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Clouds enhance Greenland ice sheet mass loss

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INTRODUCTION

Clouds are important players in the global climate system with a strong impact on the surface energy and mass budget. Yet, this impact remains a key uncertainty in climate models, especially in Polar Regions[1]. Recent studies have focused on particular events and cloud types, such as the role of thin liquid-bearing clouds in the July 2012 extreme melt event over the Greenland ice sheet[2]. However, the larger-scale impact of all clouds over Greenland remains unknown, due the absence of observations. State-of-the-art climate models show a large spread in cloud microphysical properties, impeding a reliable model-based cloud impact assessment.

This is now changing with the advent of active satellite remote sensing, which has proven to be of great importance for increasing the amount of cloud observations in Polar Regions. Here it is shown that with a refined version of an existing satellite-based radiative flux retrieval algorithm, now including thin liquid-bearing clouds, a cloud radiative forcing study can be conducted over the entire Greenland ice sheet.

Such information is crucial for improving climate models in their representation of clouds to ensure reliable future climate projections and subsequent global sea level rise.

METHODOLOGY

2B-FLXHR-LIDAR[3] algorithm retrieves broadband (LW and SW) radiative fluxes based on satellite observations

- CloudSat/CALIPSO/MODIS satellite observations
- Complementary radar and lidar for cloud detection
- Good temporal/spatial resolution (Fig. 1)
- Detection of low-level liquid clouds that previously remained undetected

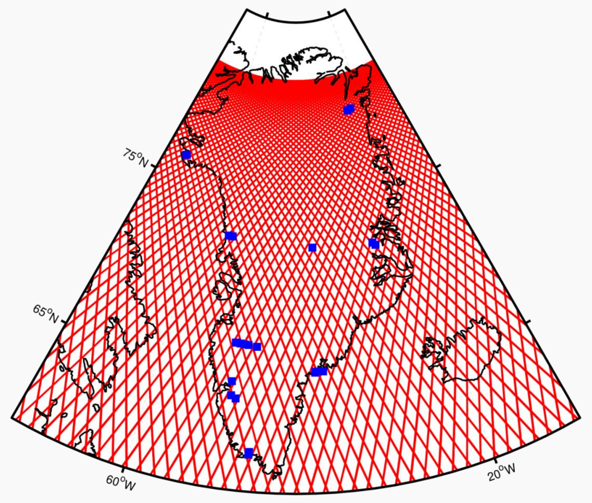


Fig. 1: CloudSat/CALIPSO overpasses over Greenland, AWS locations

2B-FLXHR-LIDAR[3] algorithm

For every vertical satellite profile

↓

Look for clouds detected by CloudSat/CALIPSO/MODIS

↓

Determine LWC/IWC content

↓ Combine with ECMWF re-analysis

Run radiative transfer model

↓

Retrieve LW/SW radiative fluxes

Validation of 2B-FLXHR-LIDAR

⇒ Downwelling fluxes at the surface compared to 11 AWS
- Mean bias LW/SW = -2.3/5.8 W m^{-2}
- Mean RMSE LW/SW = 9.8/18.2 W m^{-2}

⇒ Detected clouds compared to ground observations[4]

Cloud radiative impact study

- Flux algorithm is run with and without cloud water contents
- Resulting fluxes allow calculation of cloud radiative forcing
- ~6.3 million observations between 2007-2010
- First validated Greenland-wide dataset of cloud radiative impact

