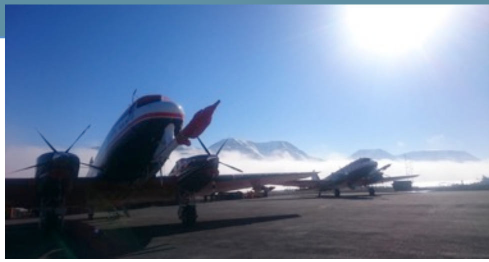

Hunting High and Low: Measuring Arctic Amplification with an Icebreaker, Two Airplanes, Several Ground-Based Instruments and Three Dozens Scientists

E.M. Knudsen, B. Heinold, S. Dahlke, H. Bozem, S. Crewell, G. Heygster, D. Kunkel, M. Maturilli, M. Mech, A. Rinke, H. Schmithüsen A. Ehrlich, A. Macke, C. Lüpkes and M. Wendisch

GFI/BCCR Seminar, Bergen
June 4, 2018

Knudsen, E.M. et al. (2018), Synoptic development during the ACLOUD/PASCAL field campaign near Svalbard in spring 2017, *Atmos. Chem. Phys. Discuss.*, doi:10.5194/acp-2018-494[1].

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Outline

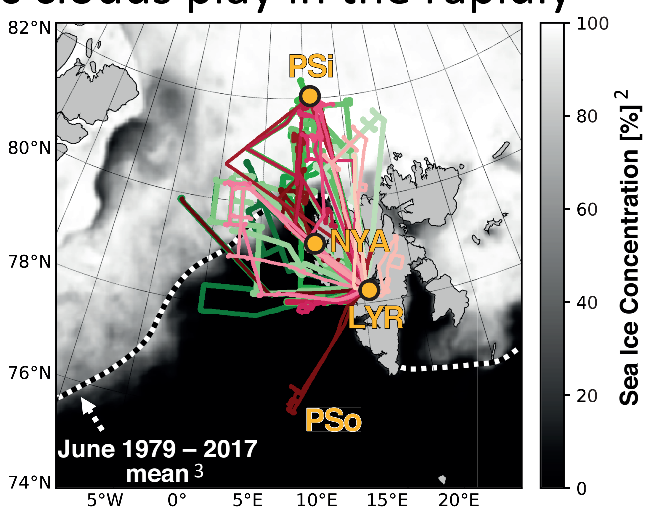
- Introduction and data
- Time series variability
- Key period characteristics
- Climatological context
- Conclusions

Introduction and Data

Introduction

The ACLOUD campaign:

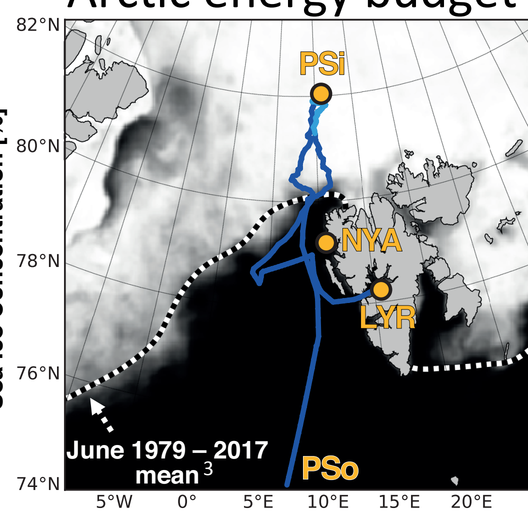
- Arctic CLoud Observations Using airborne measurements during polar Day
- May 23 – June 26, 2017
- Aircrafts Polar 5 and Polar 6
- Aimed to further understand the role Arctic clouds play in the rapidly changing Arctic climate system



LYR: Airport base Longyearbyen.
NYA: Instrument base Ny-Ålesund.

The PASCAL campaign:

- Physical feedbacks of Arctic planetary boundary level Sea ice, Cloud and AerosoL
- May 28 – June 18, 2017
- Icebreaker Polarstern
- Aimed to further understand the Arctic energy budget and its interaction with clouds and aerosols



PSo & PSi : Ocean-cruising and ice-attached Polarstern.

Data

Spatial and temporal frames:

- The Nordic Seas, with a special focus on the Fram Strait
- May 23 – June 26, 2017

Surface-based measurements:

- Near-surface meteorological and radiosonde data from Ny-Ålesund (AWIPEV; 79°N, 12°E)[5,6,7,8,9] and Polarstern (AWI; ocean-cruising > 67°N and ice-attached 82°N, 10°E)[10,11]

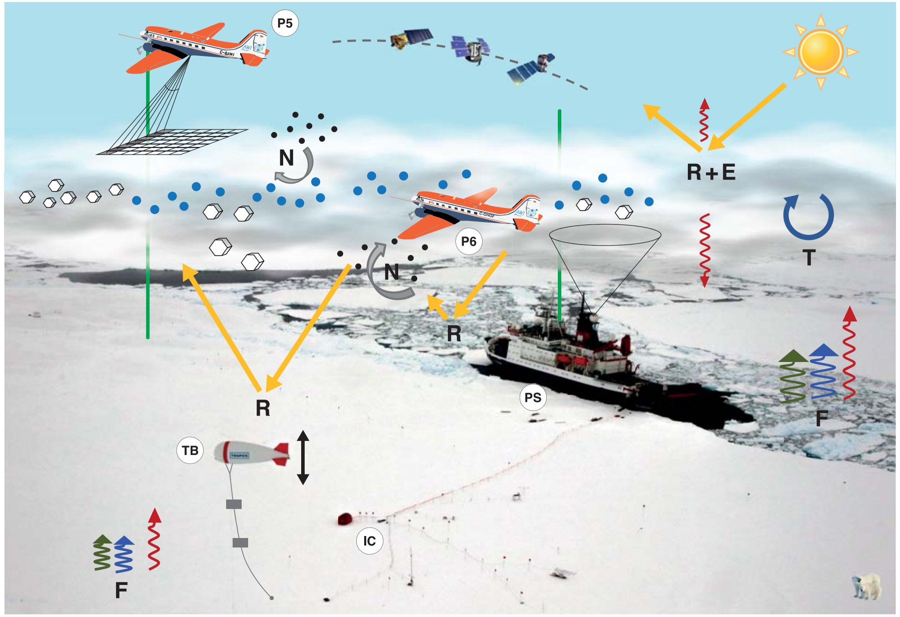
Models:

- Reanalysis data from ERA-I[16]
- Analysis data to FLEXPART[17]

Satellites:

- Sea ice data from UB[2,12], NSIDC[3] and OSI SAF[13]
- Snow data from NSIDC[14]
- Cloud data from IASI[15]

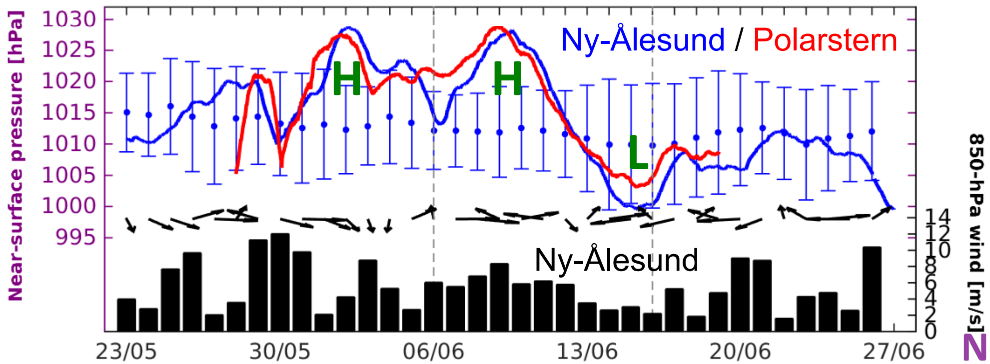
Wendisch et al. (submt.)[4]



Time Series Variability

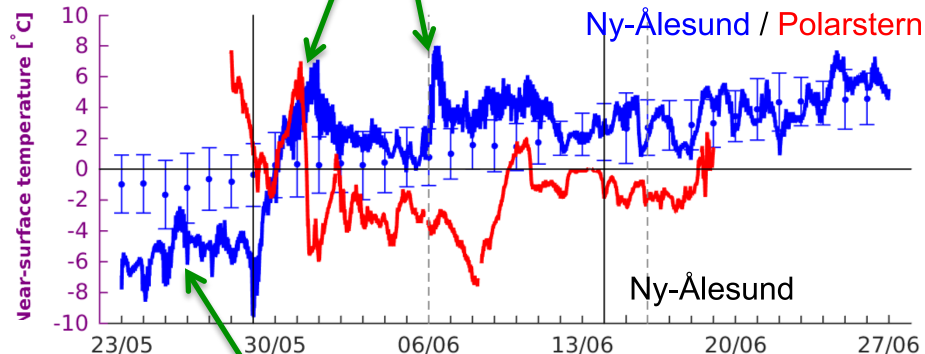
Time Series from
Near-Surface Meteorological Observations

