Arctic Amplification: Climate Relevant Atmospheric and Surface Processes, and Feedback Mechanisms (AC)³

Impact of clouds on radiative fluxes and atmospheric heating rates at Ny-Ålesund, Svalbard

Kerstin Ebell¹, Tatiana Nomokonova¹, Marion Maturilli², Christoph Ritter²

1) Institute for Geophysics and Meteorology, University of Cologne, Germany
2) Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Potsdam, Germany
Arctic clouds

• one of the main components driving the Arctic climate system → key role in the radiation budget
• sparse knowledge of cloud-radiation interactions and cloud properties at high latitudes
• highly temporally and vertically resolved cloud information from ground-based remote sensing instruments important → cloud radar, ceilometer, microwave radiometer, broadband radiation sensors → only few “supersites” in the Arctic
Cloud remote sensing at AWIPEV, Ny-Ålesund (Svalbard) since June 2016

94-GHz FMCW cloud radar (University of Cologne) → vertical information on hydrometeors (cloud droplets, ice, precipitation)

Ceilometer CL51 (Alfred Wegener Institute) → detection of cloud droplets
Sensor synergy: Cloudnet classification

Cloud radar (U. Cologne)
Ceilometer (AWI)
Microwave radiometer (AWI)

Sensor synergy: Cloudnet classification

thermodynamic information (numerical weather prediction model)

vertically resolved cloud properties ($\Delta t=30$ s, $\Delta z=20$ m)

$\textit{Cloudnet (Illingworth et al., 2007), provided by Ewan O’Connor}$

• >2 years of cloud macro- and microphysical properties for Ny-Ålesund
• operational retrieval, measurements ongoing
Sensor synergy: liquid and ice water content

Monthly mean cloud characteristics at Ny-Ålesund

Liquid water content / gm$^{-3}$

Ice water content / gm$^{-3}$

© Kerstin Ebell, all rights reserved.
Sensor synergy + radiative transfer

Retrieved cloud properties

Thermodynamic profiles
Aerosol information
Surface properties

INPUT

Broadband Radiative Transfer Model (RTM)

OUTPUT

Shortwave and longwave flux and heating rate profiles

RTM with clouds

difference is cloud radiative effect and forcing

RTM without clouds
Surface cloud radiative effect (CRE) at Ny-Ålesund

\[ \text{CRE} = (F_{\downarrow} - F_{\uparrow})_{\text{all-sky}} - (F_{\downarrow} - F_{\uparrow})_{\text{clear}} \]

positive → clouds warm the surface
negative → clouds cool the surface

monthly mean CRE
(error bars indicate variability of daily mean values)

c) SFC CRE / Wm\(^{-2}\)

annual average net surface cloud radiative effect at Ny-Ålesund for 2017: +11 Wm\(^{-2}\)

What is the relative contribution of liquid and ice to CRE?

- discrimination of cases with
  - LWP > 5 gm\(^{-2}\) \rightarrow „liquid“ clouds
  - IWP > 0 gm\(^{-2}\), LWP < 5 gm\(^{-2}\) \rightarrow „ice“ clouds

---

What is the relative contribution of liquid and ice to CRE?

“liquid” clouds dominate signal in most of the months

“ice” clouds contribute to 60-75% in a few months in winter

still equal contributions in winter

“liquid” clouds account for 70-98% in SW SFC CRE

Cloud Radiative Forcing: \( \text{CRF} = \text{HR}_{\text{all sky}} - \text{HR}_{\text{clear}} \)

- **SW**: warming above 1 km and cooling below associated to height of maximum frequency of occurrence (FOC) of liquid and LWC at \(~1\) km
- **LW**: distinct LW cooling at top of liquid layers and warming below; pronounced signal for height with maximum FOC of liquid \( \rightarrow \) follows seasonal cycle of liquid
- **NET**: dominated by LW CRF resulting in net warming of about 0.5 K day\(^{-1}\) below 1.5 km and in general a net cooling above with cooling rates down to -6 K day\(^{-1}\); upper regions with heating associated to occurrence of higher ice/liquid clouds
Next steps

• Closer look on heating rate profiles

• Differentiation between cloud types (single-/multi-layer, liquid, ice, mixed-phase)

• Do we have characteristic heating rates for certain cloud types?  
  → Comparison to observed heating rates at other Arctic sites

• Continuation of cloud observations and the analysis of radiative impact at Ny-Ålesund  
  → year-to-year variability