Evaluating short-term forecasts of the Arctic ocean-sea ice-atmosphere coupled system using wintertime statistics from the MOSAiC campaign

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Introduction

- We used coupled model simulations of the Arctic system to evaluate the atmospheric processes that impact the surface energy budget and feedback to the ocean and sea ice.
- Wintertime observations (period without solar radiation during MOSAiC, 15 October 2019 – 15 March 2020) are used to evaluate coupled processes unique to the Arctic:
  - representation of liquid-bearing clouds at cold temperatures;
  - representation of a persistent stable boundary layer
  - limiting impact of atmospheric variability on sea ice by snow.
- Forecasts from seven state-of-the-art operational and experimental forecast systems are used, five of these systems are fully-coupled ocean-sea ice-atmosphere models.
- Short-term forecasts are used to identify potential errors in the representation of “fast” processes, such as cloud feedbacks and surface fluxes, that cause biases in climate model projections of Arctic climate change.
- Relative importance of these processes in the models is studied, particularly the surface energy budget.

The Multidisciplinary drifting Observatory for the Study of Arctic Climate expedition (MOSAiC, see Shupe et al., 2022) was a year-long drift experiment that took place from Oct 2019 to Oct 2020 in the eastern Central Arctic. Compared to SHEBA, a year-long drift experiment that took place in the western Central Arctic, separating clear-sky and cloudy statistics, MOSAiC has:

- Near-surface thermal stratification for clear-sky and cloudy conditions that is skewed towards negative values (less stably stratified) (left column)
- Sensible heat fluxes skewed towards larger positive (upward) fluxes (center)
- Weak clear-sky near-surface thermal stratification during MOSAiC is consistent with a larger upward conductive flux. For cloudy cases, larger upward sensible heat flux during MOSAiC causes larger upward conductive flux since the net longwave flux is close to zero. During cloudy events, the near neutral conditions and upward sensible heat flux during MOSAiC cause snow & sea ice to be more responsive to atmospheric variability than during SHEBA (right column).

The Surface Energy Budget

Scatterplots of the three terms in the surface energy budget; LWNET (cloudy black), thin clouds (green), and clear-sky (blue) regimes; the sensible heat flux on the y-axis; the conductive flux calculated as a residual on the x-axis.

1) Cloudy conditions: MOSAiC has limited occurrences with negative (downward) sensible heat flux that coincide with negative (downward) conductive flux, whereas four models have frequent occurrences in this regime, especially models that underestimate the cloudy mode.

2) Clear-sky conditions: Large scatter outside observed range for three models that underestimate cloudy mode.

Conclusions

- Models struggle to maintain liquid water in clouds at cold temperatures, with only one of seven models producing cloud liquid water similar to observations.
- Only two models simulate observed distinct bi-modal clear-sky & cloudy modes.
- One model has cloud liquid similar to observations and the other produces enough cloud ice without cloud liquid to produce two distinct modes.
- Only two models produce observed near shutdown of turbulence for strongly stably stratified near-surface conditions.
- Diagnosis of the three surface energy budget terms, 3 models have variability in regimes with few observed occurrences; clear-skies with large upward conductive surface flux and small sensible heat flux, and large downward sensible heat flux and small conductive surface flux.
- Focused model studies are required to improve these parameterizations in order to produce reliable forecasts of the Arctic system and projections of the role of the Arctic in the climate system.

References:


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