Near-surface pressure and 850-hPa wind



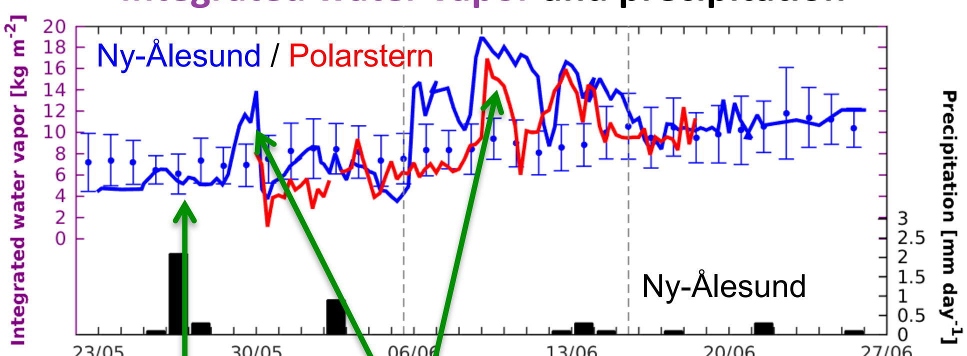
Warm air

Near-surface temperature and snow melt season



Cold air

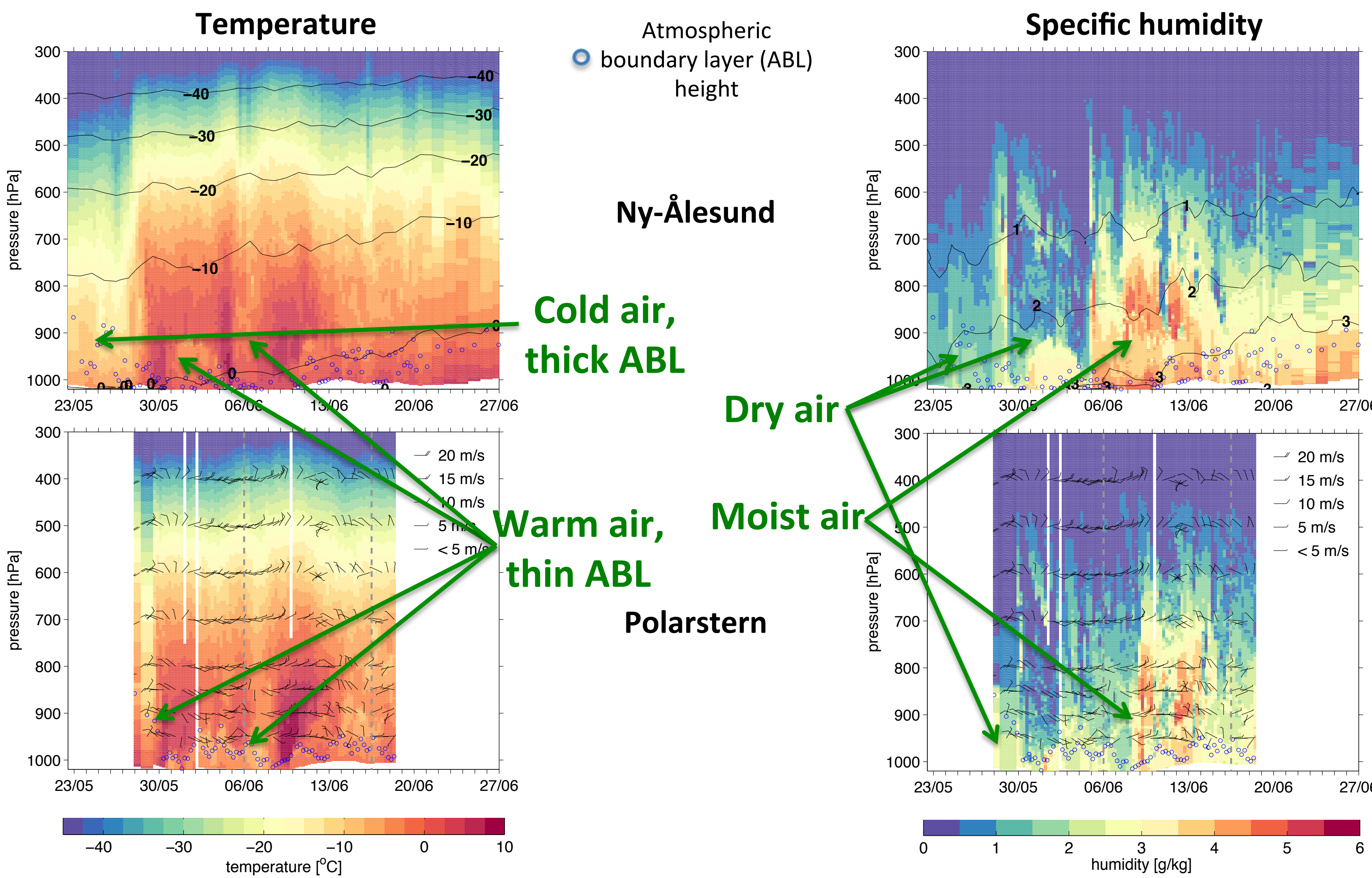
Integrated water vapor and precipitation



Moist air

Dry air

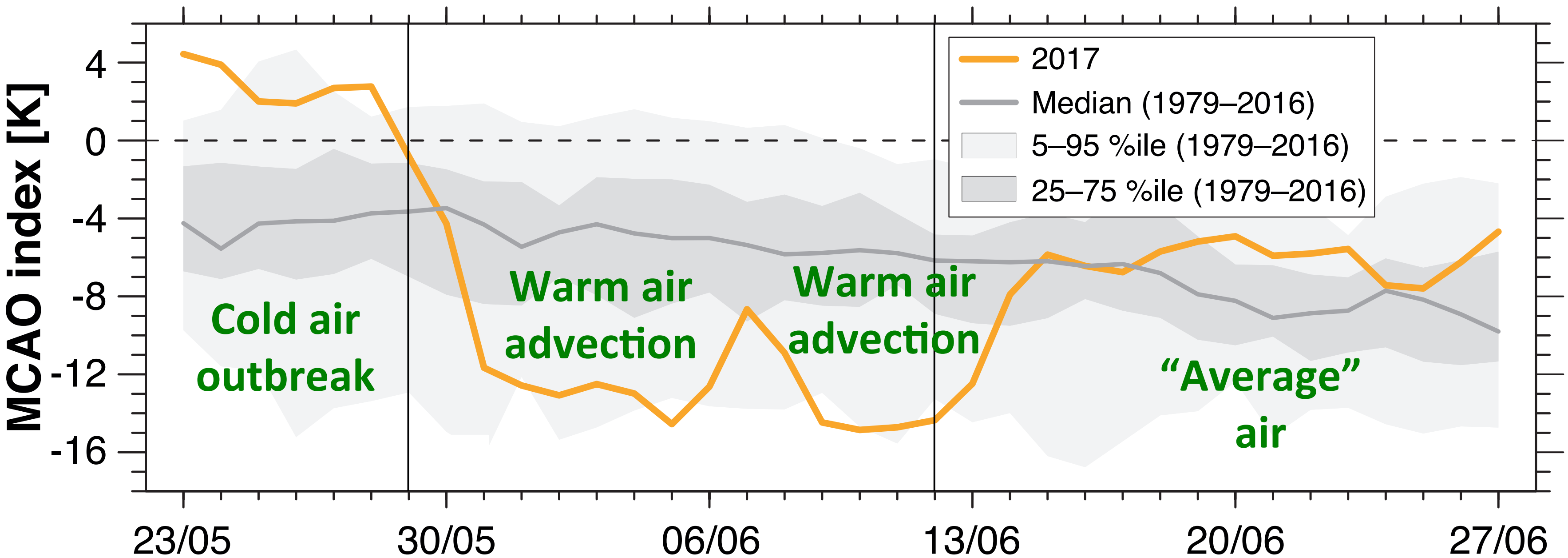
Time Series from Radiosonde Observations



Intro/Data | Time Series | Key Periods | Climatology | Conclusions

Time Series of Marine Cold Air Outbreaks (MCAOs)

MCAO index = $\theta_{850hPa} - \theta_{sfc}$ following Papritz et al. (2015)[18] and Kolstad (2017)[19]