All retrievals are constrained by observations

RESULTS AND DISCUSSION

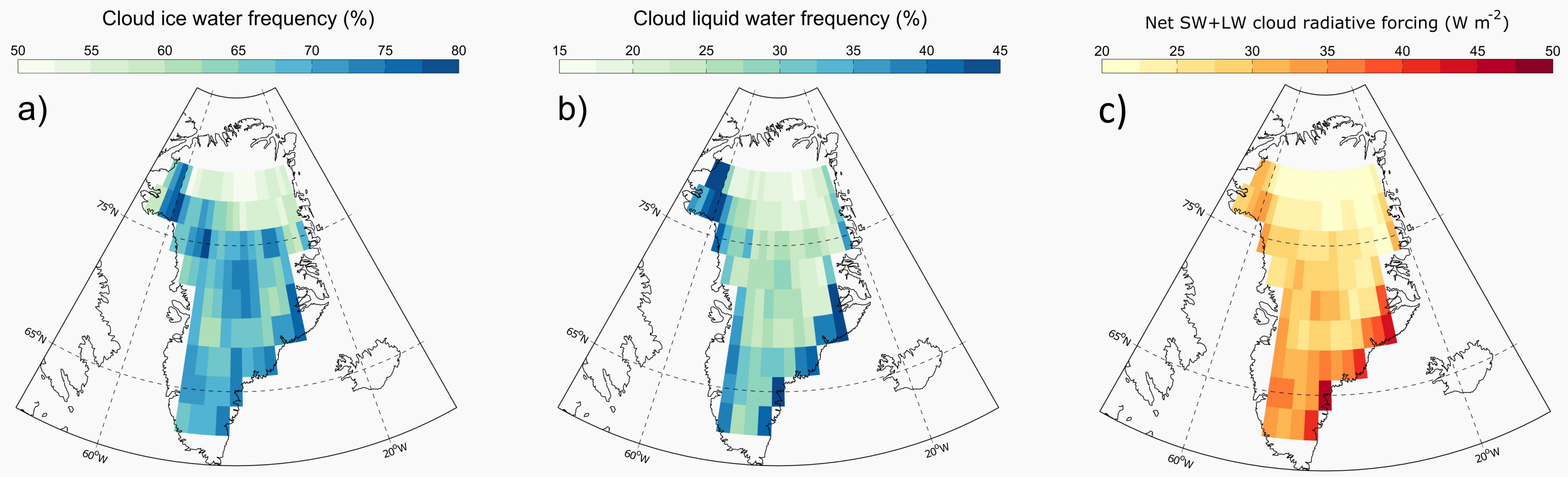
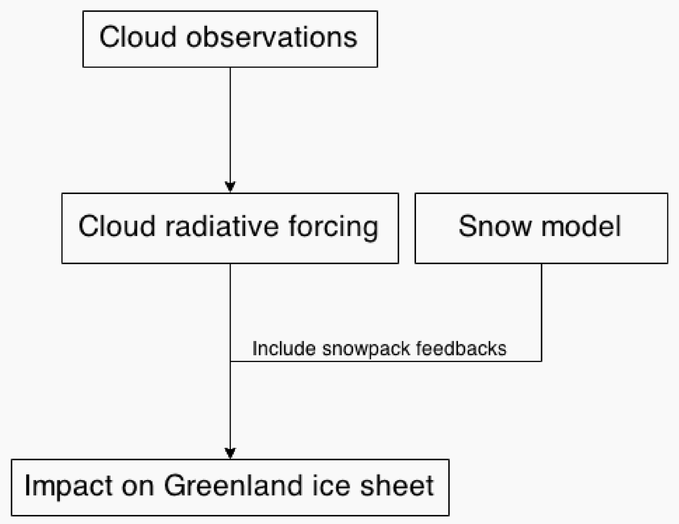


Fig. 2: (a) Cloud ice water frequency and (b) cloud liquid water frequency , as observed by CloudSat/CALIPSO/MODIS. (c) Yearly annual net cloud radiative forcing shows a strong increase in Greenland ice sheet surface energy input due to clouds.

- Fairly constant cloud fraction year-round of **68%**
- Strong spatial and seasonal variations
- Higher occurrence of liquid-bearing clouds in summer
- Higher occurrence of ice-only clouds in winter
- Mean annual cloud forcing of **28.4 (± 4.2) W m^{-2}**
- Energetically equivalent to melting **~90 Gt y^{-1}** of ice in the ablation area
- However, this estimate assumes a static surface
- To quantify how much mass is lost due to clouds, further impact studies are required that incorporate feedbacks of a changing ice sheet surface with an increased energy input, through the use of a snow model

CONCLUSION AND OUTLOOK

Satellite observations show frequent ice-only and liquid-bearing clouds over the Greenland ice sheet. Analyses with a radiative transfer model indicate that the yearly average net radiative forcing of these clouds is strongly positive, increasing the Greenland ice sheet energy input. Further impact studies should focus on feedbacks within the snowpack to assess how the surface mass balance of the ice sheet reacts to this increased energy input. This knowledge is key to understanding the governing mechanisms of ice sheet melt and subsequent sea level rise and to improve climate models for future projections.



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