Interactions between atmosphere and sea ice-ocean in the Arctic

D03

Annette Rinke, Gunnar Spreen
Wolfgang Dorn, Philip Rostosky, Paul Hezel, Klaus Dethloff
Xiaoyong Yu, Thea Schneider, Catalin Patilea, Junshen Lu, Georg Heygster

1. Summary

The research approach is a synthesis of simulations with a coupled regional atmosphere-ice-ocean model and newly derived satellite sea-ice products.

Research questions for phase II:

Q1 How do sea-ice conditions impact the air-ice/ocean momentum and energy exchange and the atmospheric boundary layer and circulation?

Q2 What is the role of cyclone–sea ice feedback mechanisms?

Hypothesis

Regional feedback processes between atmosphere and sea ice–ocean associated with leads and cyclones are critical mechanisms for Arctic amplification.

2. Achievements phase I

New and improved satellite sea-ice data

- New snow thickness product (Rostosky et al., *JGR*, 2018, 2019). ↔ **E04**
  - using lower frequencies at 7 GHz
- New thin sea-ice thickness product (Patilea et al., *TC*, 2019). ↔ **B05**
  - merging SMAP & SMOS observations
- Improved sea-ice concentration data (Lu et al., *J-STARS*, 2018). ↔ **C01, E01**
  - correcting atmospheric influence

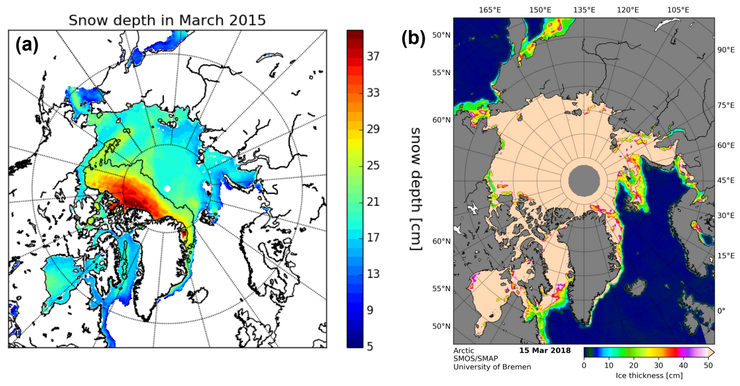


Fig. 1: (a) *Snow depth March 2015 from AMSR2;* ***(b)*** *Ice thickness (<50 cm) from combined SMAP & SMOS from 15.03.2018.*

Improved coupled atmosphere-ice-ocean modeling

- Upgrade of HIRHAM-NAOSIM (→ HN2.0; Dorn et al., *Atmos.*, 2019).
- Evaluation of climatological ice extent, volume and their trends (Dorn et al., *Atmos.*, 2019), ice drift and its impact factors (Yu et al., TCD, 2019), summer melt (Rinke et al., *JGR*, 2019).
- Implementation of improved process descriptions (→ HN2.1):
  - Momentum and heat transfer coefficients over sea ice (Lüpkes and Gryanik, *JGR*, 2015). ↔ **A03**
  - Sea-ice albedo (Jäkel et al., *TC*, 2019). ↔ **C01**

