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

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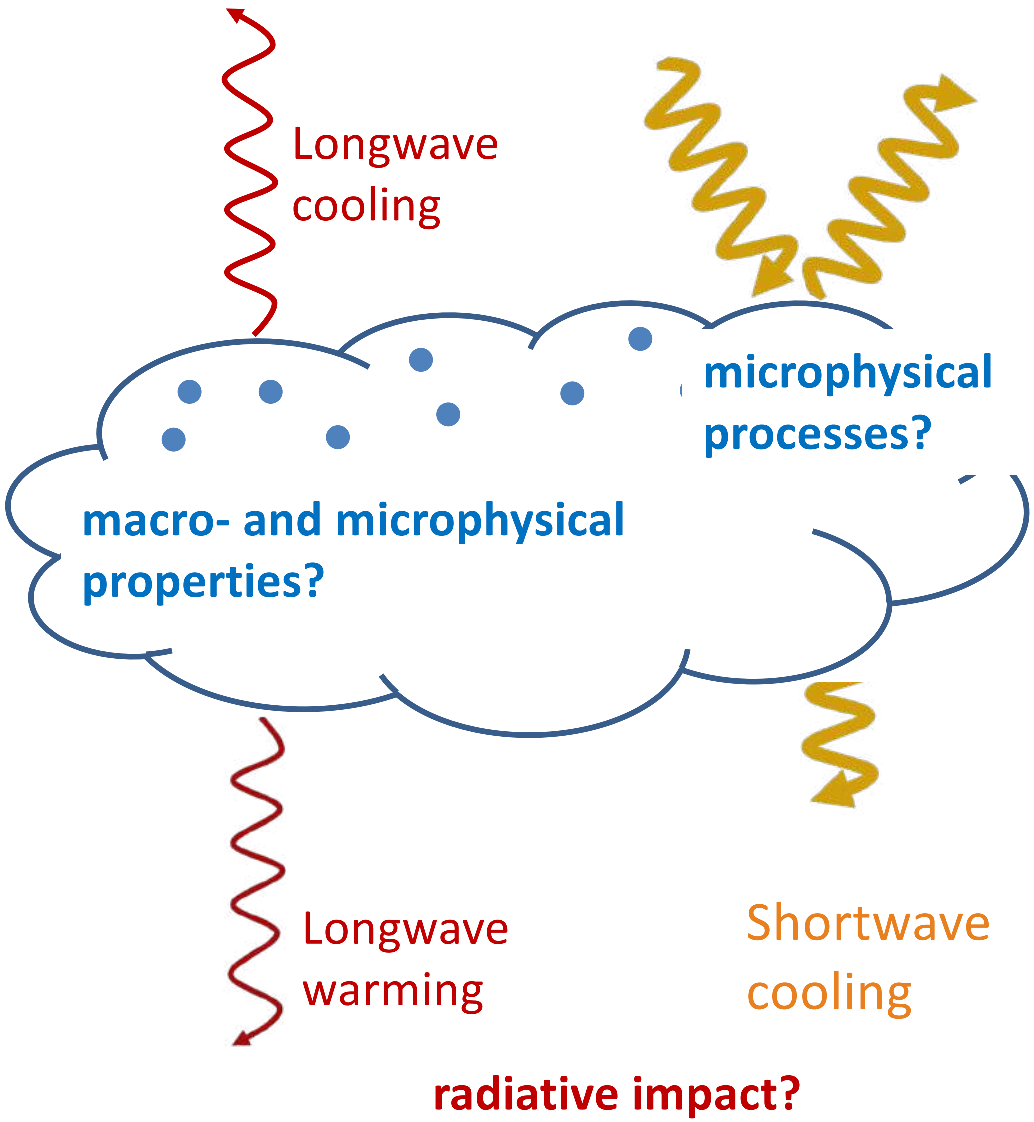
Arctic clouds