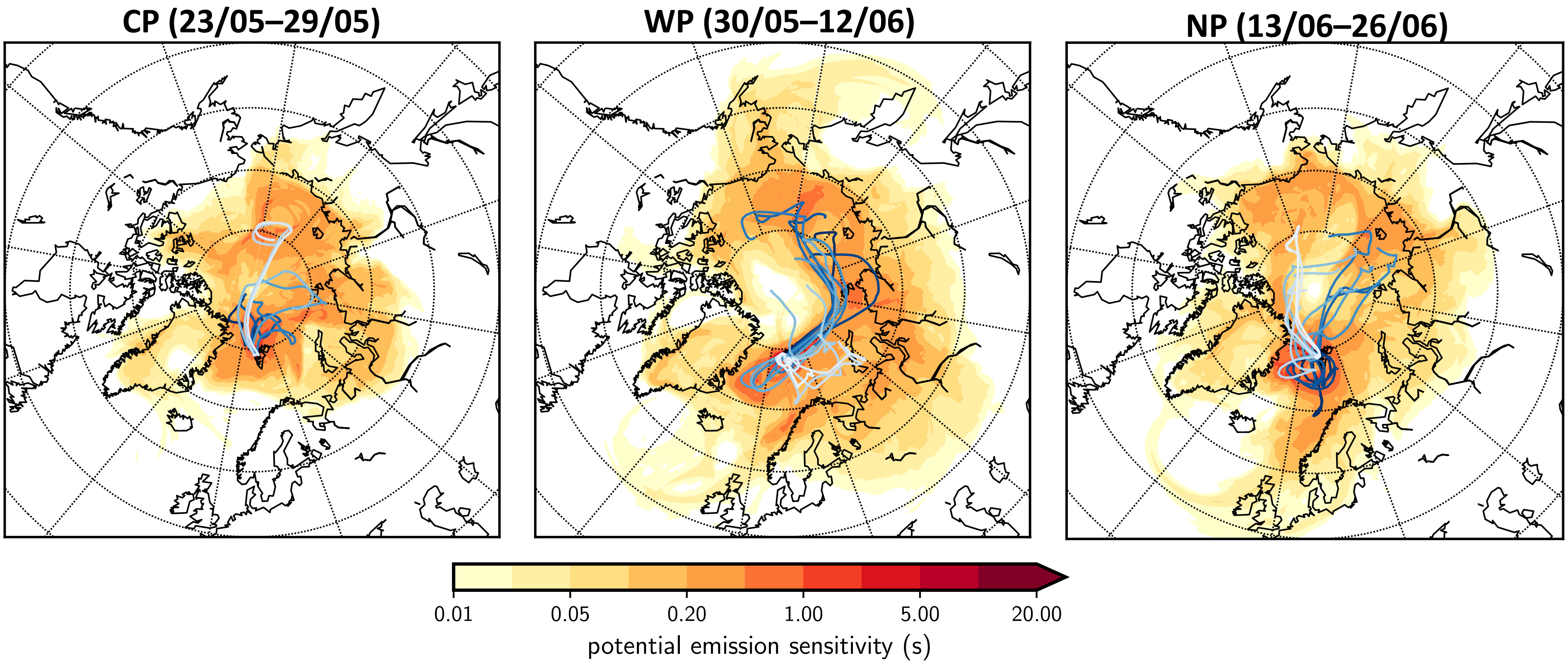


Three key periods:

1. The cold period (CP): May 23–29, 2017 (7 days)
2. The warm period (WP): May 30 – June 12, 2017 (14 days)
3. The normal period (NP): June 13–26, 2017 (14 days)

Key Period Characteristics

Key Period Air Mass Distribution



Cold period (CP):

- Air from the north (Arctic)

Warm period (WP):

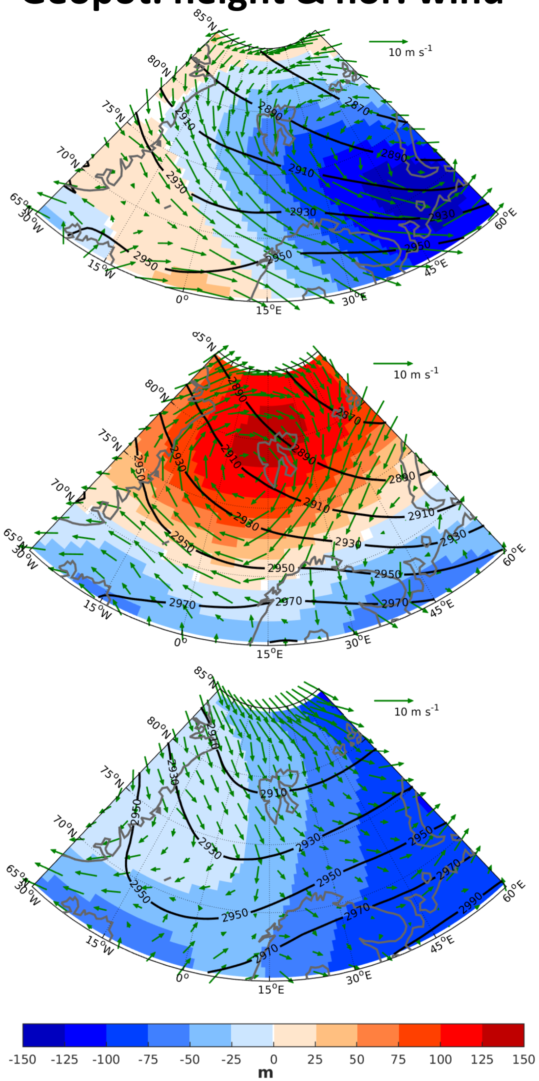
- Air from the south and east (open ocean or adiabatically warmed)

Normal period (NP):

- Air mixed, but mainly from the west (adiabatically warmed)

Key Period 700-hPa Atmospheric Circulation and Thermodynamics

Geopot. height & hor. wind

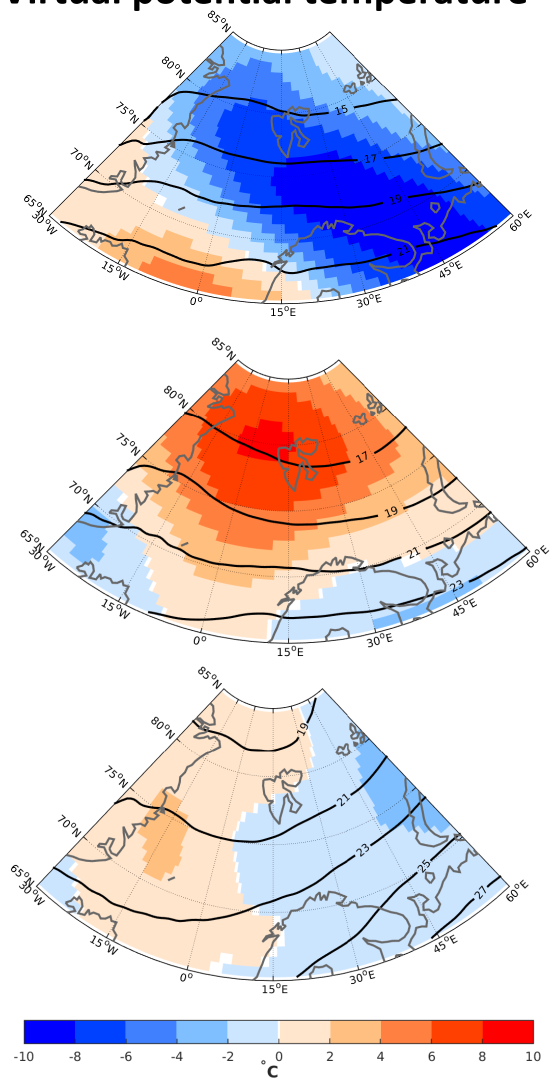


Cold period

Warm period

Normal period

Virtual potential temperature[20]

