The influence of atmospheric conditions on cloud properties at Ny-Ålesund

Nomokonova T.[1], K. Ebell[1], U. Löhnert[1], M. Maturilli[2] and Christoph Ritter[2]

[1] *Institute of Geophysics and Meteorology, University of Cologne, Cologne, Germany*

[2] *Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Potsdam, Germany*

1. Introduction

- Besides the observed trend in the temperature and moisture, anomalies on daily to monthly time scales frequently occur in the Arctic [1,2].
- The anomalies and their long-term change affect cloud occurrence and cloud properties and, thus, influence the cloud radiative effect (CRE), which is considered as one of the major sources of uncertainties in the Arctic radiation budget.
- Having more than 2 years of cloud observations at Ny-Ålesund, we analyze how periods of increased/decreased temperature and moisture are related to certain weather patterns, cloud occurrence and hydrometeor phase.

2. Definition of T and IWV periods

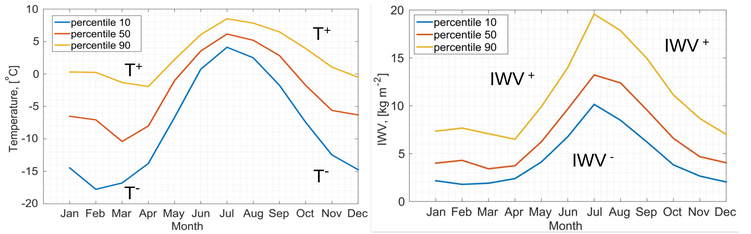

Fig. 1: *Monthly percentiles of 2m 6-hourly mean temperature and IWV from Baseline Surface Radiation Network and microwave radiometer observations at Ny-Ålesund from 2011 to 2018 used as criteria for determination of periods of decreased (below 10th percentile) and increased (above 90th percentile) T and IWV.*

3. Frequency of occurrence of T and IWV periods

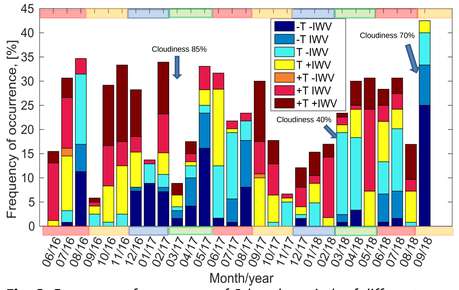

Fig. 2: *Frequency of occurrence of 6-hourly periods of different atmospheric conditions at Ny-Ålesund from June 2016 to September 2018.*

- FOC of T^+IWV^+ (humid and warm) and T^+ IWV$^+$ (warm):
  - highest (20%) in autumn
  - ~13% in winter
- FOC of T^- IWV^- (cold and dry):
  - high in 2017 (from 01/17-08/17) and 09/18 (~25%)
- FOC T^-IWV (dry period):
  - highest in summer
  - highest (~20%) in 03/18 might lead to the lowest cloudiness (only 40%).

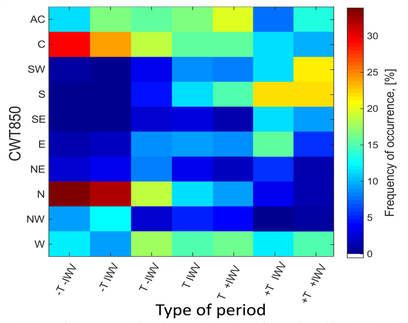

Fig. 3*: Circulation weather type (CWT) [3] based on the ERA-Interim 850 hPa for different types of periods. (AC – anticyclonic, C - cyclonic)*

- Dry and cold periods are associated with northern and western air flows (Fig.3).
- Moist and warm air masses mostly come from the south, south-west (North Atlantic).