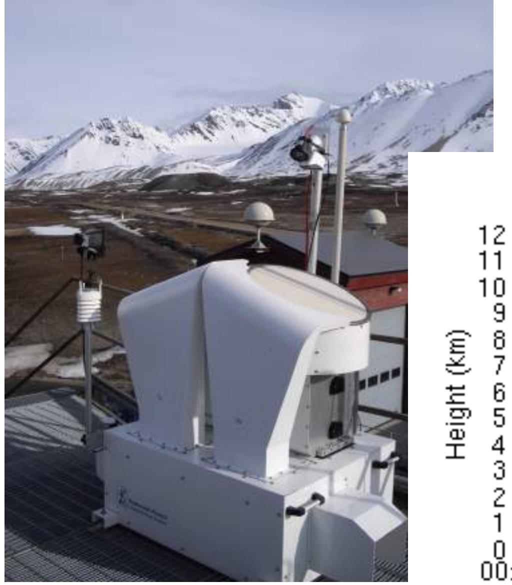
- one of the main components driving the Arctic climate system
  → key role in the radiation budget
- sparse knowledge of cloud-radiation interactions and cloud properties at high latitudes
- highly temporally and vertically resolved cloud information from ground-based remote sensing instruments important
  → cloud radar, ceilometer, microwave radiometer, broadband radiation sensors

→ only few “supersites” in the Arctic

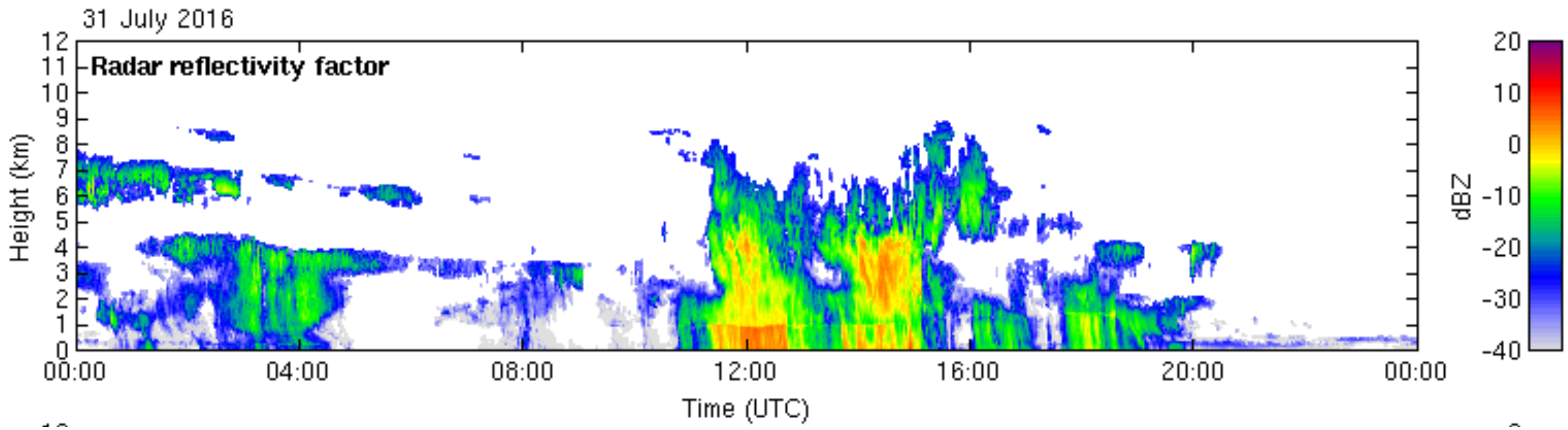


Cloud remote sensing at AWIPEV, Ny-Ålesund (Svalbard)

