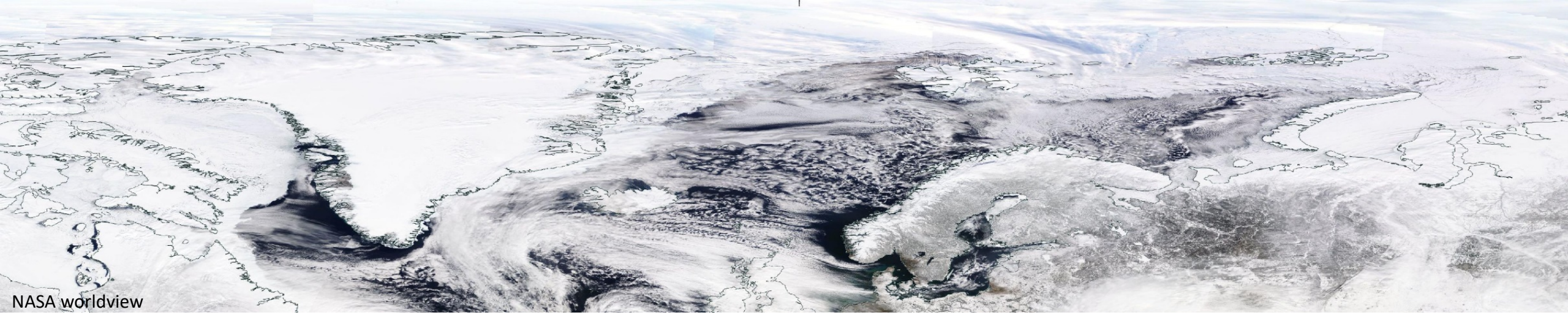

Cloud ice processes enhance spatial scales of organization in Arctic stratocumulus

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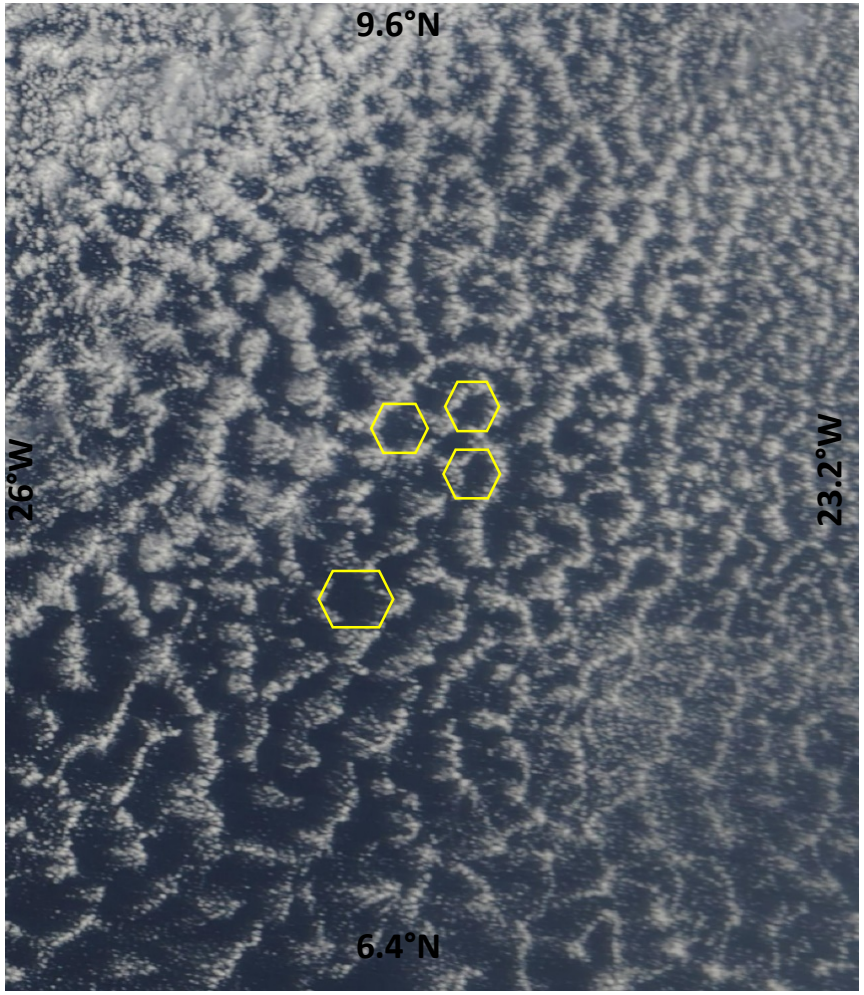
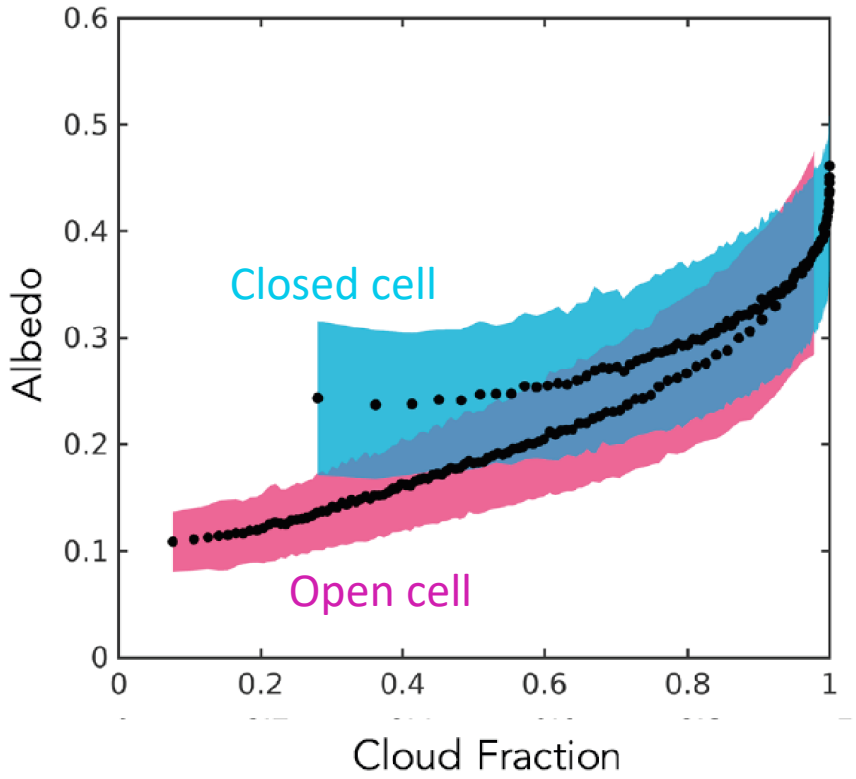
Cloud organization at the high latitudes



