Long-Term Observations of Water Vapor, Clouds and Precipitation in the Arctic: Trends and Process Studies at the Research Station AWIPEV, Ny-Ålesund (Svalbard)

Kerstin Ebell[1] (kerstin.ebell@uni-koeln.de), C. Buhren[1], S. Dahlke[2], M. Maturilli[2], C. Ritter[2], M. Lauer[1]

[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. Motivation

- Enhanced warming of the Arctic, i.e., Arctic amplification, directly affects the hydrological cycle
- Ny-Ålesund (Svalbard) is located in the warmest region of the Arctic *[1]*, where also the local amplification is large *[2]*
- Detailed measurements of water vapor, clouds, and precipitation are crucial to better understanding multi-scale processes and trends

→ In this study: Exploitation of the comprehensive measurements performed at the Arctic research station AWIPEV at Ny-Ålesund, Svalbard

2. Site and instrumentation

Fig. 1*: Location of Ny-Ålesund on Svalbard. Norwegian Polar Institute, https://toposvalbard.npolar.no*

- Ny-Ålesund (78.9°N, 11.9°E) is characterized as a tundra site in a complex environment (fjord, mountains, glaciers) (Fig. 1)
- Comprehensive instrument suite at AWIPEV (Fig. 2) with enhanced cloud and precipitation observations since 2016 *[3]*
- Long-term measurements, e.g., standard meteorology *[6]*, radiosondes *[9]*, radiation *[10]*, since the 1990s

→ significant increase of annual mean 2 m temperature; largest increase in DJF (Fig. 3)

Fig. 2*: University of Cologne and AWIPEV instrumentation (selection only) at the AWIPEV atmospheric observatory, Ny-Ålesund.*

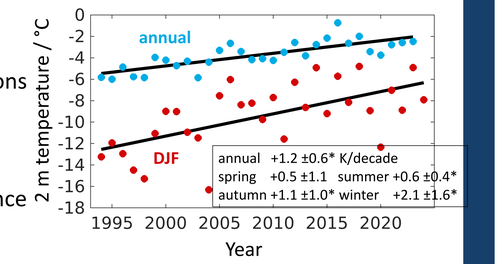

Fig. 3*: Annual (blue) and DJF (red) mean 2 m temperature based on [7,8]. Updated plot from [6]. The trends for all seasons are reported as well. *indicates a significant trend.*

3. Water vapor trends and variability

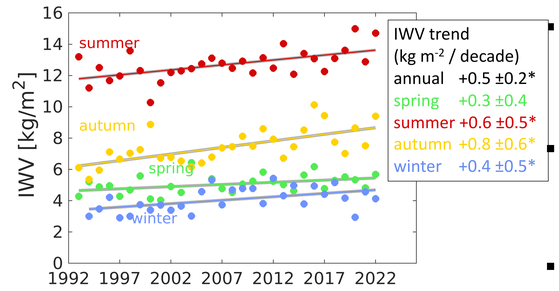

Fig. 4*: Seasonal mean IWV from radiosonde measurements based on [11,12,13]. Updated plot from [9]. *indicates a significant trend.*

- Radiosondes show a significant moistening trend for 1993-2022 (Fig. 4)
- Large intra-annual variability of monthly mean IWV from HATPRO MWR (Fig. 5)
- Interannual variability driven by variability in large-scale weather patterns
- Rapid atmospheric moisture transitions via, e.g., enhanced poleward transport („atmospheric rivers“, AR)

→ only captured by highly temporally resolved MWR measurements (Fig. 6)

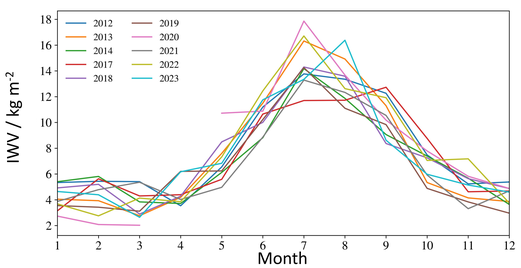

Fig. 5*: Monthly mean IWV from HATPRO MWR measurements for different years in 2012–2023.*

