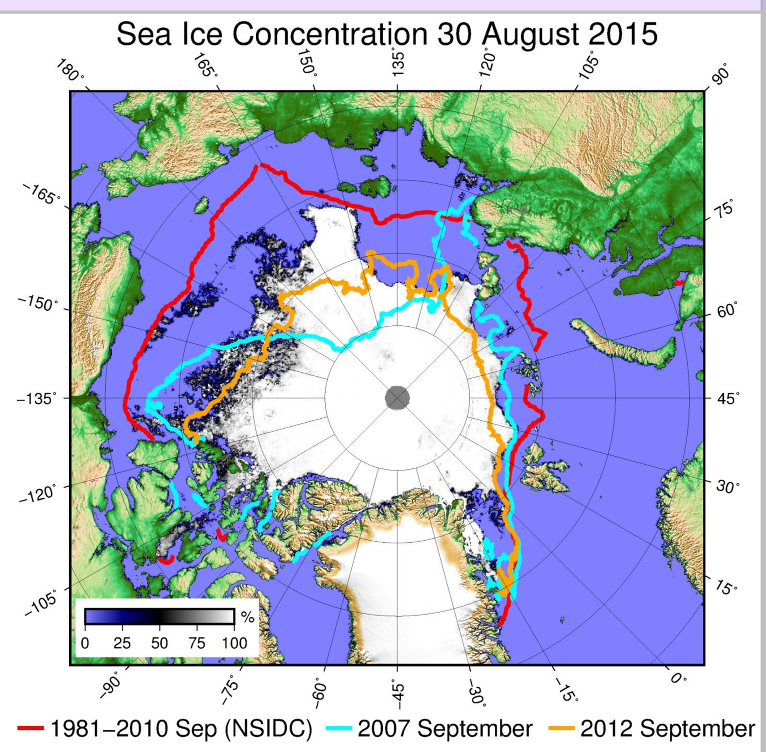


Fig. 1: Current sea-ice area from AMSR2 (6 km resol.) vs. historic summer sea-ice extents

Main drivers & feedback mechanisms

- Both atmospheric circulation changes and local feedback processes contribute to sea-ice decline and Arctic Amplification
- Cloud–related processes are important factor for sea-ice loss, but not well represented in climate models
- Poorly understood interactions between cyclones & sea ice (e.g. ice fracturing, ridging and ice-edge shift; increased transport of heat & moisture)