MODIS reflectance, 21 March 2013, off African coast

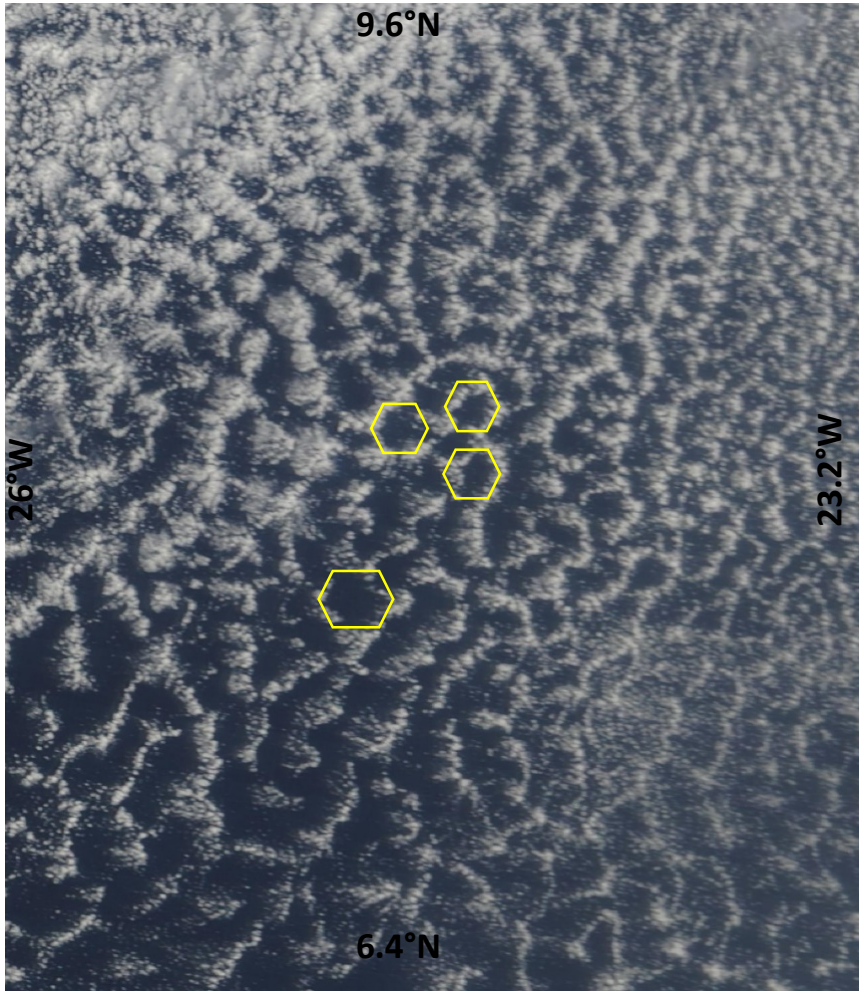
Organized ‘honeycomp-like’ cloud structures are well-studied for the subtropics and can impact cloud radiative properties



Cloud fraction alone does not determine cloud albedo!