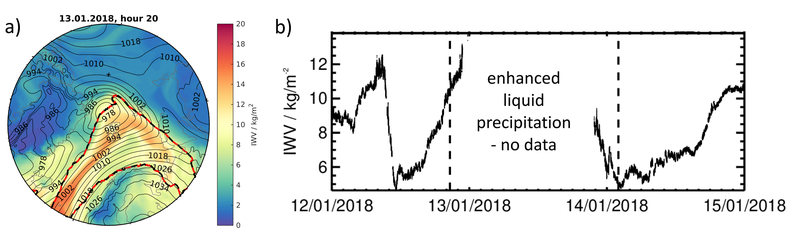

Fig. 6*: Example of an atmospheric river event. a) ERA5 IWV and detected AR (red line) on 13 Jan 2018, 20 UTC. b) IWV from HATPRO MWR (~2 s resolution). Missing data due to data quality filtering (rain). [5]*

4. Inter- and intra-annual cloud variability

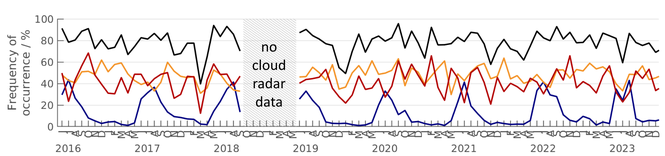

Fig. 7*: Monthly cloud occurrence based on synergetic cloud radar, ceilometer, and model product (Cloudnet, [14]). Updated plot from [15].*

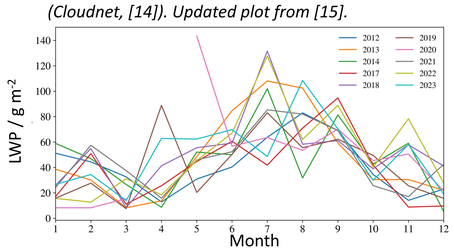

Fig. 8*: Monthly mean LWP from HATPRO MWR measurements for different years in 2012–2023.*

- High cloud occurrence of 78% (Fig. 7)
- Cloud liquid water frequently occurs in winter, even at temperatures well below 0°C (Fig. 7 & 8)
- Large interannual variability of monthly mean LWP (Fig. 8)

5. Precipitation and atmospheric rivers

- Arctic precipitation often related to atmospheric rivers (AR) and associated weather systems (cyclones, fronts) *[16]*
- ARs occur on average only 8% of the time at Ny-Ålesund (Fig. 9)
- 42% of precipitation amount occurs when atmospheric rivers are present (22% for O-AR; Fig.9, Tab. 1)
- cyclones contribute 40% of the total precipitation (21% for O-CY)

Tab 1*: Contribution of atmospheric rivers (AR), cyclones (CY), and fronts (FR) to the precipitation amount (in %). From [5].*

	2018	2019	2020	2021	all
O-AR	29	24	11	15	22
AR-FR	7	2	6	3	6
AR-CY	8	5	9	5	8
AR-CY-FR	5	9	8	2	6
O-CY	18	26	26	24	21
CY-FR	3	3	4	6	4
O-FR	3	4	5	5	4
residual	27	27	30	40	29

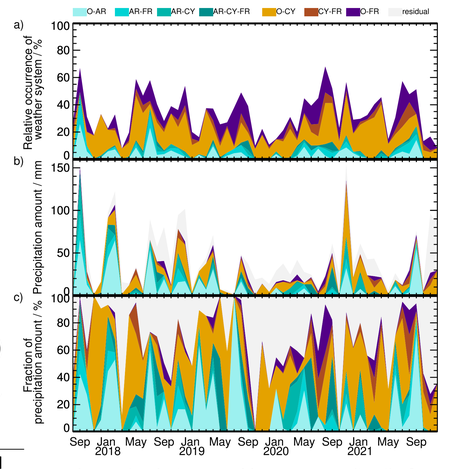

Fig. 9*: a) Relative monthly occurrence (in %) of weather systems at Ny-Alesund. Atmospheric rivers (AR), cyclones (CY), or fronts (FR) can be separated (only, O) or collocated. Monthly precipitation amount associated with different weather types in b) absolute and c) relative values with respect to the total monthly precipitation amount. Precipitation, which is not associated with any of these weather types, is denoted as "residual". From [5].*

6. Outlook

- Continuous time series of comprehensive water vapor, cloud, and precipitation observations at AWIPEV, Ny-Ålesund
- Intensive observation period for water in all its phases („IOP4H2O“) planned for 2025, incl. new G band radar (→ in-cloud water vapor profiles)
- Focus on extreme precipitation events at Ny-Ålesund → strongly coupled to enhanced water vapor transport from lower latitudes; trends?
- Linkage of precipitation to the associated cloud system
- Temporal variability of water vapor and the impact on clouds and precipitation at Ny-Ålesund

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References:

A detailed list of references can be found here https://uni-koeln.sciebo.de/s/pB2Z436QydPJQrJ