4. Occurrence of clouds and phase

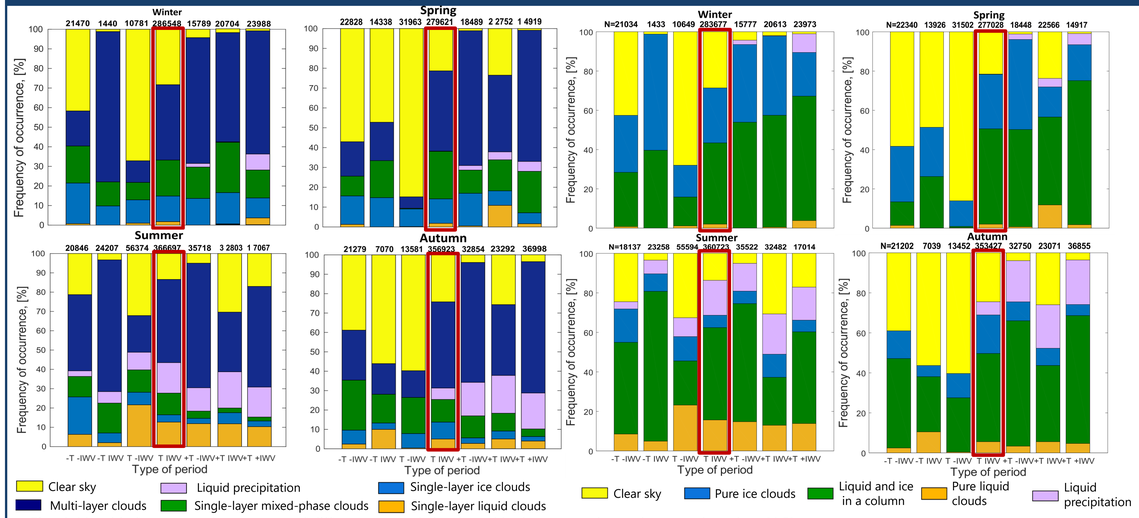

Fig. 4*: Monthly frequency of occurrence of different types of clouds and hydrometeors for each season based on [4,5].*

- Less single-layer (SL) mixed-phase clouds (MPC) during warm and moist periods in summer and autumn, more SL clouds in cold and dry periods in autumn.
- For T^- IWV$^-$ more SL clouds almost twice (20%) but less multi-layer (ML) clouds
- Less ML clouds in spring and autumn during cold and dry periods
- More clouds during warm and moist periods, mostly liquid-containing multi-layer clouds (>60%).
- Less clouds in dry and/or cold periods in all seasons (except -T IWV).
- More than 60% clear sky in spring and autumn during dry and/or cold periods.
- The lowest cloud FOC (15%) in spring during dry periods, no liquid.

6. Cloud radiative effect (preliminary results)

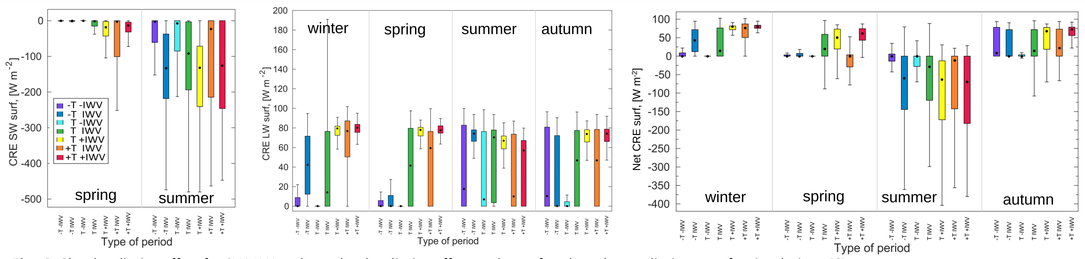

Fig. 6*: Cloud radiative effect for SW, LW and net cloud radiative effect at the surface based on radiative transfer simulations [6].*

- SW CRE at the surface is negative. During humid periods CRE is lower (summer, -150 W/m^2) than the one for typical conditions (summer, -100 W/m^2).
- In summer SW CRE is negatively correlated with occurrence of liquid-containing (pure liquid + mixed profiles) clouds.
- In spring SW CRE is close to 0 due to high occurrence of clear sky conditions.
- LW CRE at the surface is typically positive. In winter and spring warm and humid periods lead to CRE higher than typical due to high occurrence of liquid-containing clouds. In winter the increase in CRE is up to a factor of 4.
- For all seasons LW CRE is correlated with the occurrence of multi-layer clouds and the amount of liquid water.
- Cold and dry conditions lead to low values of LW CRE (except T^- IWV in winter and summer).
- The net CRE is mostly close to 0 for cold and dry conditions, while its absolute values are significantly higher than typical for warm and humid periods.
- In winter, spring, and autumn the net CRE is positive, while it is negative in summer.