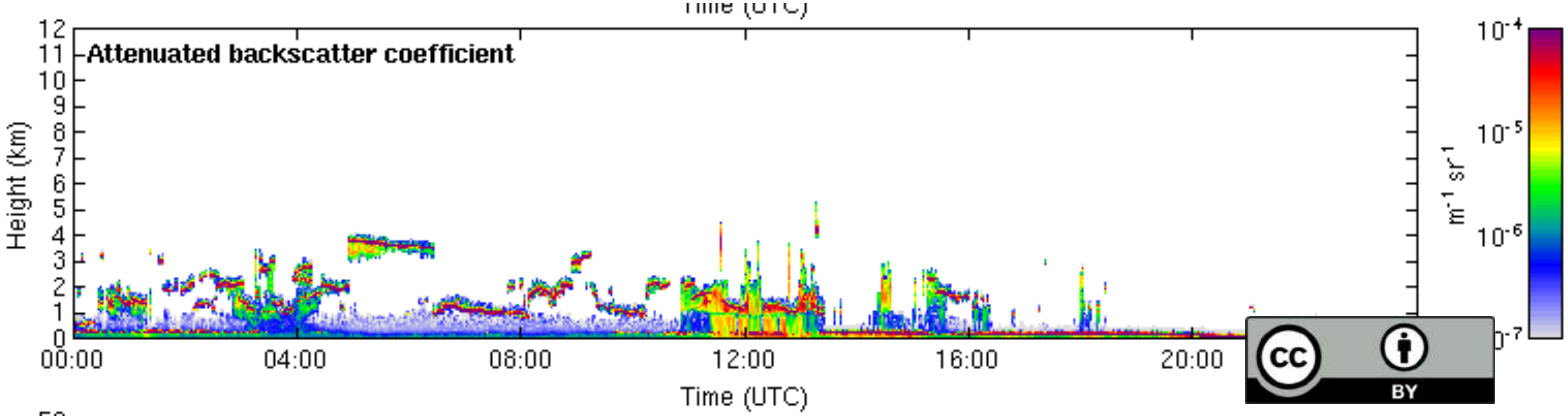
since June 2016



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

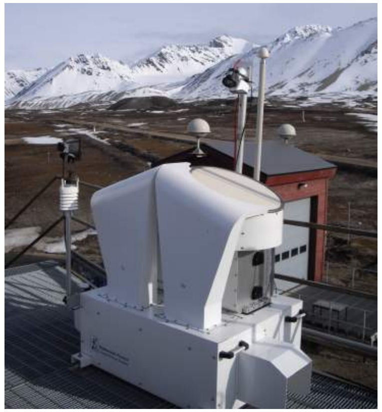


Ceilometer CL51 (Alfred Wegener Institute)
→ detection of cloud droplets



Sensor synergy: Cloudnet classification

Cloud radar
(U. Cologne)

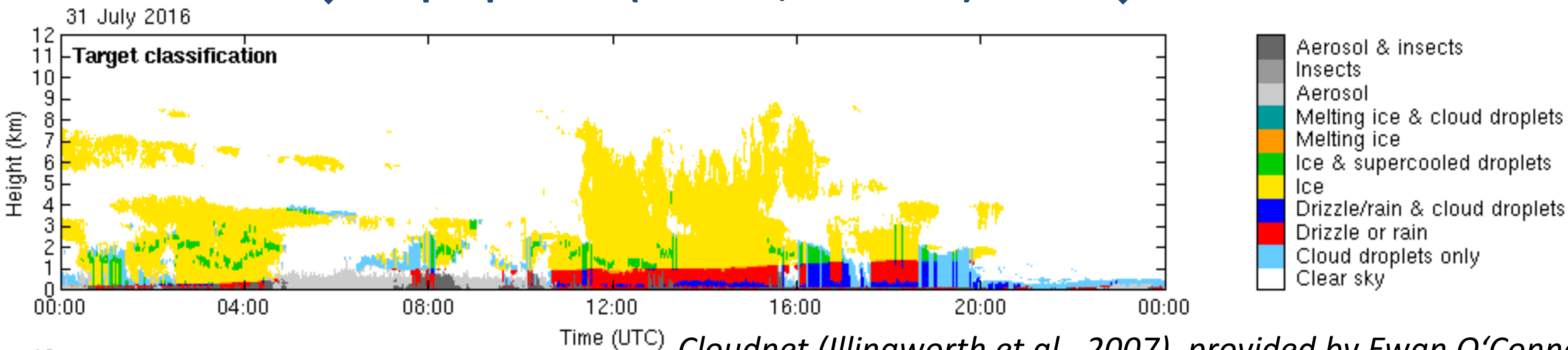


Ceilometer
(AWI)