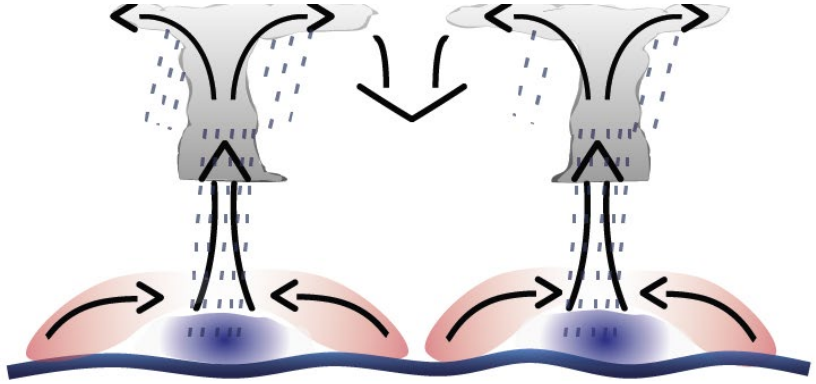
McCoy et al., 2017, JGR

Cloud organization at the high latitudes



MODIS reflectance, 21 March 2013, off African coast

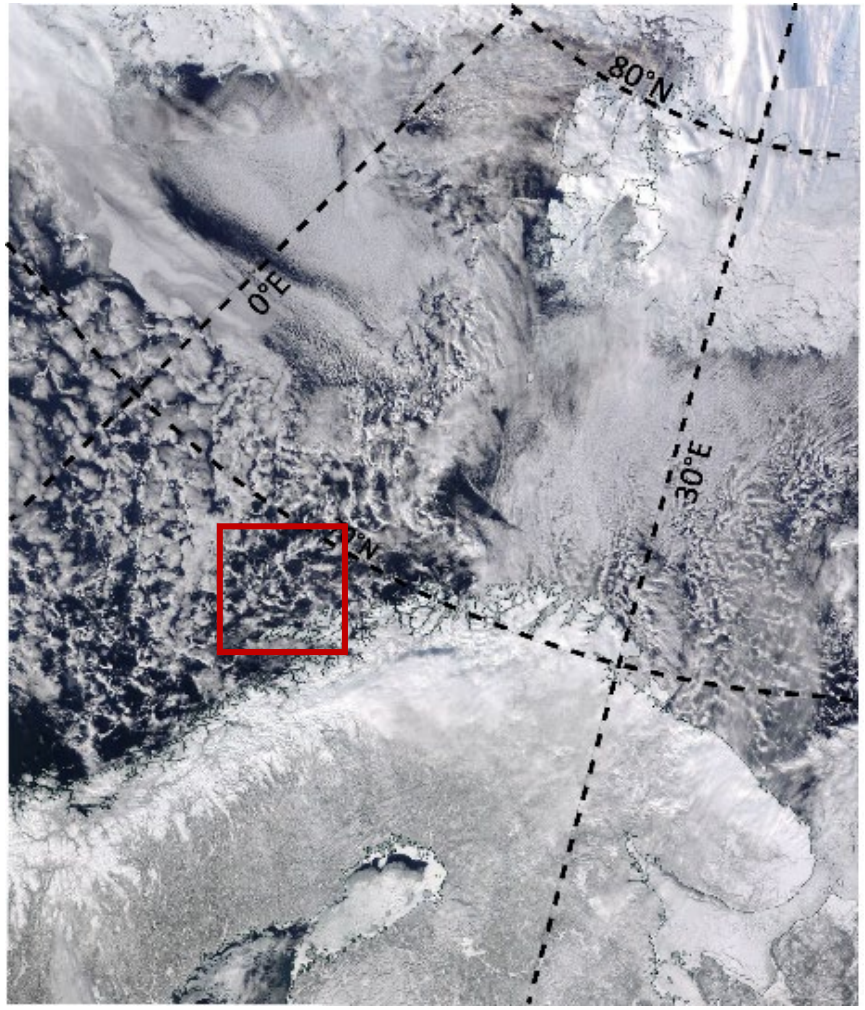
Organized open-cell cloud cells are initiated by precipitation formation



Mechanism:

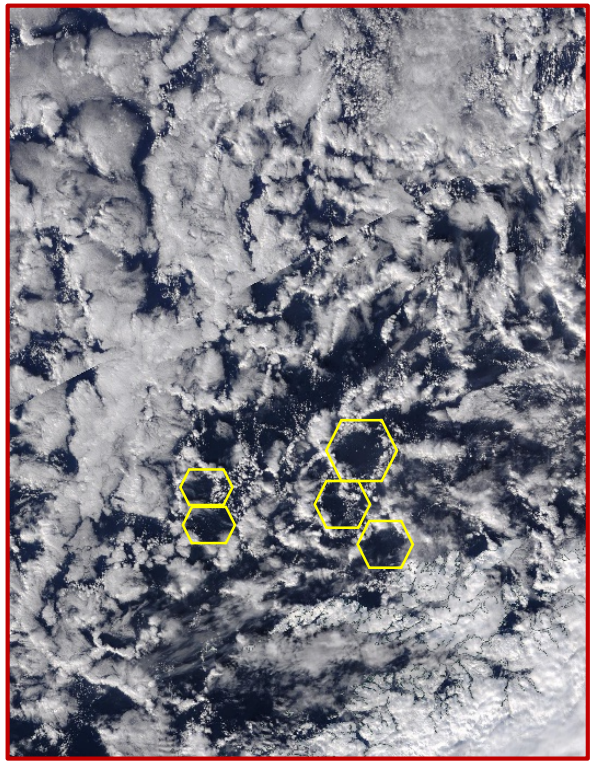
- Precipitation formation at cloud base
- Evaporation and latent cooling in the sub-cloud layer leads to cold pool formation
- Warm air is lifted above the surface cold pool to form new cloud structures

Cloud organization at the high latitudes



MODIS reflectance, 23 March 2013, North Atlantic

Cloud organization also occurs at high latitudes (e.g. off the Norwegian coast, as seen in the satellite image). However, these cloud are often **mixed-phased**.