5. Liquid water path

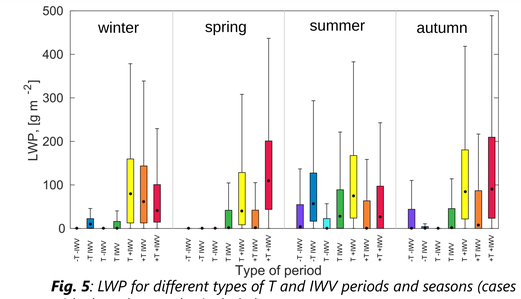

Fig. 5*: LWP for different types of T and IWV periods and seasons (cases with clear sky are also included)*

- In winter LWP is the largest during moist and warm periods. LWP is 2-times higher during T IWV$^+$, although FOC of liquid is higher during T^+IWV^+.
- LWP is correlated with occurrence of liquid/containing clouds during warm and moist periods in other seasons.
- LWP for dry and cold periods is low due to high occurrence of cloudless conditions. In summer season the median LWP for T^-IWV is ~ 50 g m^{-2}, which is two times higher than typical.

7. Conclusions

- Periods of increased and decreased temperature and moisture show a correlation with weather patterns.
- Different atmospheric conditions affect cloud occurrence and hydrometeor phase.
- By modulating the cloud occurrence and properties, different conditions influence SW, LW, and net CRE.
- Differences between typical CRE and those during different period type can reach a factor of 4.

8. Outlook

- How are the defined T and IWV periods related to cloud macrophysical and microphysical properties (e.g. cloud base height and temperature, LWP, IWP)?
- The influence of the periods on CRE for different types of clouds (liquid, ice, mixed-phase).

References:

1. *M. Maturilli, M. Kayser, 2016: Arctic warming, moisture increase and circulation changes observed in the Ny-Ålesund homogenized radiosonde record, Theoretical and Applied Climatology, doi: 10.1007/s00704-016-1864-0.*
2. *J. E. Overland and M. Wang, 2016: Recent Extreme Arctic Temperatures are due to a Split Polar Vortex, Journal of Climate, 29, 5609-5616, doi: 10.1175/JCLI-D-16-0320.1.*
3. *Philipp, Andreas & Beck, Christoph & Huth, Radan & Jacobeit, Jucundus. (2014). Development and comparison of circulation type classifications using the COST 733 dataset and software. International Journal of Climatology. 36. 10.1002/joc.3920.*
4. *Nomokonova, T., Ebell, K., Löhnert, U., Maturilli, M., Ritter, C., and O'Connor, E.: Statistics on clouds and their relation to thermodynamic conditions at Ny-Ålesund using ground-based sensor synergy, Atmos. Chem. Phys. ,19, 4105-4126, https://doi.org/10.5194/acp-19-4105-2019, 2019.*
5. *A. Illingworth, R. Hogan, E. O'Connor, and D. Bouniol, 2007: Cloudnet, Bulletin of the American Meteorological Society, 88(6), 883.*
6. *Ebell, K., T. Nomokonova, M. Maturilli, C. Ritter: Radiative effect of clouds at Ny-Ålesund, Svalbard, as inferred from ground-based remote sensing observations, submitted to J. Appl. Meteorol. Climatol., submitted, 2 April 2019*

Acknowledgements:

We gratefully acknowledge the funding by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – Projektnummer 268020496 – TRR 172, within the Transregional Collaborative Research Center "ArctiC Amplification: Climate Relevant Atmospheric and SurfaCe Processes, and Feedback Mechanisms (AC)³.

We gratefully acknowledge Ewan O'Connor for providing the Cloudnet algorithms to the Ny-Ålesund measurements. We thank AWIPEV team for their continuous support in the measurements at Ny-Ålesund.