Microwave radiometer
(AWI)

thermodynamic information (numerical weather prediction model)

vertically resolved cloud properties (Δt=30 s, Δz=20 m)

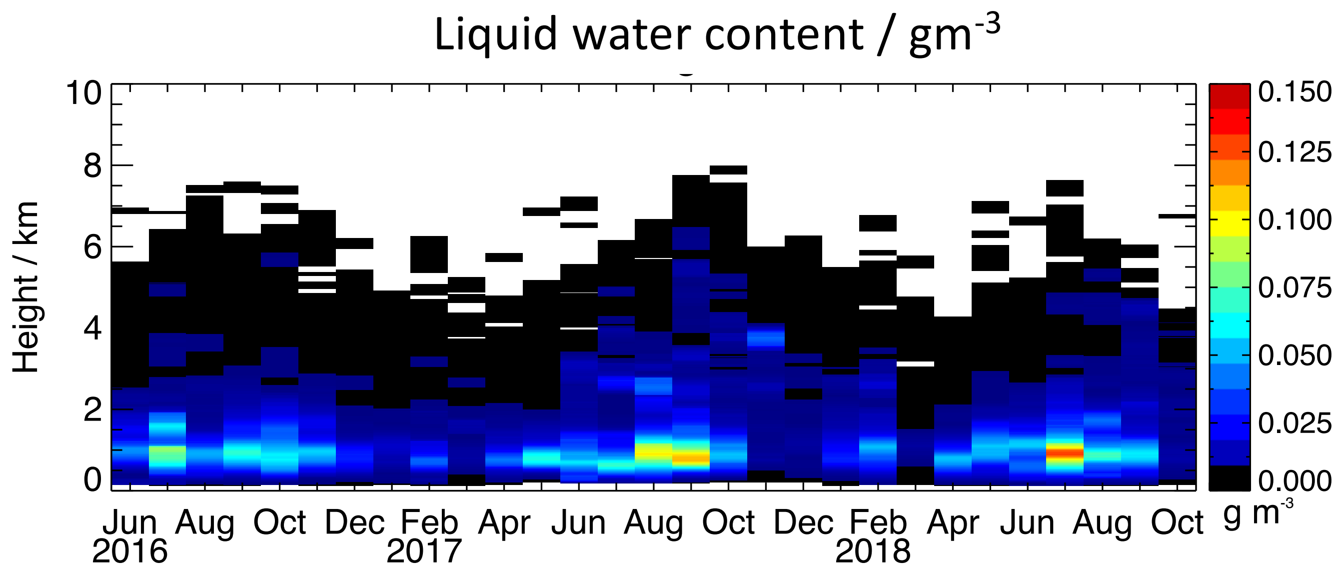


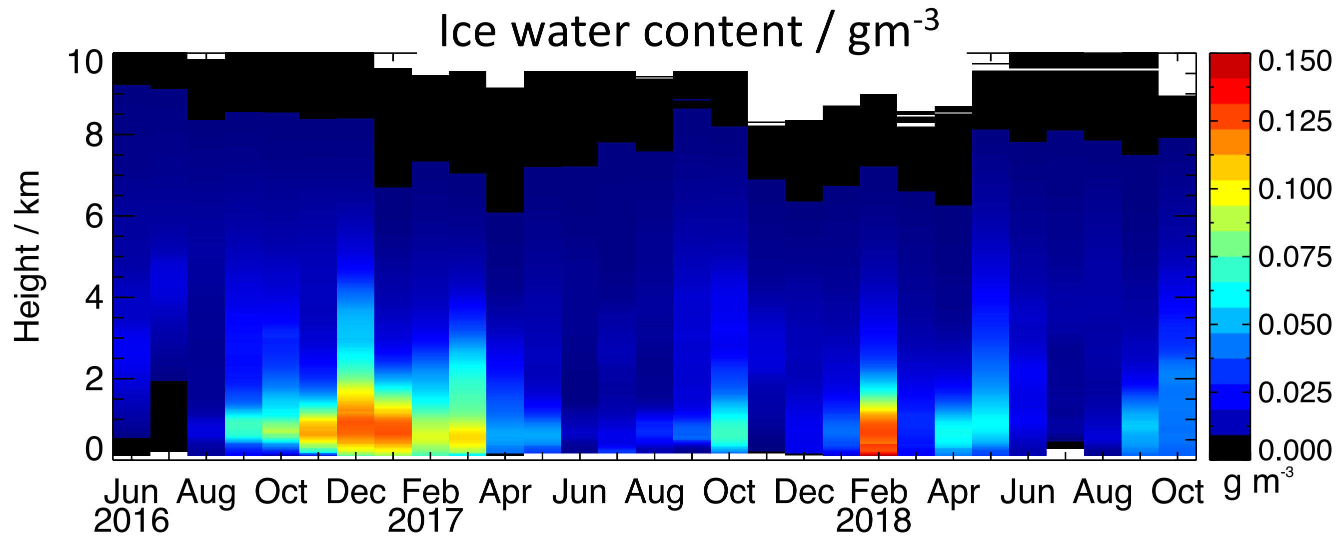
Cloudnet (Illingworth et al., 2007), provided by Ewan O'Connor

- >2 years of cloud macro- and microphysical properties for Ny-Ålesund
- operational retrieval, measurements ongoing