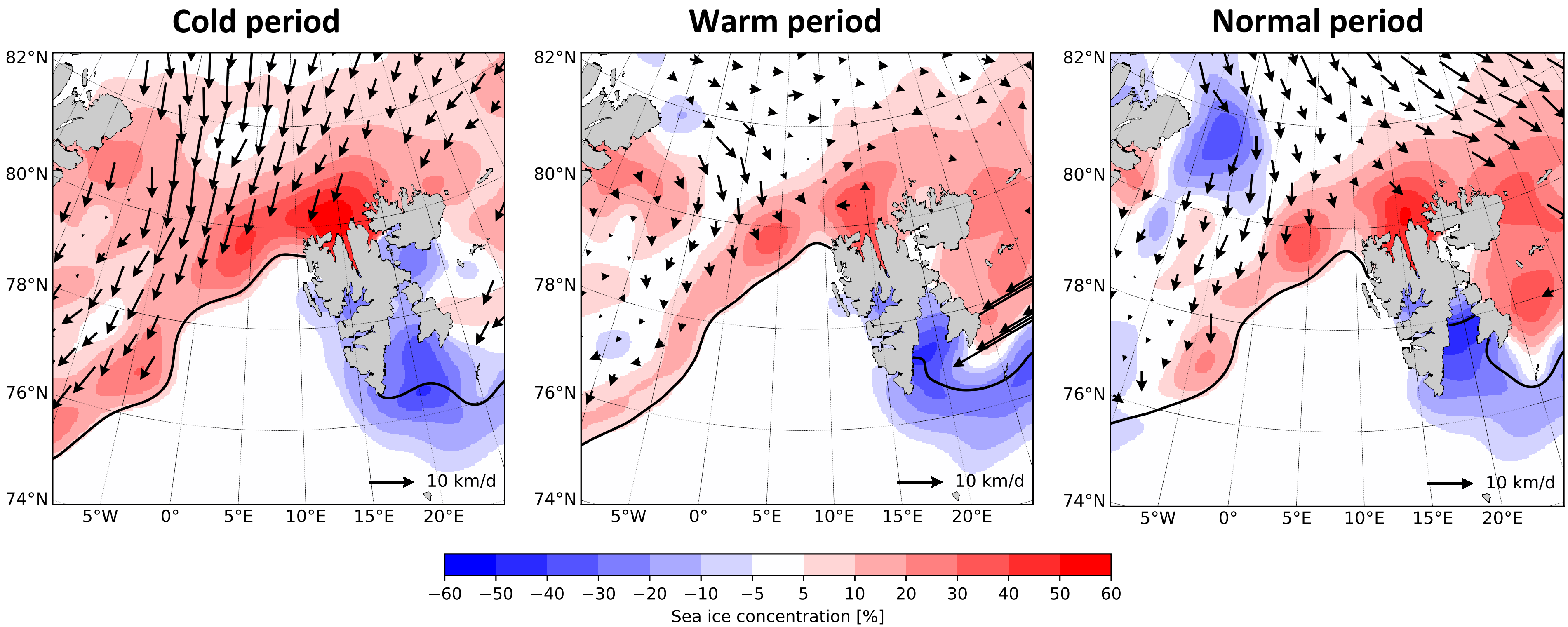


Cyclonic circulation
↓
Cold and dry Arctic air

Anticyclonic circulation
↓
Warm and moist maritime air

Zonal divide
↓
Mixed, average air

Key Period Sea Ice Dynamics



Strong S-SW sea ice drift

↓

Anomalously high Fram Strait concentration

Reduced sea ice drift

↓

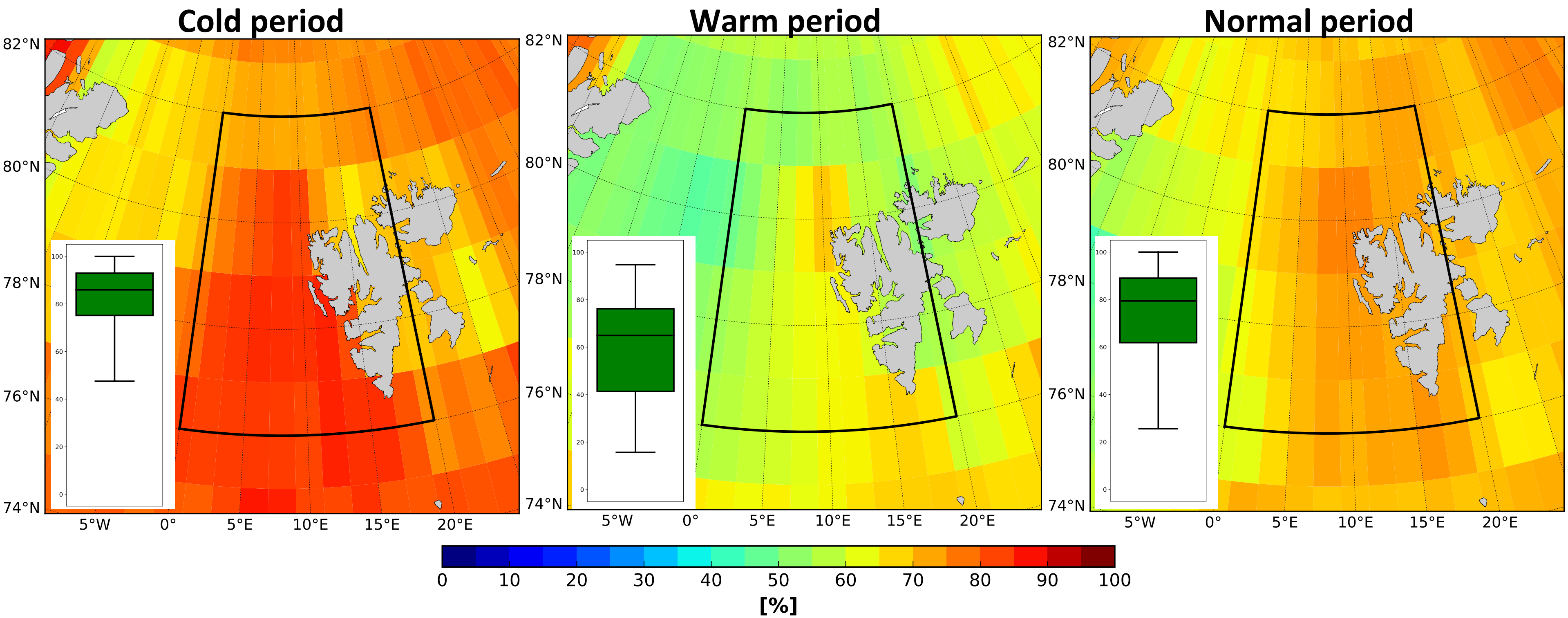
Fram Strait sea ice compaction

SE sea ice drift

↓

Unusual opening of the Northeast Water Polynya

Key Period Cloud Cover Fractions



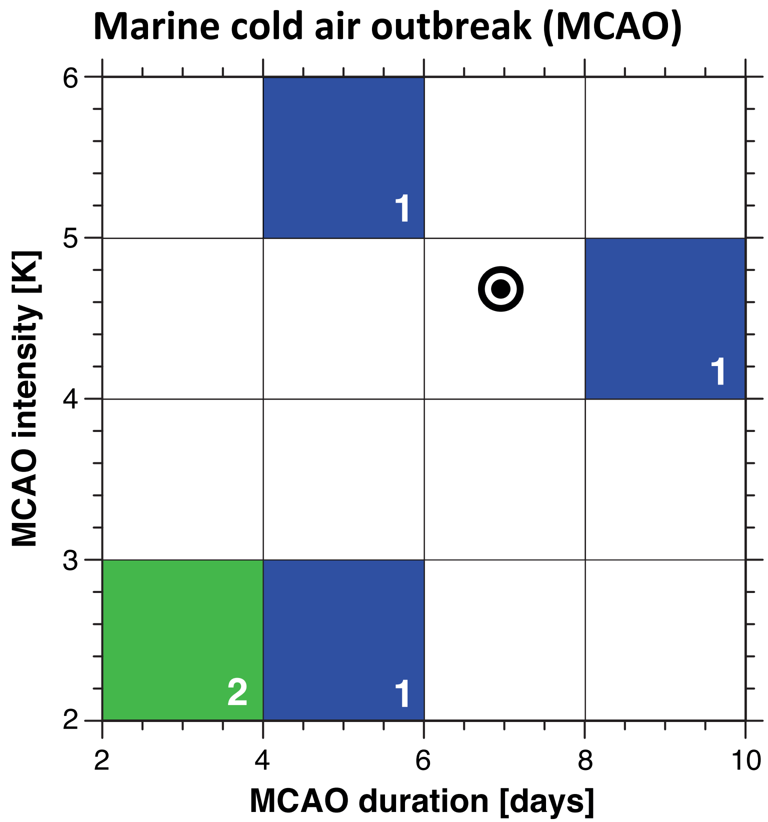
Highest coverage (85 % in boxed area), especially over the open ocean, dominated by low-level clouds