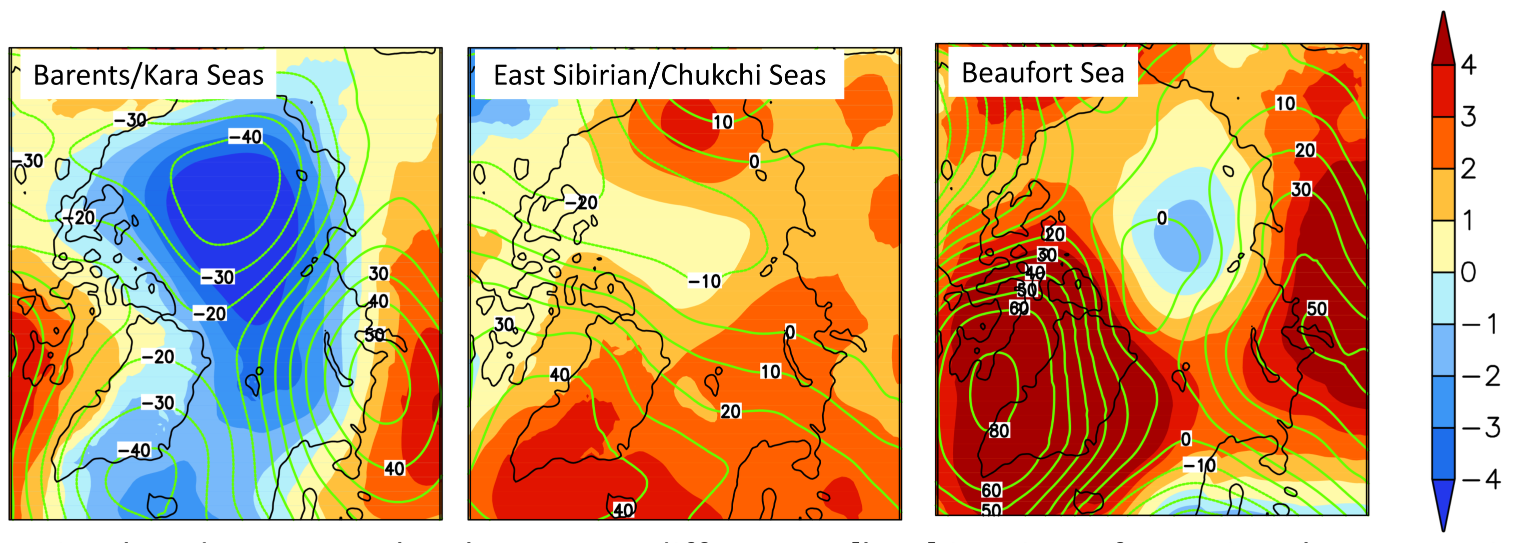
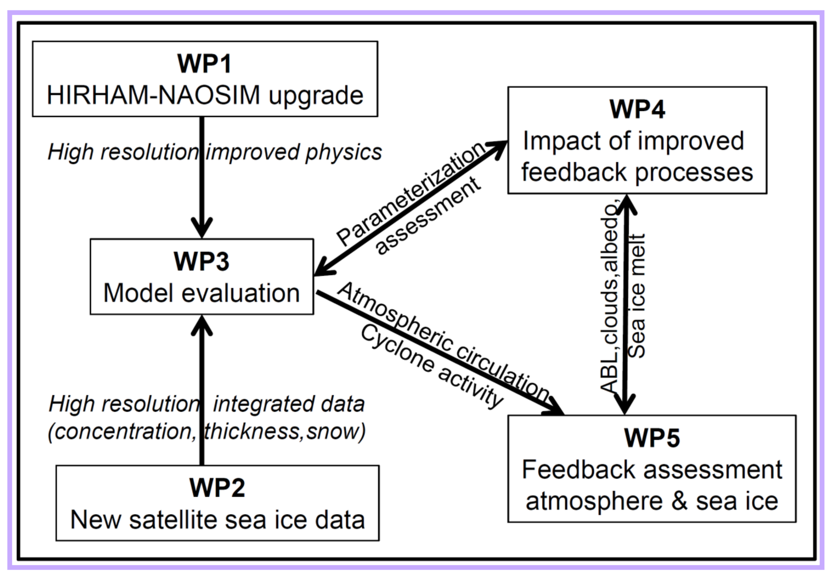


Fig. 2: Simulated mean sea level pressure differences [hPa] in winter for regional Sept. sea-ice anomalies from HIRHAM–NAOSIM ensemble covering 1948–2008), adapted from Rinke et al. (2013)

Sea-ice and snow data sets

- Available long time series of sea-ice concentration reach only a resolution of 25 km which is not well suited for the evaluation of higher resolution RCMs
- Knowledge of sea-ice thickness and snow depth on sea ice is not comprehensive
- Establishing quantitative uncertainty bounds for observations is still a challenge

3 Research plan



WP 1 Upgrade of the coupled HIRHAM–NAOSIM model

- atmosphere & ocean components will be upgraded to new versions with improved physical parameterizations and higher resolution
- HIRHAM: 0.25° (~25 km), 40 vert. levels
  NAOSIM: 1/12° (~9 km), 50 vert. levels

WP 2 Remote sensing data sets of sea-ice parameters

- Improved high-resolution sea-ice concentration (→ *AMSR–E/2 data, 6x6 km res.*)
- Combined sea-ice thickness data set for thick and thin ice (→ *CryoSat-2 & SMOS*)
- Improved snow depth on sea ice (→ *SSM/I und AMSR-E/2*)

WP 3 Model simulations and evaluation

- HIRHAM-NAOSIM ensemble simulations (→ *1979-present; at least 10 ensemble members with respect to ice-ocean initial conditions*)
- Climate-oriented evaluation (→ *regional patterns of atmospheric & sea-ice variables, and their seasonal, inter-annual variability and trends*)
- Quantification of the internally generated variability (→ *across-member scatter*)

WP 4 Impact of improved regional feedback processes

- Quantify impact of improved process descriptions by series of sensitivity studies
- Parameterization of transfer coefficients for heat & momentum over sea ice; A03
- Parameterization of clouds (*Tompkins, Sundqvist*); E01
- Parameterization of surface albedo (*BC–enrichment of snow/ice surface*); D02