Sensor synergy: liquid and ice water content

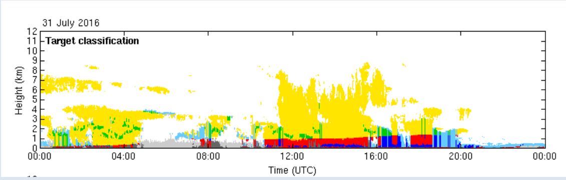
Monthly mean cloud characteristics at Ny-Ålesund





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

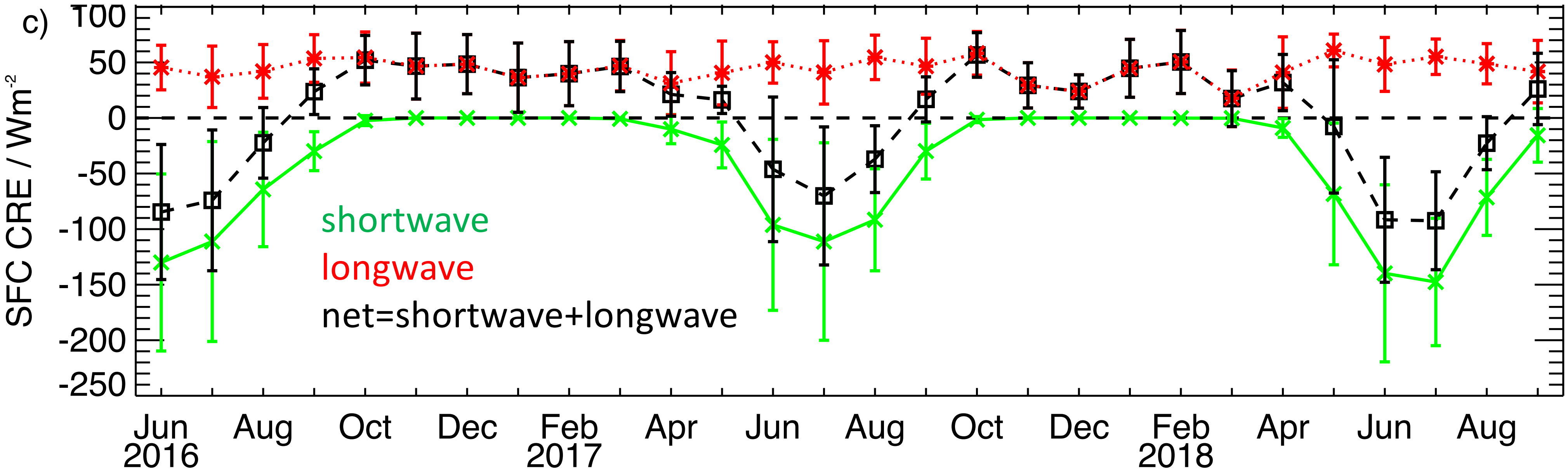
RTM without clouds

Surface cloud radiative effect (CRE) at Ny-Ålesund

$CRE = (F\downarrow - F\uparrow)_{all\text{-}sky} - (F\downarrow - F\uparrow)_{clear}$