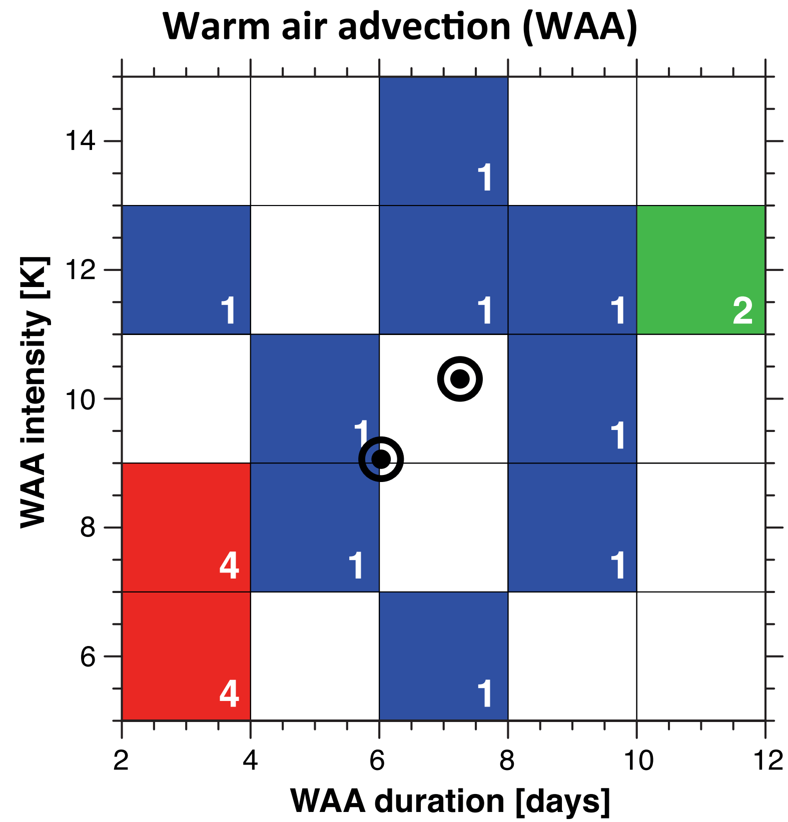
Lowest coverage (65 % in boxed area), especially over the sea ice, dominated by mid-level clouds

Medium coverage (80 % in boxed area), with large spread, dominated by mid-level clouds

Climatological Context

Climatologically Anomalous Events





- 5 events 1998–2016, 1 in 2017
  - 2017 event strong, lasting 7 days with an intensity of 4.7 K
- 19 events 1998–2016, 2 in 2017
  - 2017 events moderate, lasting 6-7 days with intensities of 9.1–10.3 K

Comparison to Other Arctic Campaigns

Snow melt season onset:

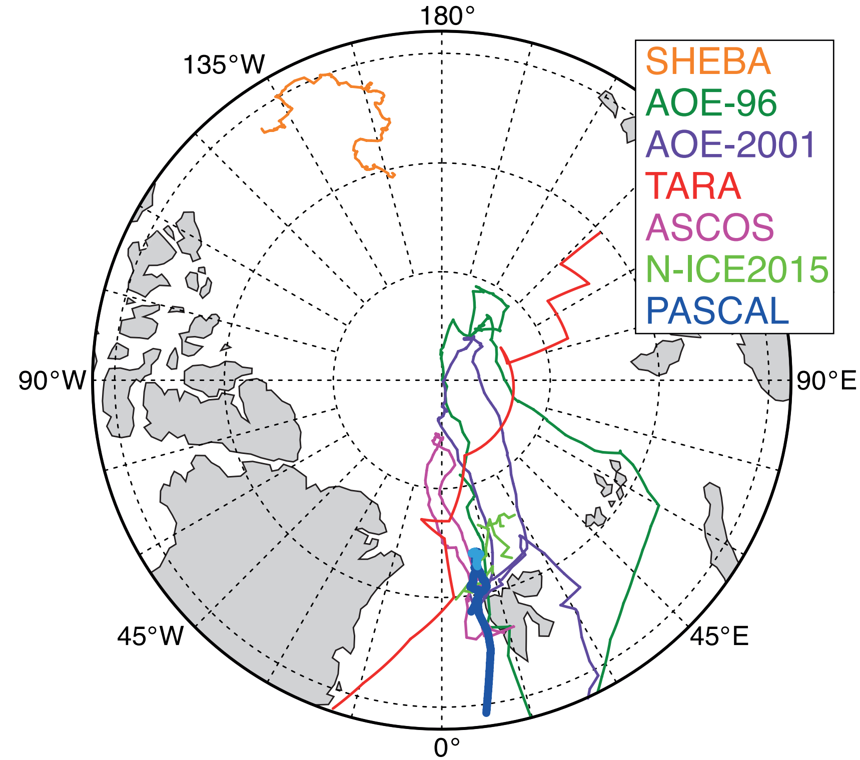
- SHEBA (1997/98) around May 30[21], TARA (2006/07) around June 9[22]
- ACLOUD/PASCAL around May 29

Atmospheric circulation:

- AOE-96 (1996) and AOE2001 (2001) mainly cyclonic, ASCOS (2008) anticyclonic[21]
- ACLOUD/PASCAL cyclonic during CP and anticyclonic during WP

Temperature range:

- N-ICE2015 (2015) about [-10,2]°C[23]
- ACLOUD/PASCAL about [-3,6]°C



Conclusions

Conclusions

Knudsen, E.M. et al. (2018),
Synoptic development during the ACLOUD/PASCAL field
campaign near Svalbard in spring 2017,
Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2018-494[1].

Thank you for your attention!

- Synoptic development during the ACLOUD airborne and PASCAL ship-based field campaigns May 23 – June 26, 2017
- Short-term variability in atmospheric circulation dominated over the long-term forcing of the Arctic amplification
- Three key periods:
  1. The cold period (CP; May 23–29, 2017; 7 days),
     characterized by cold and dry Arctic air from the north associated with widely covering low-level clouds
  2. The warm period (WP; May 30 – June 12, 2017; 14 days),
     characterized by warm and moist maritime air from the south and east associated with less covering mainly mid-level clouds
  3. The normal period (NP; June 13–26, 2017; 14 days),
     characterized by close-to-average temperate and moist air from a mixture of regions associated with a mix of earlier cloud conditions

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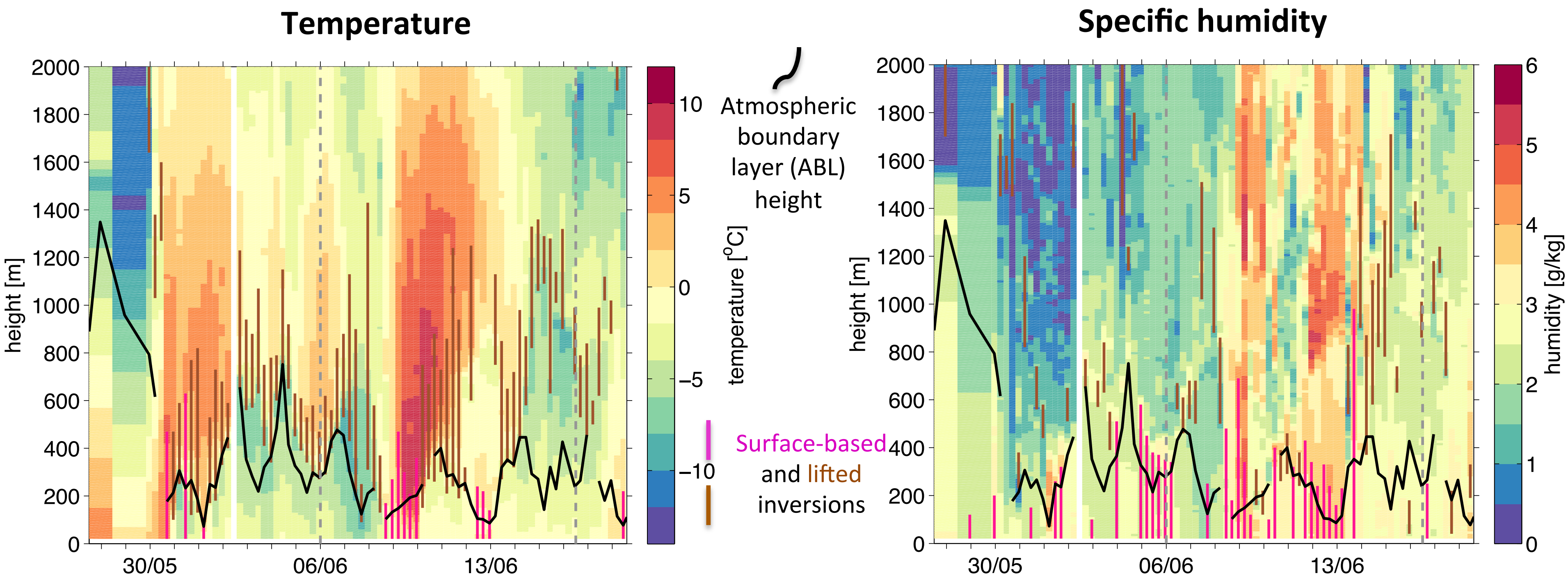
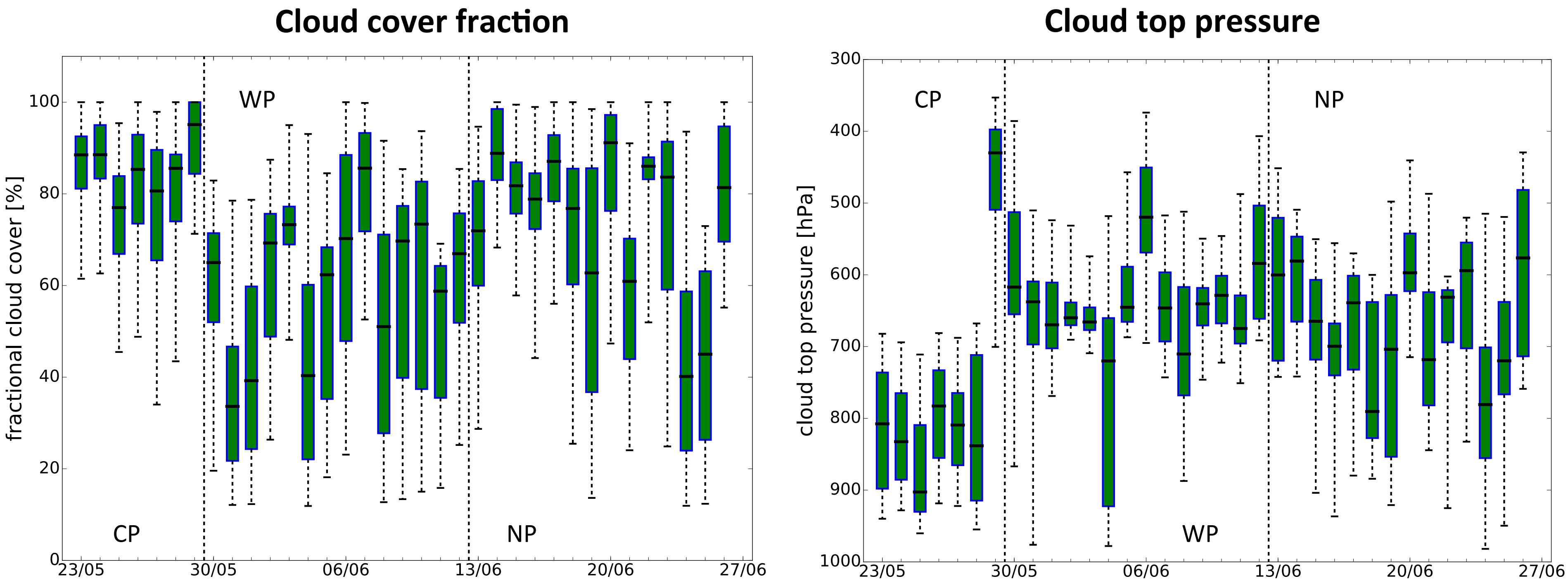
Additional Figures

