Interactions between Arctic boundary layer and low level mixed-phase clouds

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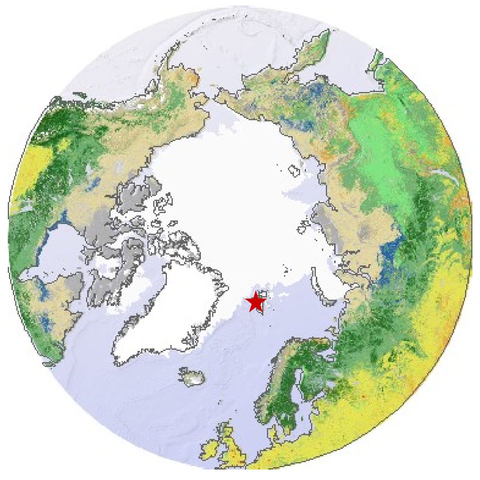
Observing Mixed-Phase Clouds

- Low-level stratiform liquid containing clouds have a major influence on Arctic surface radiation balance[1]
- **Focus on mixed-phase cloud microphysics**
- How does the environment at measurement site influence cloud properties (life cycle, altitude, geom. thickness, water content...)?



Observations at Ny Ålesund

- Comprehensive cloud observations carried out at the AWIPEV station[2]
- Ground based remote sensing, surface meteorology and instrument synergy (Cloudnet).
- Here using data from June 2016 – February 2018 and only considering occurrences of **persistent low-level mixed-phase clouds.** Criteria: Co-located ice and liquid found; liquid layer persists > 1h; cloud liquid located close to cloud top; cloud top < 2.5 km

Turbulence and cloud properties

- The thermodynamical coupling of the cloud to the surface constrains the extent of interactions possible with the underlying surface: Surface is a potential source of humidity and aerosol.
- Turbulence and thermodynamical structure has been linked with microphysical processes (liquid and ice formation, sublimation of precipitation)[3].

Evaluating cloud-surface coupling

Using potential temperature (θ) -profiles from soundings to determine coupling state[3]

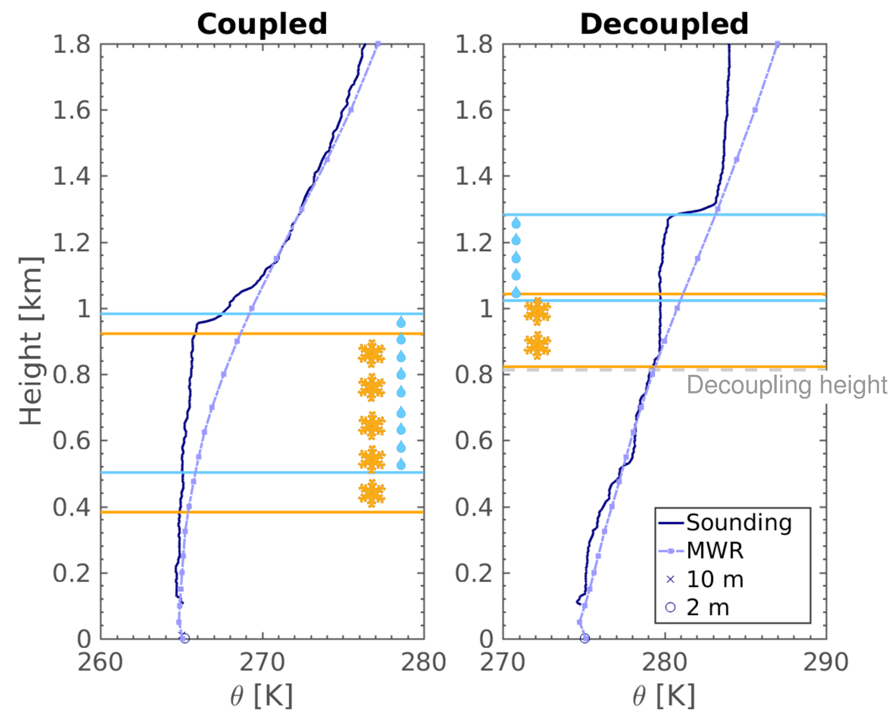


Fig 1. Examples of potential temperature -profiles for coupled and decoupled MPC as measured with sounding, microwave radiometer (MWR), and surface observations. Cloud boundaries and decoupling height determined by the sounding profile are also shown.