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

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

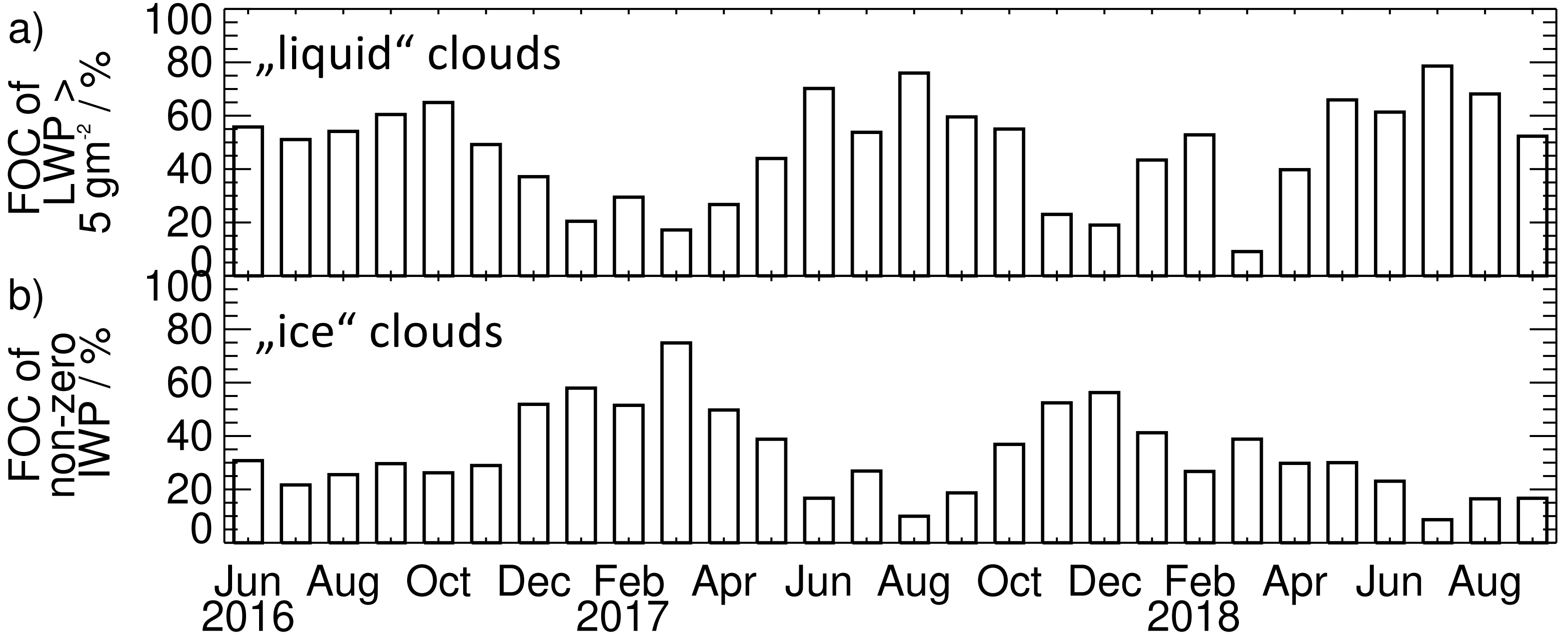


annual average net surface cloud radiative effect
at Ny-Ålesund for 2017: +11 Wm^{-2}

Ebell, K., T. Nomokonova, M. Maturilli, and C. Ritter, 2020: Radiative Effect of Clouds at Ny-Ålesund, Svalbard, as Inferred from Ground-Based Remote Sensing Observations. *J. Appl. Meteor. Climatol.*, **59**, 3–22, https://doi.org/10.1175/JAMC-D-19-0080.1