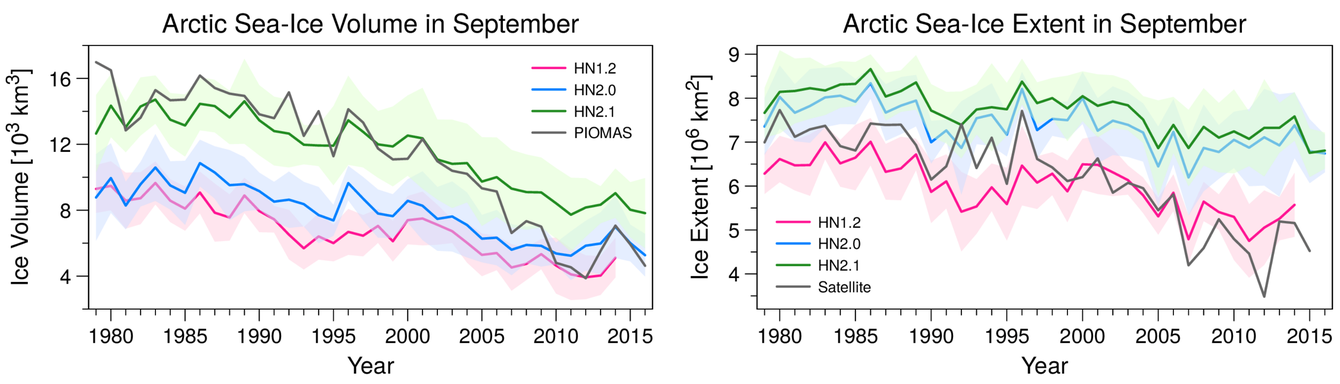


Fig. 2: *Trends of September ice volume (left) and extent (right) from ensemble simulations with different versions of HIRHAM–NAOSIM in comparison to observationally-based data.*

Atmosphere and sea ice-ocean feedback processes

- Quantification of summer ice melt related atmospheric circulation and cloud-radiation feedbacks (Rinke et al., *JGR*, 2019). ↔ **D01, E04**
- Assessment of the atmospheric feedback in autumn and winter on summer ice anomalies (Rinke et al., *Env. Res. Lett.*, 2017). ↔ **D01, E02**
- Impact analysis of intense summer storms on ice-ocean (Semenov et al., *Atmos.*, 2019).
- Quantification of winter storm's impact on ice-ocean in the Arctic North Atlantic (Graham et al., *Sci. Rep.*, 2019).

3. Research plan phase II

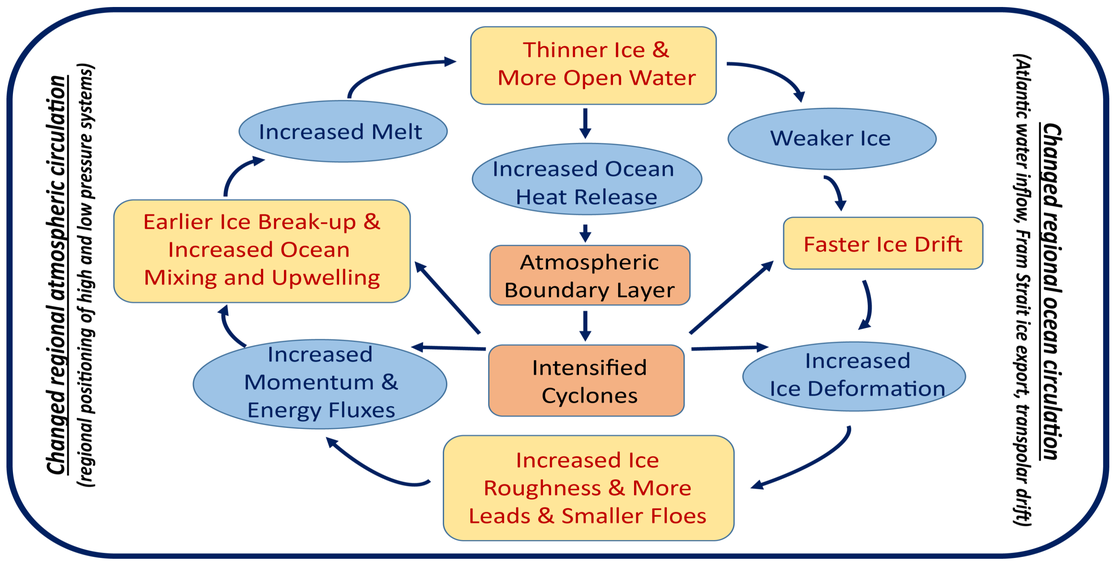


Fig. 3: *Potential positive feedback loop involving sea-ice characteristics (leads, roughness), interacting with cyclones under the influence of changing atmospheric and oceanic circulations. Such a positive feedback can contribute to Arctic amplification.*

WP1: Open-water leads

- Compilation of an Arctic-wide lead fraction satellite-derived dataset:
  - Extend existing Sentinel-1 SAR method to whole Arctic.
  - Add new SAR Radarsat Constellation Mission (RCM) data & improve method.
- Daily lead statistics including shape and direction.
- Validation with MOSAiC data and airborne campaigns.
- Model evaluation and re-parametrization of refreezing open-water leads.
- Impact of leads on atmosphere (e.g., turbulent fluxes, surface energy budget, atmospheric stratification, clouds) and related feedbacks.