The methods compare well

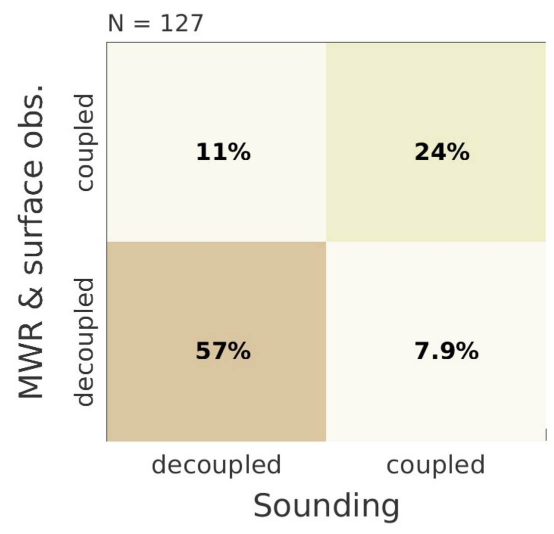


Fig 3. Comparing cloud coupling state using the two approaches. MWR profile closest to sounding time, and surface observations corresponding to MWR scan were used.

Soundings are infrequent and only give a snapshot
→ continuously evaluating coupling

1) surface layer stability: $\theta_{10m} - \theta_{2m}$

- 30 min averages
- If surface layer is stably stratified → cloud decoupled

2) θ-profile retrieved with microwave radiometer (MWR)

- Boundary layer scan every 20 min
- Estimating the stability of the sub-cloud layer with $\theta_{1/2*\text{cloud base height}} - \theta_{surface}$

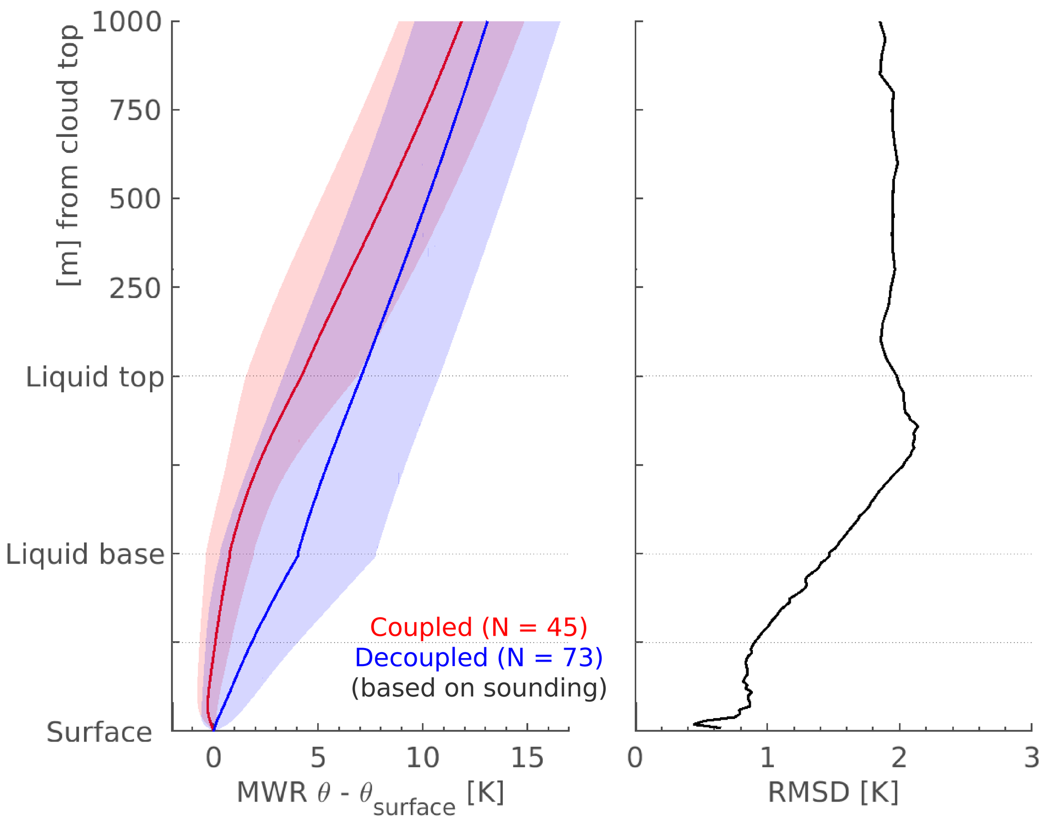


Fig 2. MWR θ-profiles for coupled and decoupled clouds, where cloud coupling is determined from the sounding profile (left), and the RMSD between MWR and sounding θ -profiles for the corresponding cases (right).