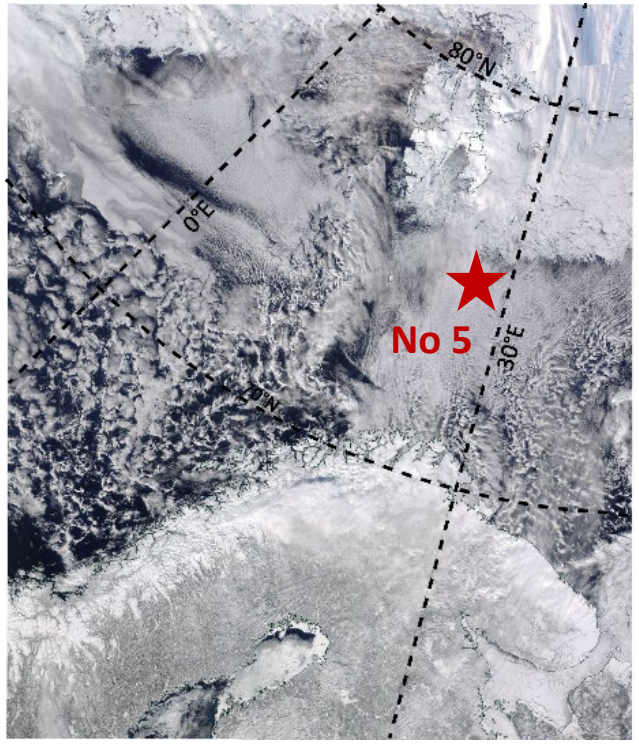


This remains so far unexplored!

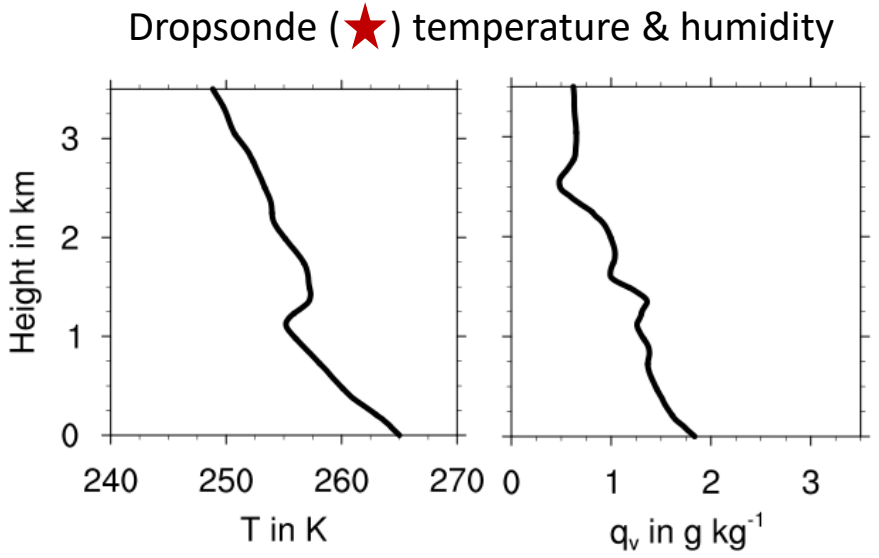
- Does cloud organization in the mixed-phase regime follow the same mechanism as observed for warm-phase clouds?
- What specifically is the role of cloud ice?

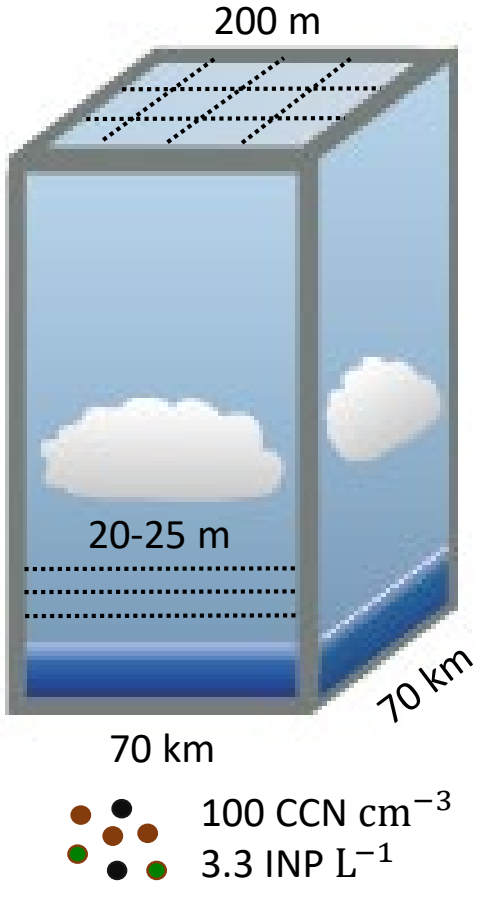
Approach: large eddy simulations (LES) using COSMO