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

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



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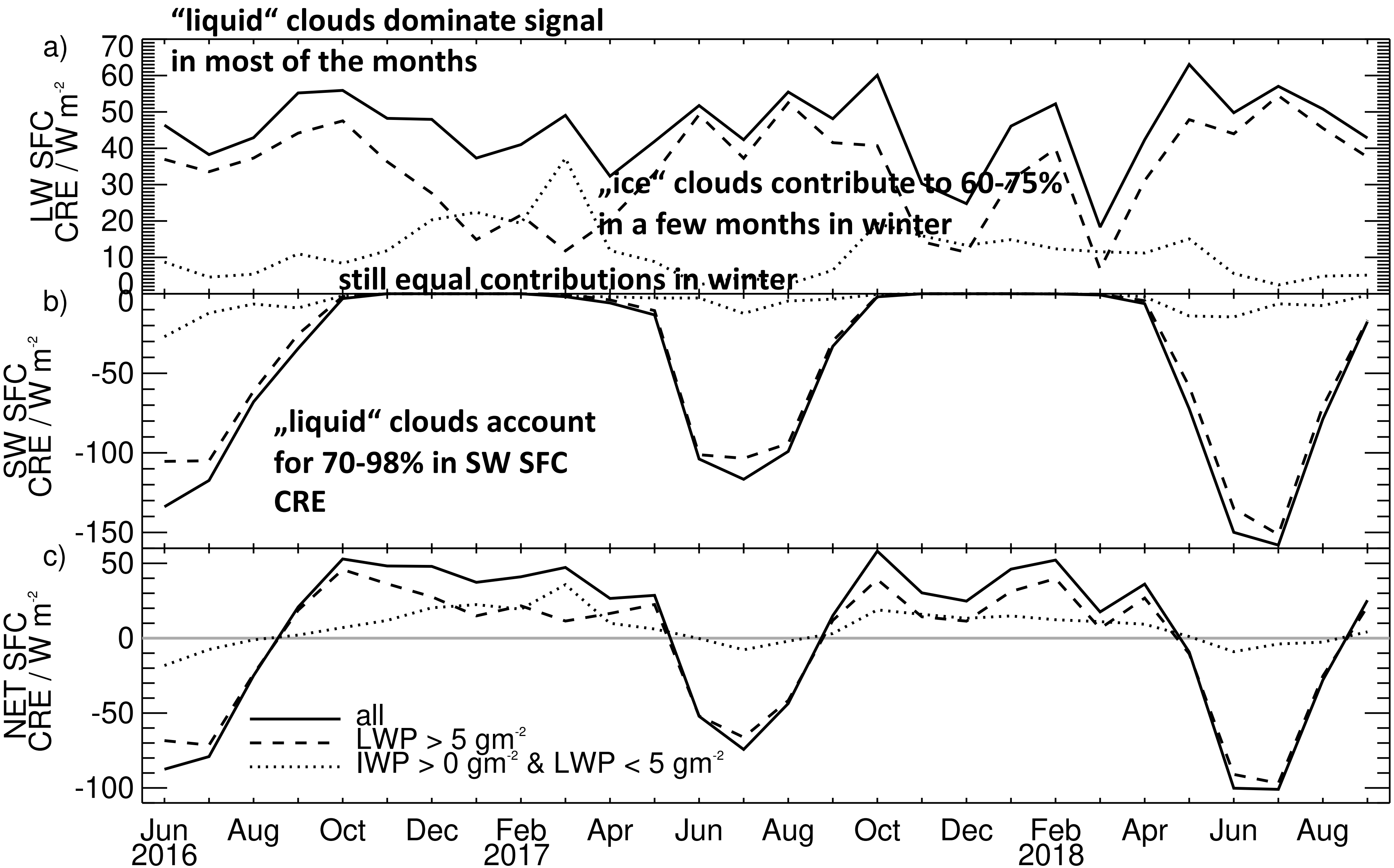