Turbulence below of coupled and decoupled clouds

Intensity of turbulence in the sub-cloud layer is estimated using wind lidar - VAD scan with 4 beams

Using retrieved vertical wind (w) to calculate w variability (σ_w) and skewness (S_w)

Four beam retrieval for $\overline{u'w'}$ and $\overline{v'w'}$
$\rightarrow u_*^2(z) = \sqrt{\overline{u'w'}^2 + \overline{v'w'}^2}$

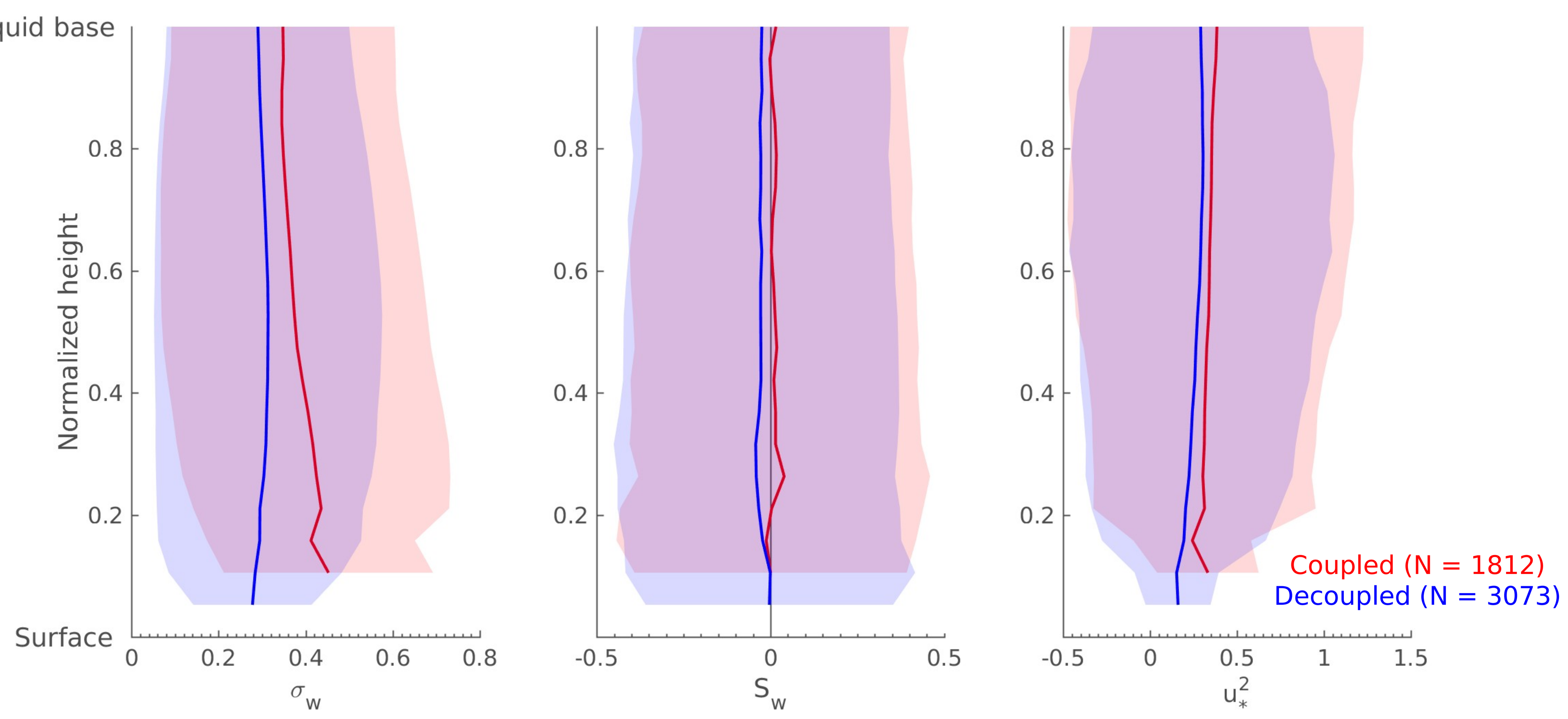


Fig 4. Mean (lines) ± standard deviation (shaded areas) profiles of turbulence parameters retrieved from wind lidar (see details above). Cloud coupling is determined using the combination of MWR and surface observations.

