Cloud properties during marine cold air outbreaks in COMBLE: a preliminary survey

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COMBLE Objectives

**In a nutshell:** What is the role of marine boundary layer clouds during cold-air outbreaks over open water in the Arctic climate system?

**Context:** the COMBLE campaign addresses fundamental questions related to aerosol-cloud-precipitation feedbacks in the Arctic climate system. The campaigns focus on a cloud regime that remains poorly understood: shallow convection in the marine boundary layer during cold air outbreak events.

... how to define cold-air outbreaks (CAOs)?
CAO conditions

Andoya (M1)
1. M > 0 K
2. $U_{10} > 10$ kts (5 m/s)
3. Wind direction: as below:

$$M \equiv \theta_{SST} - \theta_{850 \, hPa}$$

Bjornoya (S2)
1. M > 1 K
2. $U_{10} > 10$ kts
3. Wind direction: as below:

Data sources: radiosonde (hourly interpolated at M1, 3-6 hourly WMO soundings at S2), MET, NOAA SST
surface winds during CAOs in COMBLE

Winds were generally squarely onshore. Stronger winds at Bear Island.

Photos courtesy LANL.
CAO frequency by month (fraction of time)

Andoya
Bear Island

NOAA SST, MET,
INTERPOLATEDSONDE
WMO sonde (ENBJ)
surface temperature during CAOs

BL thermal instability during CAOs

\[ M \equiv \theta_{SST} - \theta_{850\,hPa} \]
climatological frequency of M values

weak thermal instability

strong thermal instability
sensible heat flux during CAOs

latent heat flux during CAOs

expected values in CAOs: 100-600 Wm⁻² (Brummer et al. 1997; Papritz et al. 2015; Papritz and Spengler 2017)
sensible heat flux during CAOs

bulk aerodynamic formula estimates

U: 10m wind speed, q: specific humidity

\[
SH = \rho C_p C_{SH} U (T_{SST} - T_{2m})
\]

latent heat flux during CAOs

\[
LH = \rho L_v C_{LH} U (q_{sat,SST} - q_{2m})
\]
precipitation rate during CAOs

PBL depth during CAOs
liquid water path during CAOs

cloud base height during CAOs
Cloud vertical structure during CAOs

KAZR
Some good CAO cases
Satellite imagery & radar mosaic reflectivity
03/13/2020 0950 UTC

MODIS image
(data source: https://earthobservatory.nasa.gov/)

MET Norway radar mosaic
(data source: https://thredds.met.no)
Satellite imagery & radar mosaic reflectivity
03/29/2020 0950 UTC

MODIS image
(data source: https://earthobservatory.nasa.gov/)

MET Norway radar mosaic
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