Time Series of Inversions from Polarstern



- **Until May 30, ABL high and few inversions**
- **After this, ABL height [100,800] m and almost continuous inversions**
- **ABL thick → lifted temperature inversion, ABL shallow → surface-based temperature inversion**

Time series of Cloud Cover Fractions and Top Pressures



Cold period (CP):

- Highest coverage, lowest clouds
- Low variability

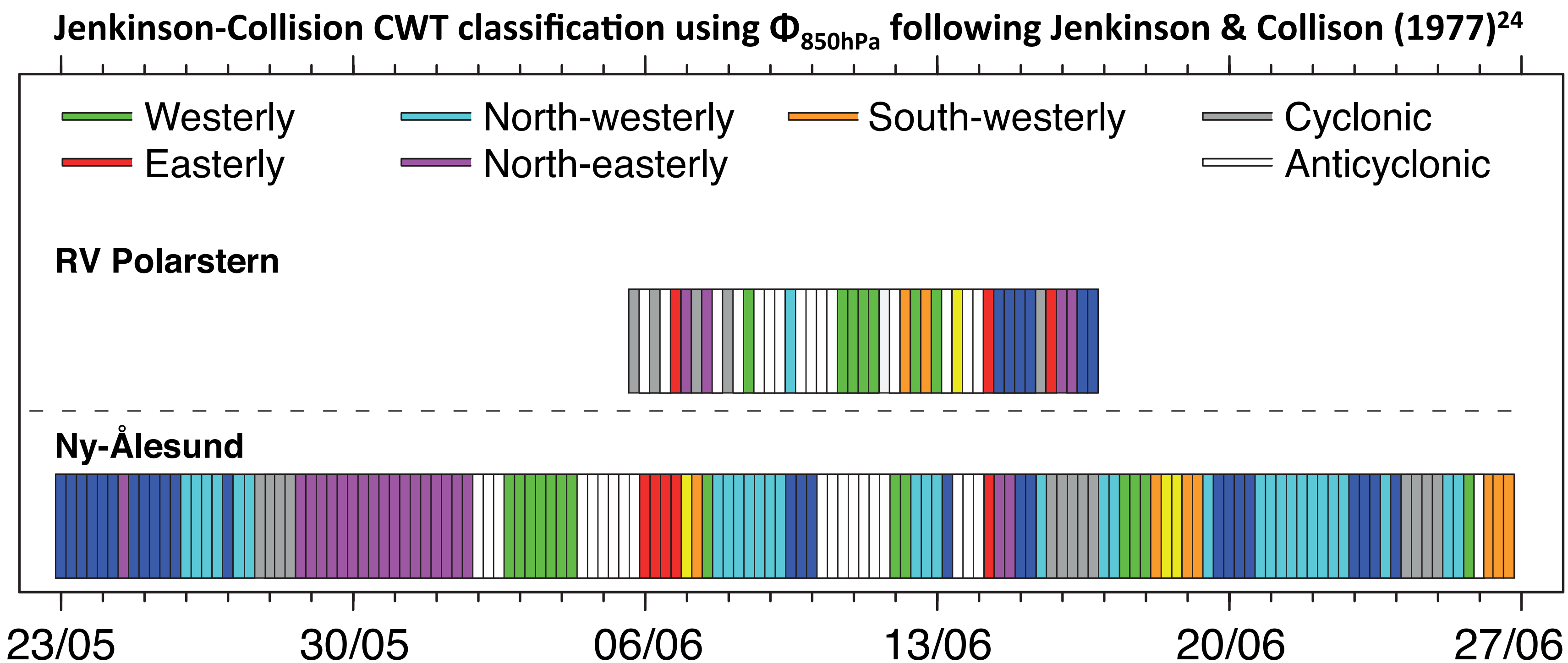
Warm period (WP):

- Lowest coverage, highest clouds
- High variability

Normal period (NP):

- Similar to WP, but…
- …higher coverage and more high-clouds

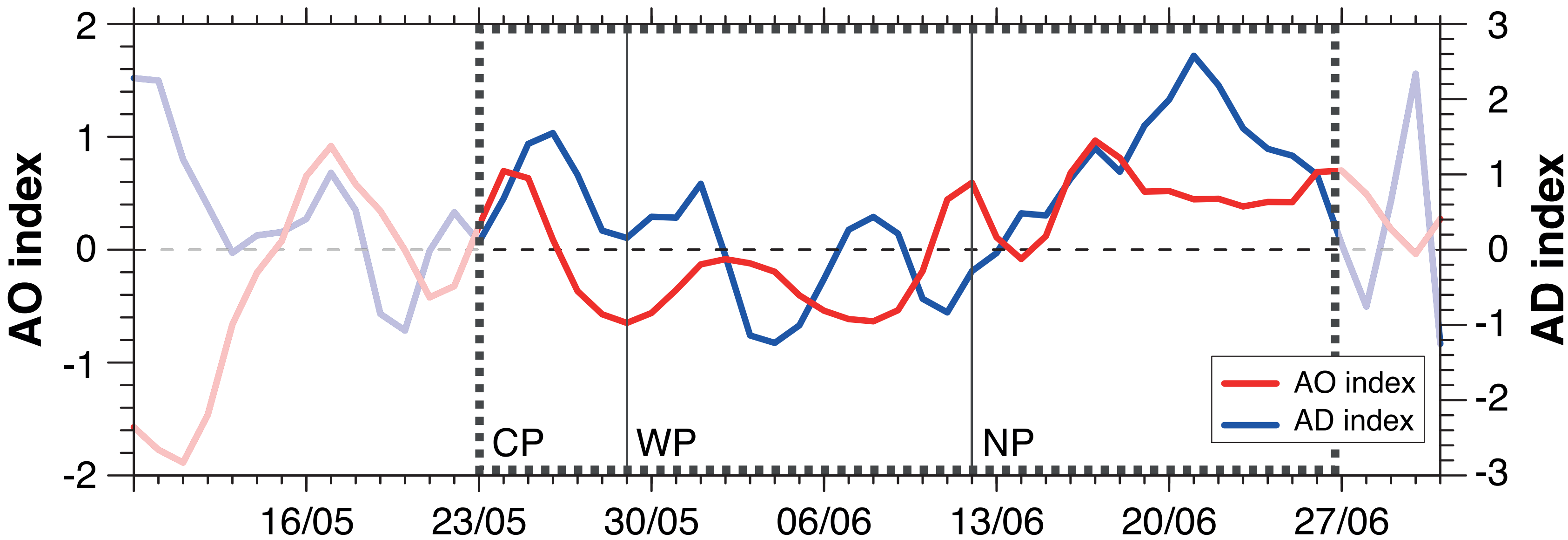
Time Series of Circulation Weather Types (CWTs)



