Interactions between sea ice and atmosphere: known and unknown

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Arctic ice melting and thinning since the 1980s

Declines in Arctic ice thickness

Maksym et al. 2019

Kwok & Cunningham (2015)
The melting season has been longer

Maksym et al. 2019
Local melting is more important than exporting ice out of the basin

Local melting is mainly due to the warming atmosphere since the 1980s

Spring Export (March-Aug)

September extent

Trend of annual mean surf.Temp

Trend of tropospheric Temp

Screen et al. 2012

Smith et al. 2019

Smedsrud et al. 2017
Drivers of observed sea ice loss

- Anthropogenic forcing
- Internal forcing

Three pathways
- Atmospheric pathways
- Oceanic pathways
- Freshwater discharge

Arctic Amplification
- Sea ice loss
- Albedo feedback
- Cloud cover and water vapor
- Black carbon aerosol
- Local thermal inversion/Lapse rate feedback
- Vegetation feedback
- Poleward heat and moisture transport by atmosphere and ocean
- Many others

Instability of the ice cover
Atmospheric circulation changes and atmosphere–sea ice couplings are most significant in JJA

Observed SLP trends from 1979 to 2017

Observed coupling in JJA

Stroeve and Notz 2018

Ding et al. 2017
Open issue 1: how to understand the observed local relationship?

ECHAM5 response to observed sea ice melting (1979-2014)

Zonal mean component of linear trends of geopotential height (m/decade contour) and temperature (shading)

CAM4 response to observed sea ice melting

Z500 response in JJA

Ding et al. 2017

Liu et al. 2015
Open issue 1: is the local coupling due to anthropogenic forcing?

Observed and simulated JJA height linear trends (1979-2014)

Ensemble mean

JJA Z200 trend

a Obs (79–14)  

b CMIP5 (79–14)  
c LENS (79–14)  

→ 2m/sec / decade

JJA Z700 trend

d Obs (79–14)  
e CMIP5 (79–14)  
f LENS (79–14)  

→ 1m/sec / decade

Ding et al 2017
Open issue 2: Remote drivers of atmospheric circulation in the Arctic

Tropical drivers (the ENSO, IPO, Asian summer monsoons, Atlantic SST, MJO, QBO etc.)
Extratropical drivers (the AMO, PDO)

Some models seem to favor an opposite phase or show no skill

Trenberth et al. 2014

Screen and Deser 2019
Open issue 3: why do models show a lower sensitivity?

**Observed Arctic sea-ice loss directly follows anthropogenic CO₂ emission**

*Dirk Notz*¹ and *Julienne Stroeve*²,³

**Abstract**
Most models show a *lower sensitivity*, which is possibly linked to an underestimation of the modeled increase in incoming longwave radiation and of the modeled Transient Climate Response.

- models are less sensitive  
  **Solution:** recalibration
- Internal variability is important  
  **Solution:** understand the internal source

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*Science*

*The Third National Climate Assessment*
*Walsh and Wuebbles 2014*
Open issue 4: Roles of clouds in Arctic warming processes

Three important discoveries about roles of clouds

1. Importance of Liquid-Containing Clouds for Arctic Climate
2. Increased Absorbed Shortwave Radiation Associated with Sea Ice Loss During Summer
3. Fall Clouds Respond to Arctic Sea Ice Loss

Kay et al. 2016

Huang et al. 2019
Open issue 5: Different effects of Arctic cyclones (dynamic processes) and anticyclones (thermodynamic processes) on seasonal sea ice loss

Frequency of cyclone tracks (1979-2014)

- DJF
- JJA

Crawford and Serreze 2016

Frequency of Arctic anticyclones

- Anomalous Z300
- Frequency of Arctic anticyclones

Wernli and Papritz 2017

Melting sea ice via wave fracture, ocean mixing, moisture and heat transport, sea ice export

Melting sea ice through changing radiation fluxes
The influence of Arctic amplification on mid-latitude summer circulation

- **In past climate**
  - Relatively cool Arctic
  - Relatively warm Arctic
  - Storm systems

- **In warming climate**
  - Weakening of storm tracks

**a**

- Equatorward shift of polar jet vs. poleward shift of subtropical jet

**b**

- Amplification of quasi-stationary short-wave trains

**c**

- Arctic circle warming over land

Coumou et al. (2018)
The influence of Arctic amplification on lower-latitude winter circulation

Screen et al. 2018
**Scientific issues**

- Local atmosphere-sea ice relationship in JJA: How to understand its causality? How well do models replicate this relationship?
- Teleconnections between Arctic circulation with remote drivers: why observations disagree on this and models seem to be inconsistent in reproducing observed patterns.
- The relative contributions of internal and anthropogenic forcing in recent sea ice loss: do models own a reasonable sensitivity to climate forcing (internal and anthropogenic) in the Arctic?
- Roles of clouds and their interactions with other systems (atmosphere, sea ice, sea state, boundary layer, precipitation, energy fluxes etc.).
- Feedbacks of Arctic warming to the lower latitudes in summer and winter: how to tease apart factors and outcomes?
- Short time scale drivers: which is more important to melt sea ice, Arctic cyclones or anticyclones? Their governing dynamics?
- Across-time scale interactions: Are Arctic cyclones and anticyclones sensitive to large scale circulation, SST and radiative forcing?