COSMO-LES case study for the Aerosol-Cloud Coupling and Climate Interactions in the Arctic (ACCACIA) campaign in March 2013



MODIS reflectance, 23 March 2013



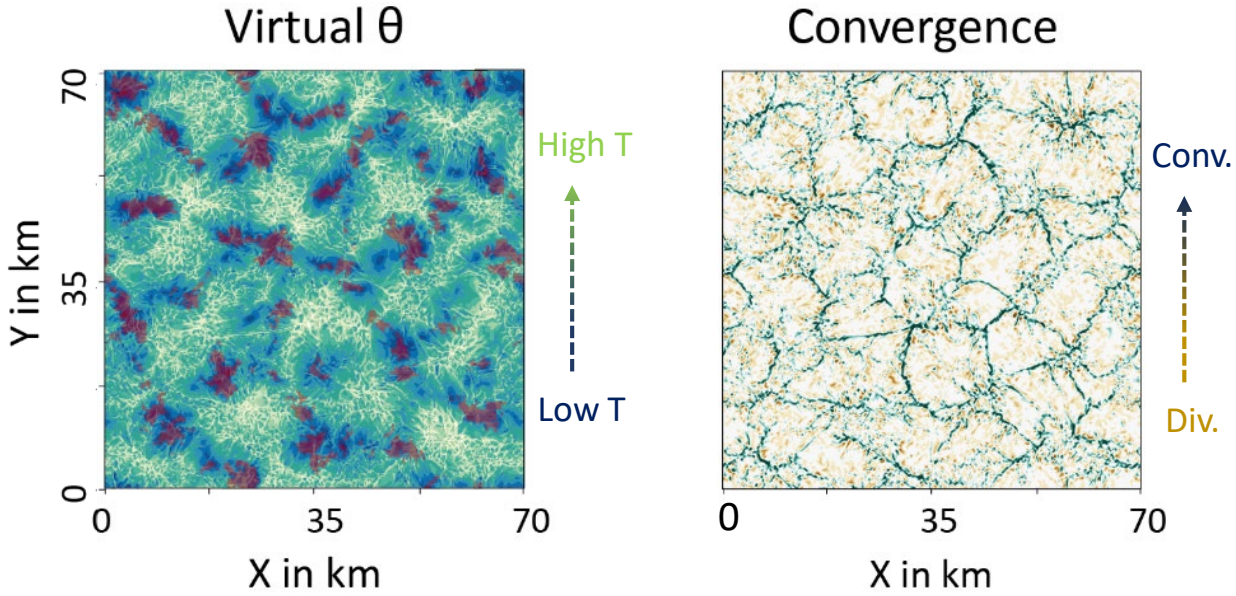


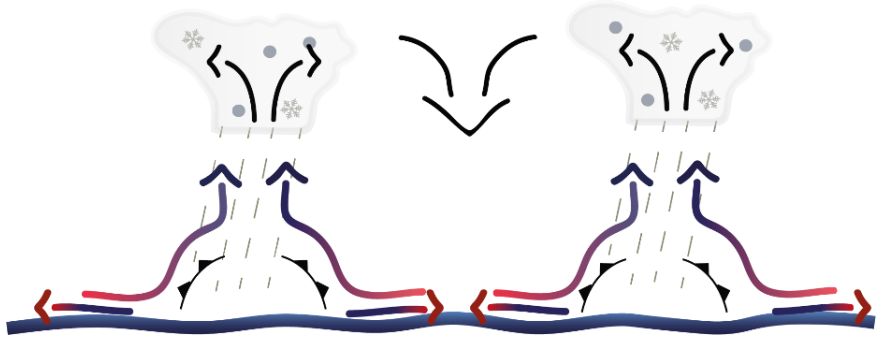
Campaign and LES setup: Young et al. (2016; ACP) and Young et al. (2017; ACP)
Cloud microphysics: Seifert and Beheng (2006; MAP) and aerosol scheme according to Possner et al. (2017; GRL)