WP 5 Feedback assessment related to atmospheric circulation

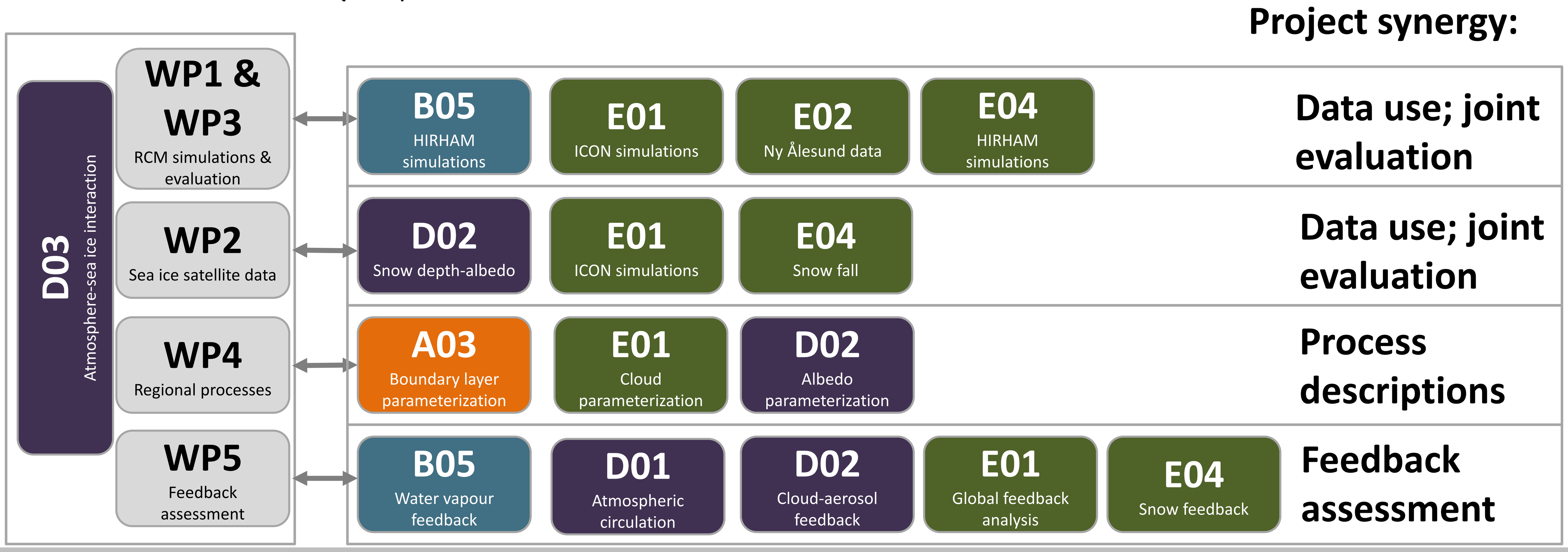
- Analysis of extreme sea-ice events to identify critical mechanisms causing and amplifying sea-ice anomalies (→ *contribution of atmospheric circulation anomalies & anomaly patterns of temperature, water vapour, clouds, radiation to sea-ice concentration variation; e.g. correlation of daily anomalies*)
- Sensitive regions in the Arctic Ocean where sea-ice anomalies strongly feed back to the atmosphere (→ *composite analysis of regional sea-ice anomalies*)
- Feedback processes between cyclone activity and ice-ocean conditions (→ *composites of intense storms; composites of low and high sea-ice cover*)

4 Role within (AC)³ & perspectives

Collaboration within (AC)³

- D03 provides sea-ice data and regional feedback descriptions
- D03 relies on data from (AC)³ for process- and climate-oriented evaluation

Project synergy:



Perspectives

- Model evaluation/improvement and feedback assessment using (AC)³, **MOSAiC** data
- Detailed analysis of ocean processes and involved feedback mechanisms (e.g., potential impact of enhanced oceanic heat fluxes in Atlantic/Pacific; ocean mixed layer & halocline characteristics)
- Relative contribution of atmospheric & oceanic processes to sea-ice decline
- Interaction with land component (e.g., impact of sea-ice changes on water cycle & terrestrial snow cover) and related large-scale feedback
- Merged satellite retrieval of sea-ice, ocean, atmosphere parameters