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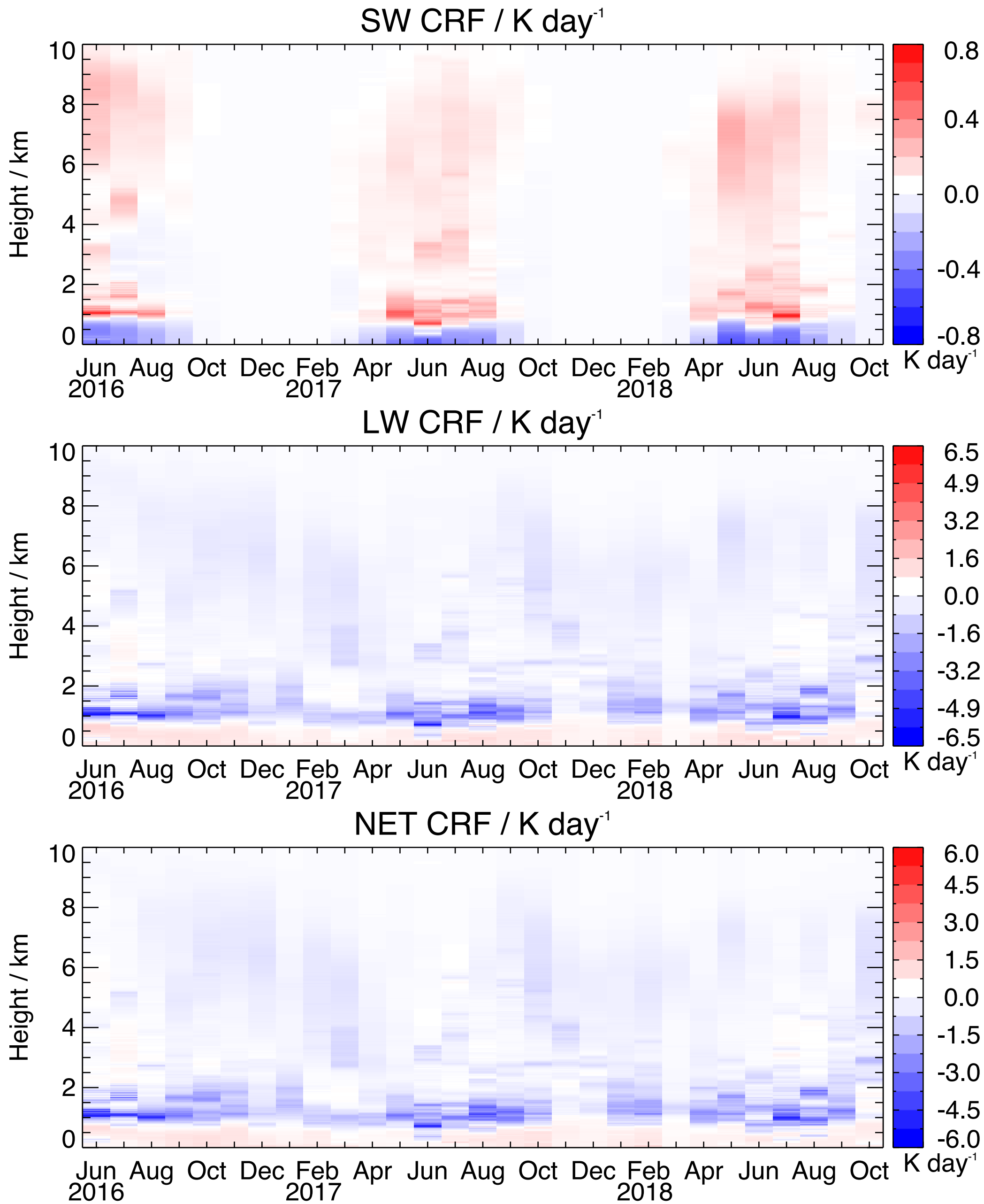
Impact of clouds on atmospheric heating rates (HR)



Cloud Radiative Forcing:
$CRF = HR_{all\ sky} - HR_{clear}$

- **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 → 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