Simulated cloud organization in the mixed-phase regime

Simulated mixed-phase clouds also develop cellular structures

Mechanism: cold pool formation through locally high precipitation rates



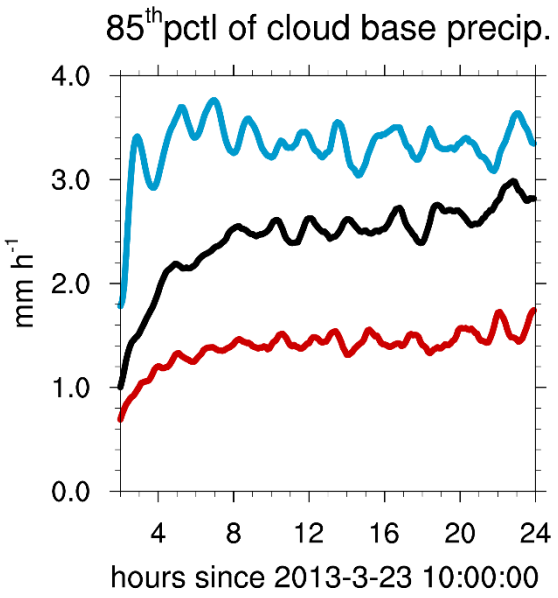


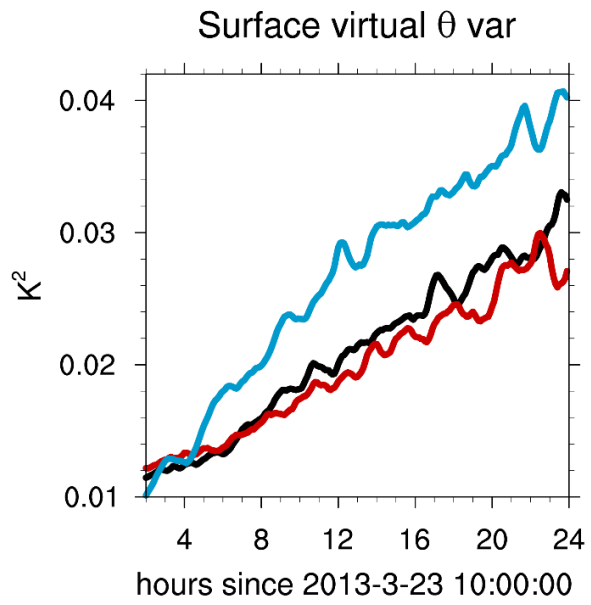
Eirund et al., 2019, GRL

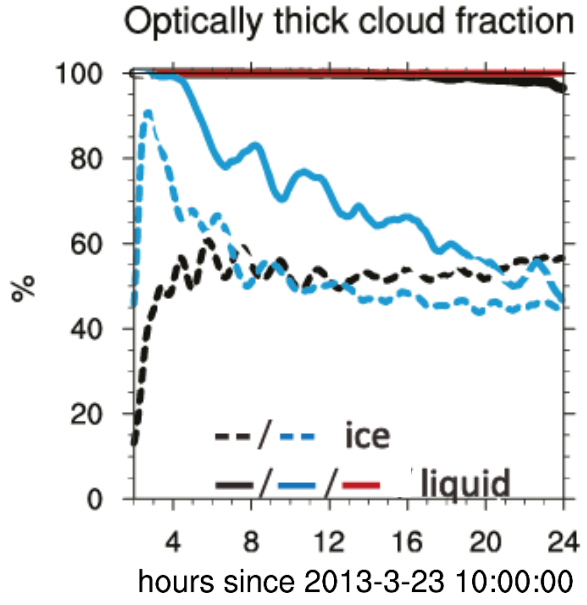
The impact of cloud ice on organization

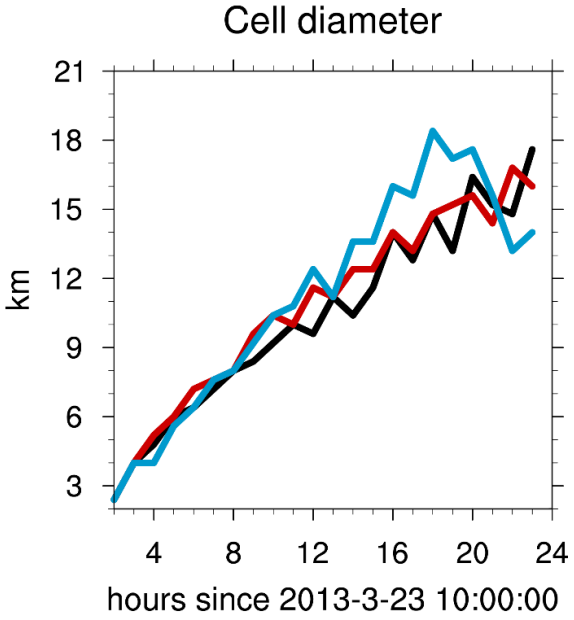
Our hypothesis:

Cloud ice → increased cloud base precipitation → stronger surface cold pools → larger cloud cells ✓ **confirmed**









Simulations:

Control: control simulation for clouds over the open ocean

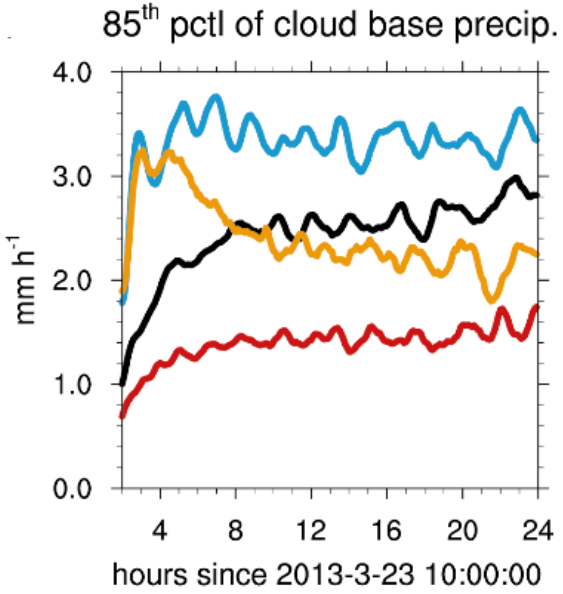
NoIce: all ice processes omitted

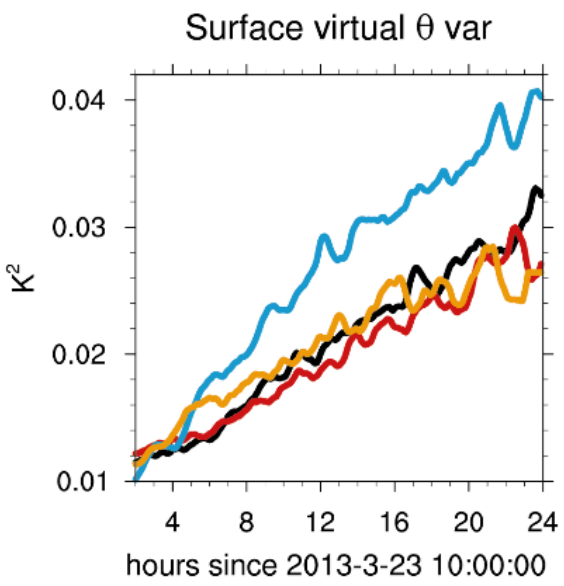
HighINP: Initial INP concentration x4, resulting in 12 INP L^{-1}

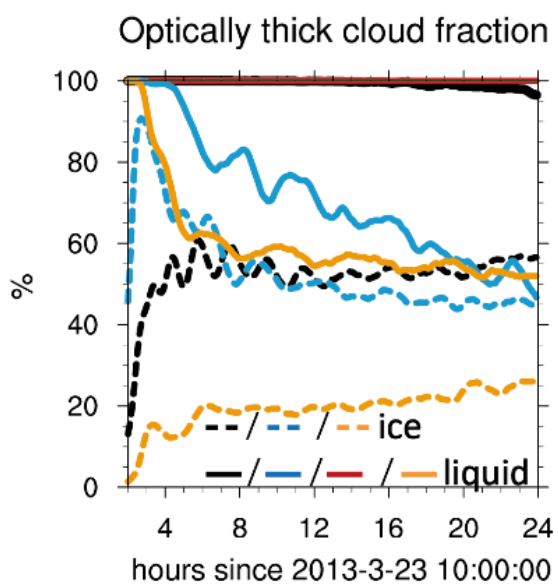
For clouds with a high ice water path (IWP) as in HighINP, cold pools strengthen, cloud cells grow, and thick clouds are reduced

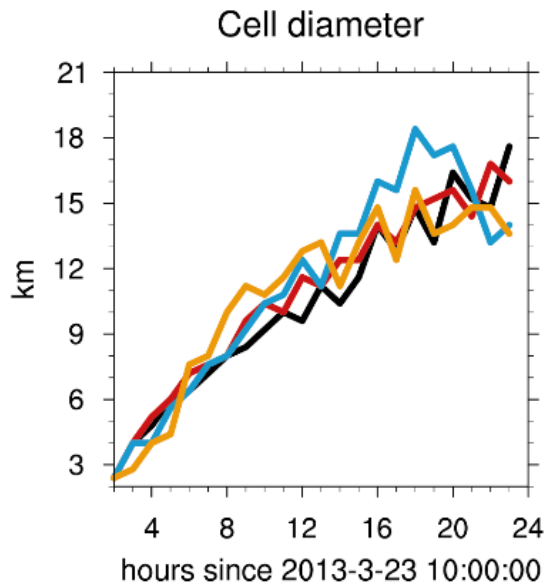
Eirund et al., 2019, GRL

A decrease in the cloud condensation nuclei (CCN) concentration also impacts cloud organization









Simulations:

Control: control simulation for clouds over the open ocean

NoIce: all ice processes omitted

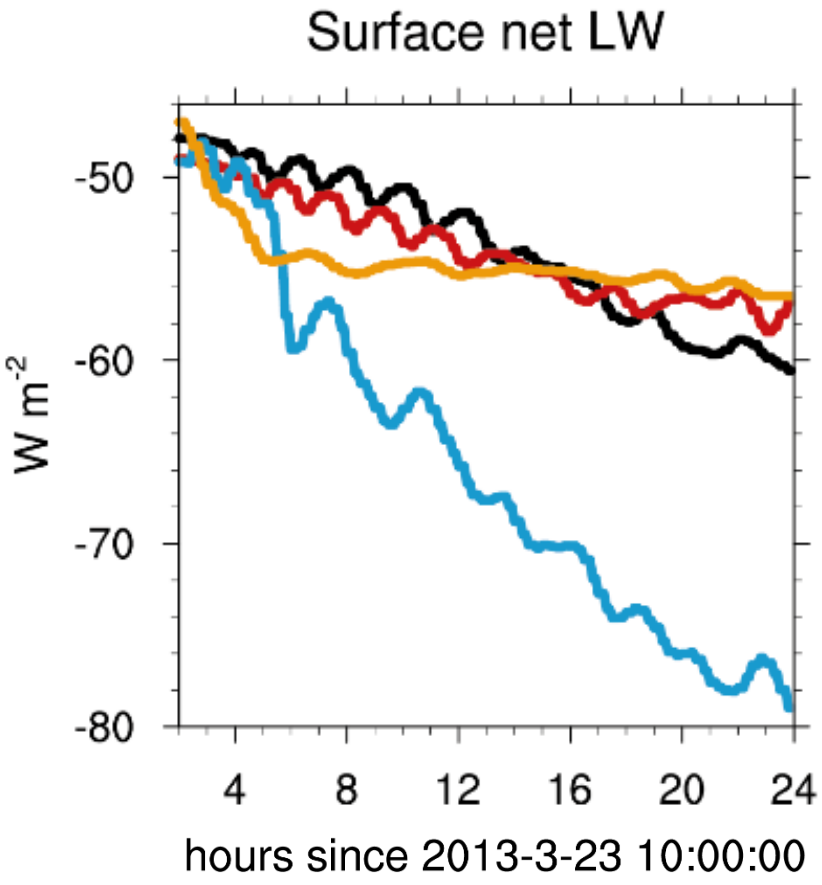
HighINP: Initial INP concentration x4, resulting in 12 INP L^{-1}