- N-NW CWT dominated over Ny-Ålesund first 5 days, then 4 days NE
- Anticyclonic and W CWTs over Ny-Ålesund and Polarstern June 2–13
- N CWT over Ny-Ålesund and Polarstern June 14–16
- CWT varied considerably last 1.5 weeks

Time Series of Arctic Oscillation and Dipole Indices

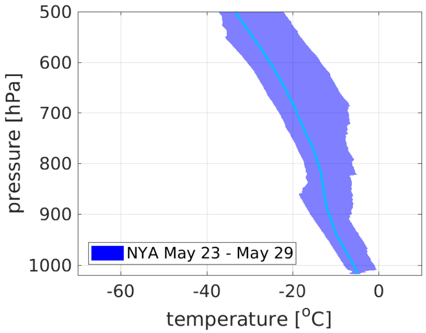
Arctic Oscillation (AO) = 1st leading EOF mode of $Z_{1000hPa}$' > 20°N following Thompson & Wallace (1998)[25],
Arctic Dipole (AD) = 2nd leading EOF mode of $Z_{1000hPa}$' > 70°N following Wu et al. (2006)[26] & Wang et al. (2009)[27]



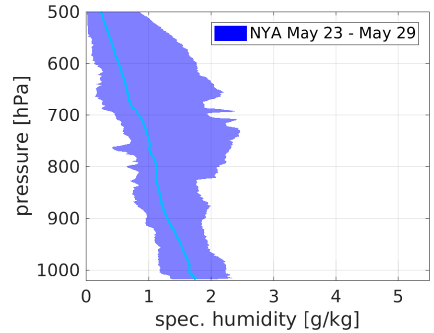
- **Positive indices before ACLOUD/PASCAL might have contributed to anomalous high sea ice concentration in the Fram Strait**
- **Positive indices dominated the cold period (CP) and the normal period (NP), negative indices the warm period (WP)**
- **Synoptic development better described by more regional indices**

Key Period Temperature and Humidity Profiles

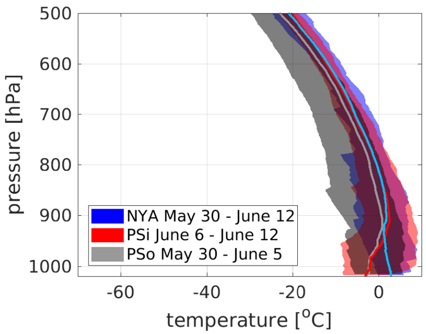
Temperature | **Specific humidity**



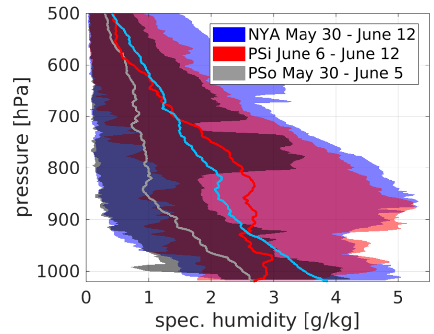
Cold period



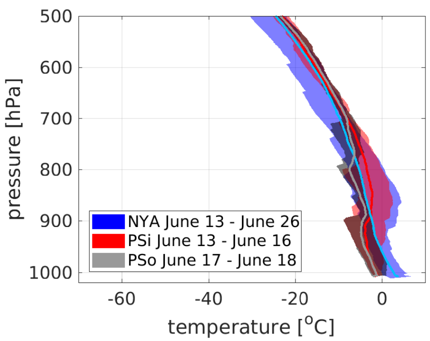
- Cold (< 0°C) and dry (< 2 g kg^{-1}) air
- Near isothermal 900–800 hPa
- Low variability



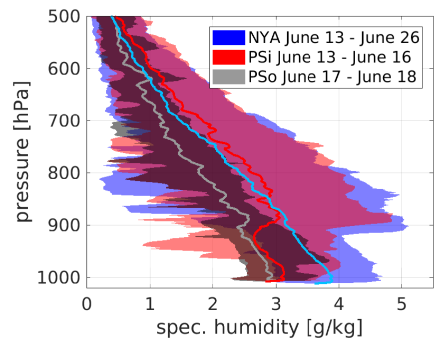
Warm period



- ≈ 10°C warming and ≈ 1-2 g kg^{-1} moistening below 500 hPa
- Inversions in lowest layer over Polarstern

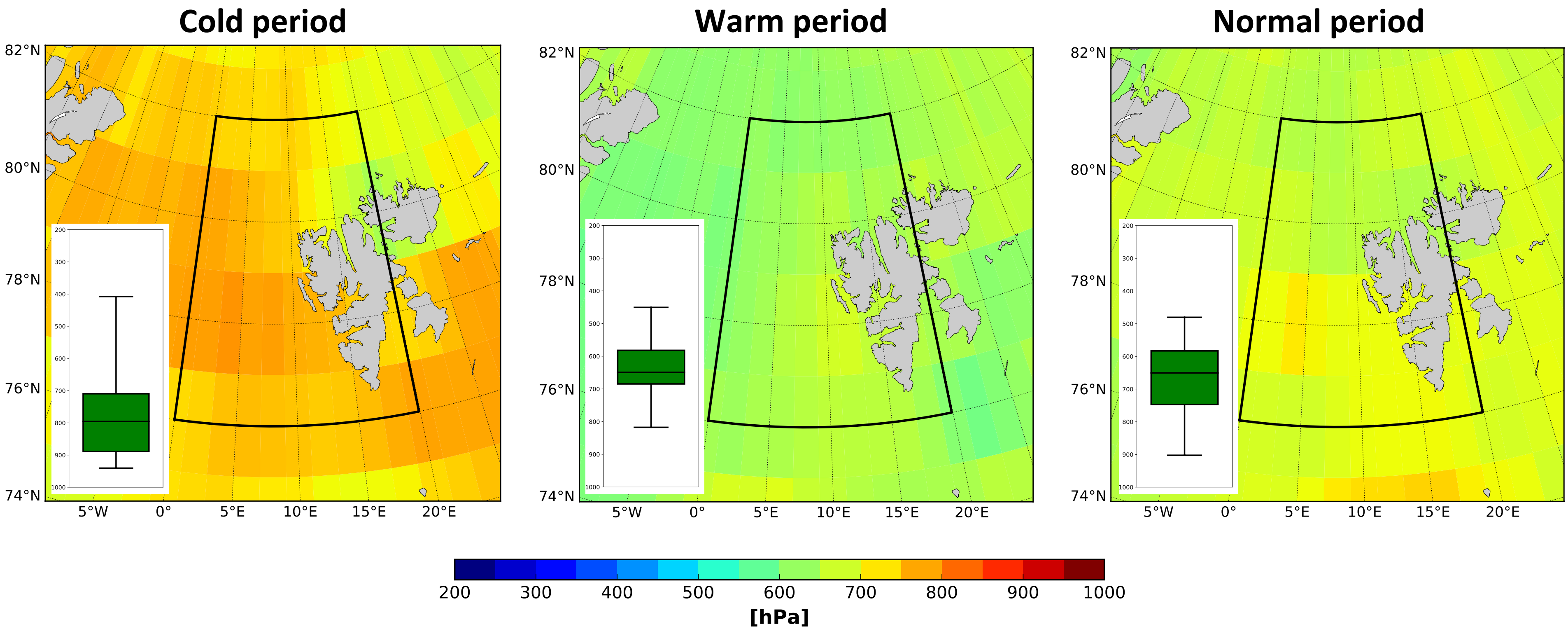


Normal period



- Similar features as in the cold period, but ≈ 10°C warmer and ≈ 1-2 g kg^{-1} moister

Key Period Cloud Top Pressures



Highest coverage (85 % in boxed area), especially over the open ocean, dominated by low-level clouds

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Climatology of Arctic Oscillation and Dipole Indices