WP2: Sea-ice roughness

- Compilation of Arctic-wide ice surface roughness satellite-derived dataset.
- In situ surface and airborne laser scanner data (→ MOSAiC) for satellite evaluation.
- Model simulations with improved air-ice drag and re-adapted roughness parameters. Sensitivity study with respect to ice-ocean drag.
- Impact of changed ice roughness on simulated turbulent fluxes, ice drift, and atmospheric circulation.

WP3: Arctic cyclones & interaction with ice-ocean

- Thermodynamic and dynamic responses of ice-ocean to cyclones (storms).
- Potential feedback of ice retreat, oceanic heat fluxes, surface warming and cyclone characteristics/conditioning.
- Role of Atlantic water inflow and ocean heat transport through the Barents Sea Opening and with the West Spitsbergen current.

4. Role within (AC)³ & perspectives

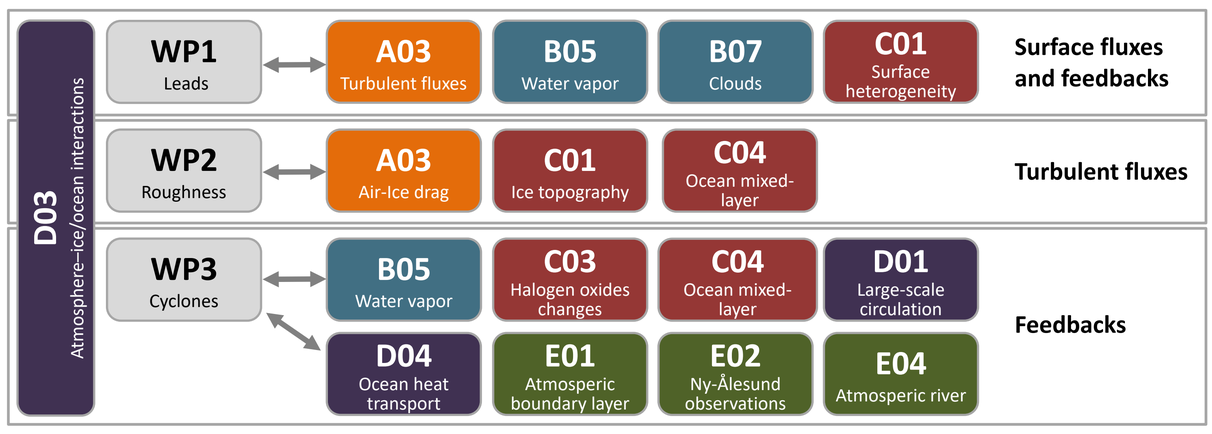
Collaborations within (AC)³

Strong links with other sub-projects, e.g.:

- Leads and clouds (B07).
- Turbulent fluxes and air-ice drag (A03).
- Ocean transports and cyclones (C04, D04).

Crosscutting Activities

- Contribution to "Surface linkages" and "Air mass transport and transformation".



Perspectives

- Further focus on feedbacks between atmosphere, sea ice and ocean.
- Example: Long-term relation between ice dynamics and ice thickness changes (modeling and observations).
- Estimate changes in strength and importance of those feedbacks under vanishing sea ice and changed ice-ocean characteristics (future-climate ensemble simulations).

TR 172 TRANSREGIONAL COLLABORATIVE RESEARCH CENTRE

(AC)³ ArctiC Amplification: Climate Relevant Atmospheric and SurfaCe Processes, and Feedback Mechanisms

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