LowCCN: Initial CCN concentration decreased from 100 to 20 cm^{-3}

Fewer CCN in LowCCN also impact cloud cell size and reduce the amount of thick clouds

Eirund et al., 2019, GRL

Changes in cloud organization alter the radiative balance



Implication for radiative balance:
the larger cloud cells in HighINP and LowCCN lead to surface longwave cooling

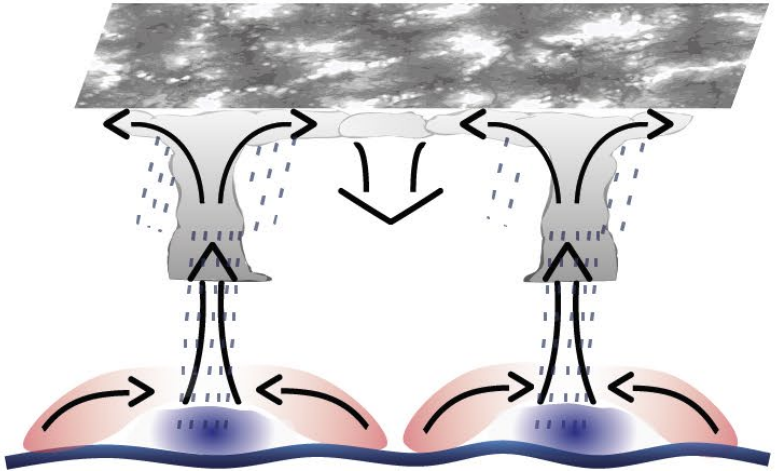
This cooling effect is stronger in HighINP, where the thick cloud cover decreases most rapidly

Simulations:
Control NoIce HighINP LowCCN

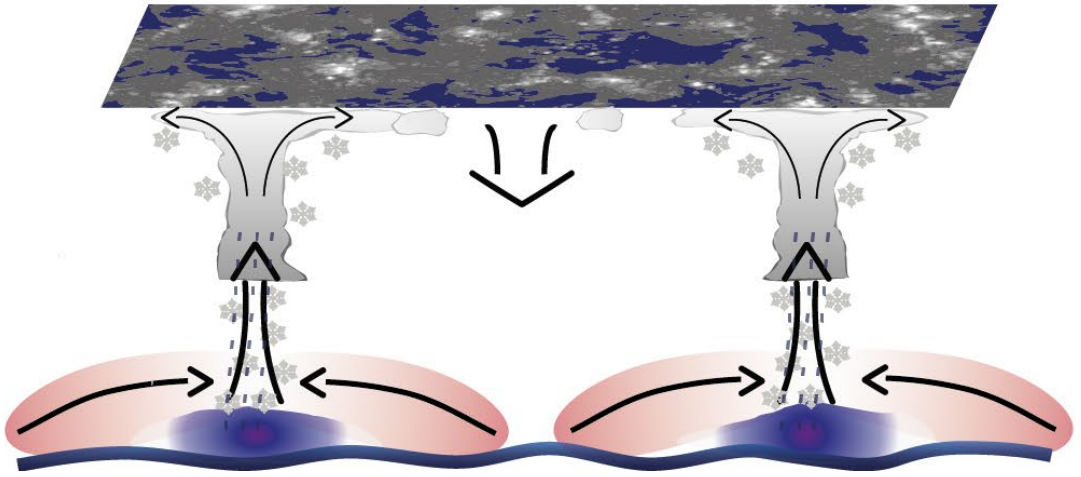
Eirund et al., 2019, GRL

Conclusions

Supercool liquid clouds (NoIce simulation)



Mixed-phase clouds with high IWP (HighINP simulation)



Mixed-phase stratocumulus at the high latitudes organize similar as known from warm-phase stratocumulus

For a high (~1:2) IWP:LWP ratio (reached e.g. through elevated INP concentrations) cloud organization intensifies:

- Increased cloud base precipitation
- Stronger cold pools through latent cooling of the sub-cloud layer
- Larger cloud cells and thinner cloud filaments

Simulated changes in cloud organization strongly impact the radiative balance at the surface

Thank you very much for your interest.

The article regarding this work can be found here: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019GL084959