Higher intensity of below cloud turbulence associated with coupled clouds.

Cloud properties

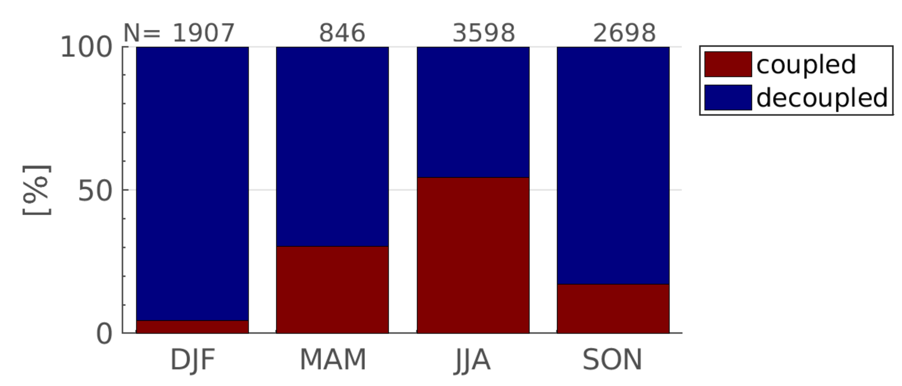
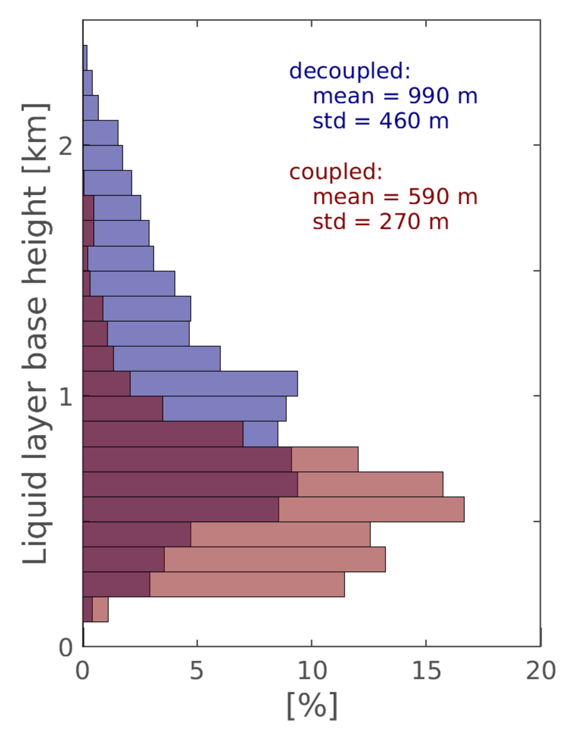


Fig 5 (above). The fraction of observed cases that are coupled varies seasonally.

Fig 6 (right). Coupled clouds are on average lower than decoupled ones. The height of the liquid layer also varies seasonally, being lowest in summer and highest in winter (not shown).



Conclusion

- Methods to evaluate cloud surface coupling and the intensity of below cloud turbulence developed
- Coupling influences turbulence, but how does it influence micro-physics?
- Future work: Using radar Doppler moments to dive into micro-physics

References
1- Shupe, M.D. and Intrieri, J.M. (2004). Cloud radiative forcing of the Arctic surface: The influence of cloud properties, surface albedo, and solar zenith angle. Journal of Climate, 17(3), p. 616-628.
2- T. Nomokonova et al. (2018). Statistics on clouds and their relation to thermodynamic conditions at Ny-Ålesund using ground-based sensor synergy, submitted to ACP.
3- G. Sotiropoulou et al. (2014). The thermodynamic structure of summer Arctic stratocumulus and the dynamic coupling to the surface, ACP 14(22), p. 12573-12592.

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