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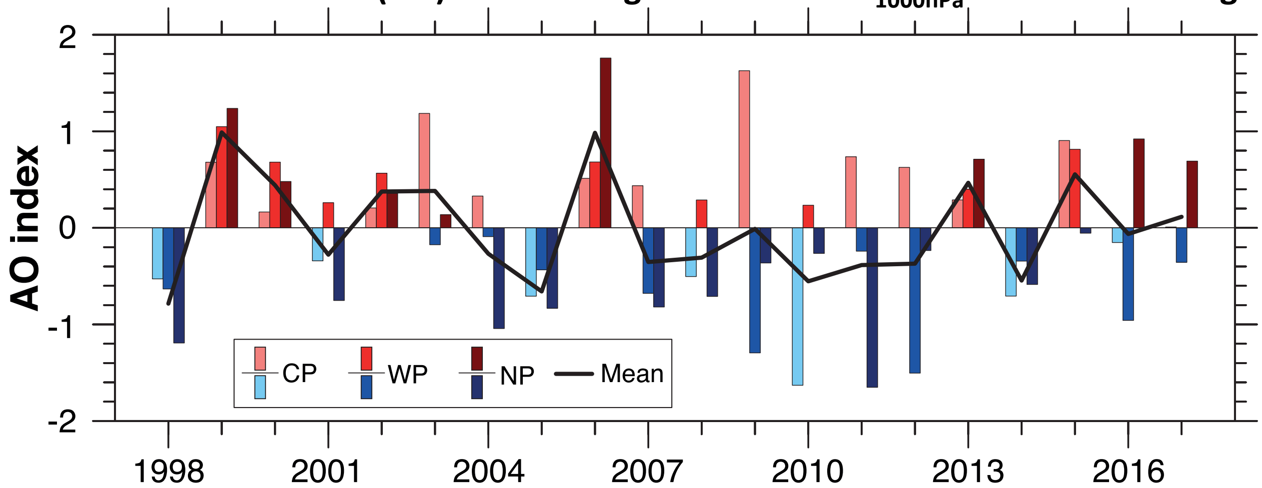
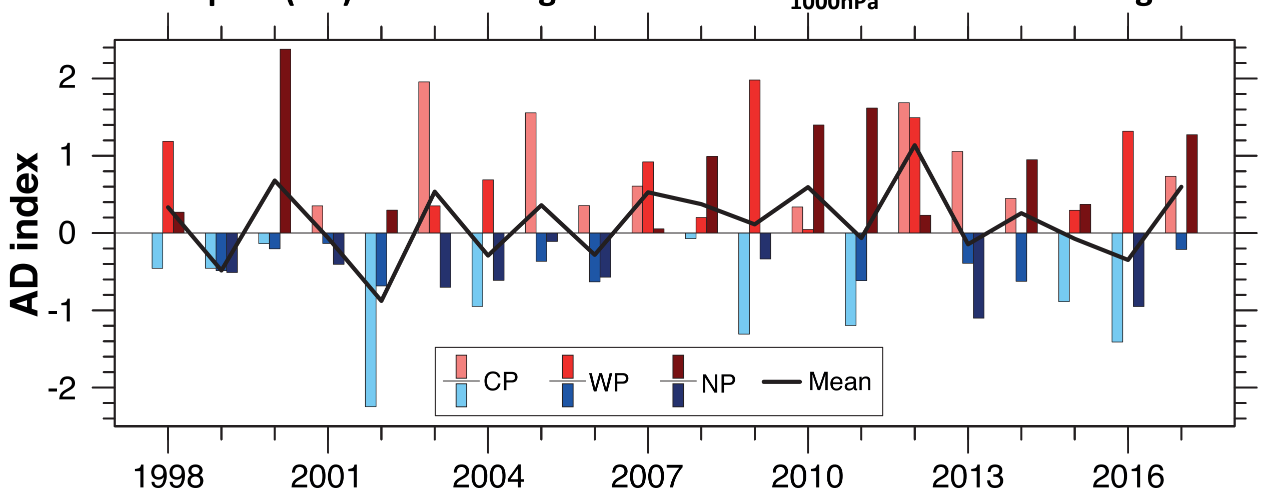


- Large interannual variability until 2006, thereafter more AO$^-$
- In 2017, strong AO$^+$ during NP

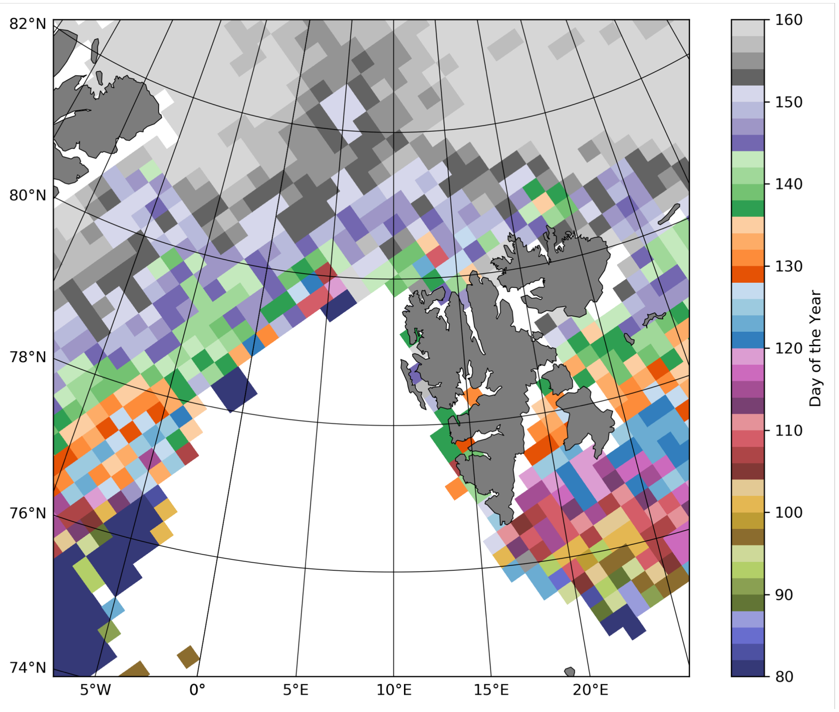
Arctic Dipole (AD) = 2nd leading EOF mode of $Z_{1000hPa}$' > 70°N following Wu et al. (2006)[26] & Wang et al. (2009)[27]



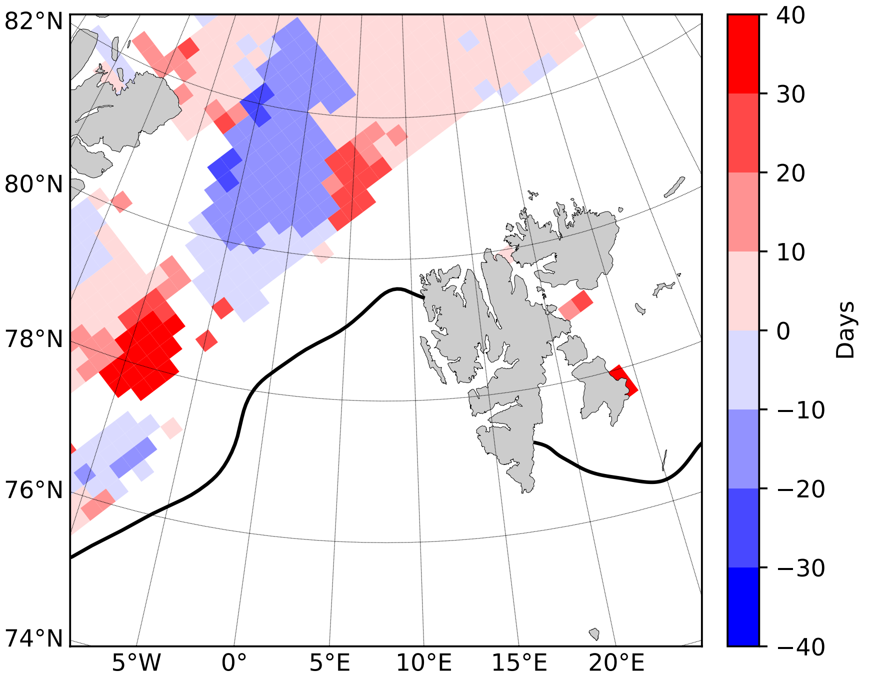
- Large interannual variability until 2007, thereafter more AD$^+$
- In 2017, moderate/strong AD$^+$ during CP/NP

Climatology of Snow Melt Onset Dates

1979–2016



2017



- **Generally, onset date increase with latitude**
- **West Spitsbergen Current ➔ ≈ 10 days later onset west of the Yermak Plateau**

- **10–30 days earlier onset east of the Northeast Water Polynya**
- **10–30 days later onset both west and east of this area**