Exploring sensitivity to ice nucleating particles and secondary ice production during COMBLE in idealised ICON large eddy simulations

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Summary

The Cold-Air Outbreaks in the Marine Boundary Layer Experiment (COMBLE), Dec 2019 – May 2020
- Investigation of Arctic marine clouds during cold-air outbreaks
- Two mobile stations installed at Andenes on Andøya (Norway) and Bjørnøya (Norwegian Sea)
- Concurrent campaign The Ny-Ålesund Aerosol Cloud Experiment (NASCENT) in Svalbard, Sep 19 – Aug 2020
COMBLE model intercomparison project (MIP)
- Intercomparison of models during one day of a cold-air outbreak on 28 March 2020, nudged to specified forcing
- Fixed ice number concentration & prognostic aerosol and ice number concentration
Mixed-phase stratiform and cumuliform clouds where secondary ice processes are imporant
ICON LES
- Large-eddy simulations with the ICON model
- ~100-m resolution on a ~25-km domain
Research questions:
- What is the role of secondary ice process in the cloud simulation?
- How does ICON compare with other models and the observations?
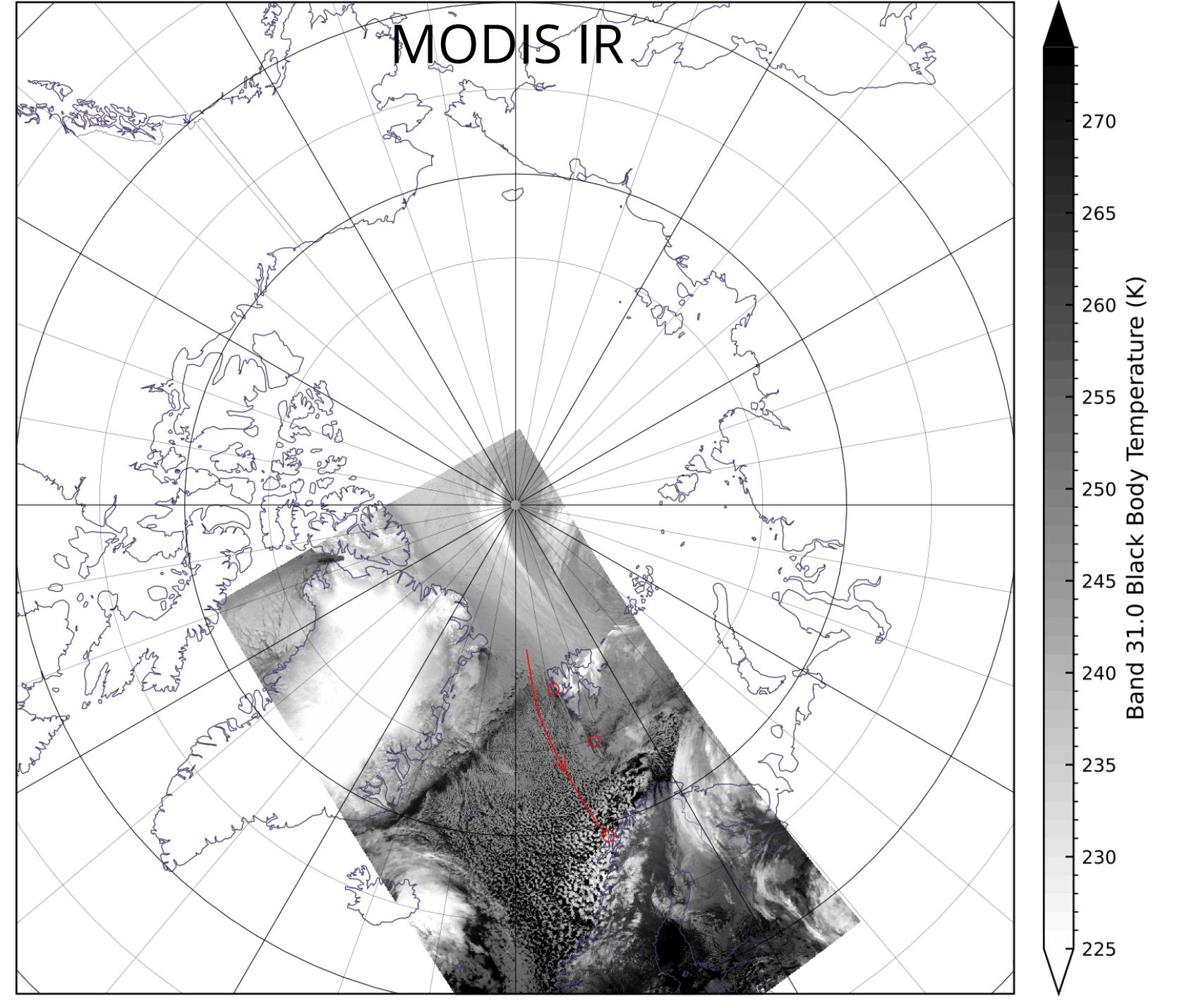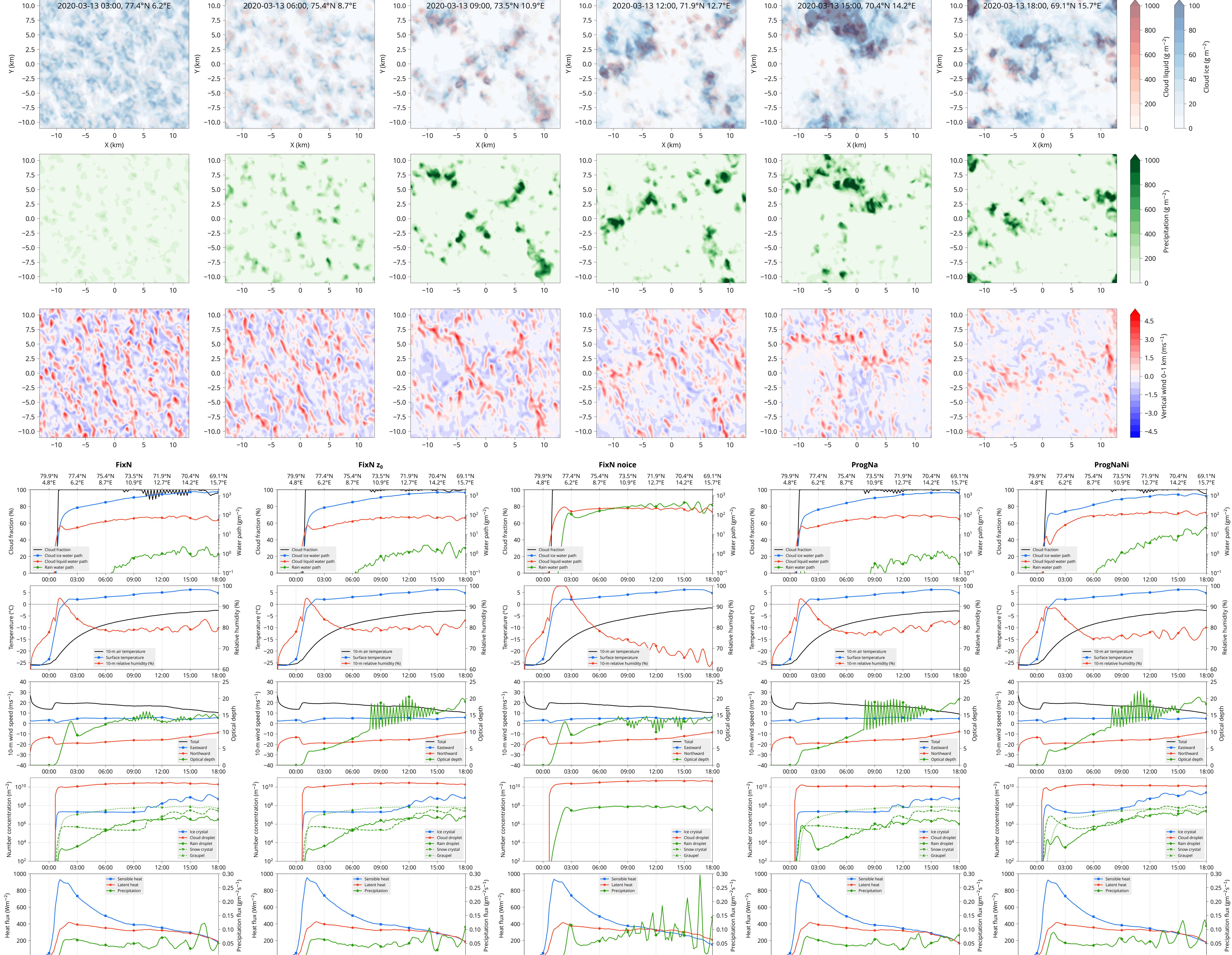
Ice production

Primary ice → Homogeneous nucleation ($<-37°C$)

Primary ice → Heterogeneous nucleation (-37 to $0°C$) ← Ice nucleating particles (INPs)

Immersion freezing (IF)
Contact freezing (CF)
Deposition freezing (DF).
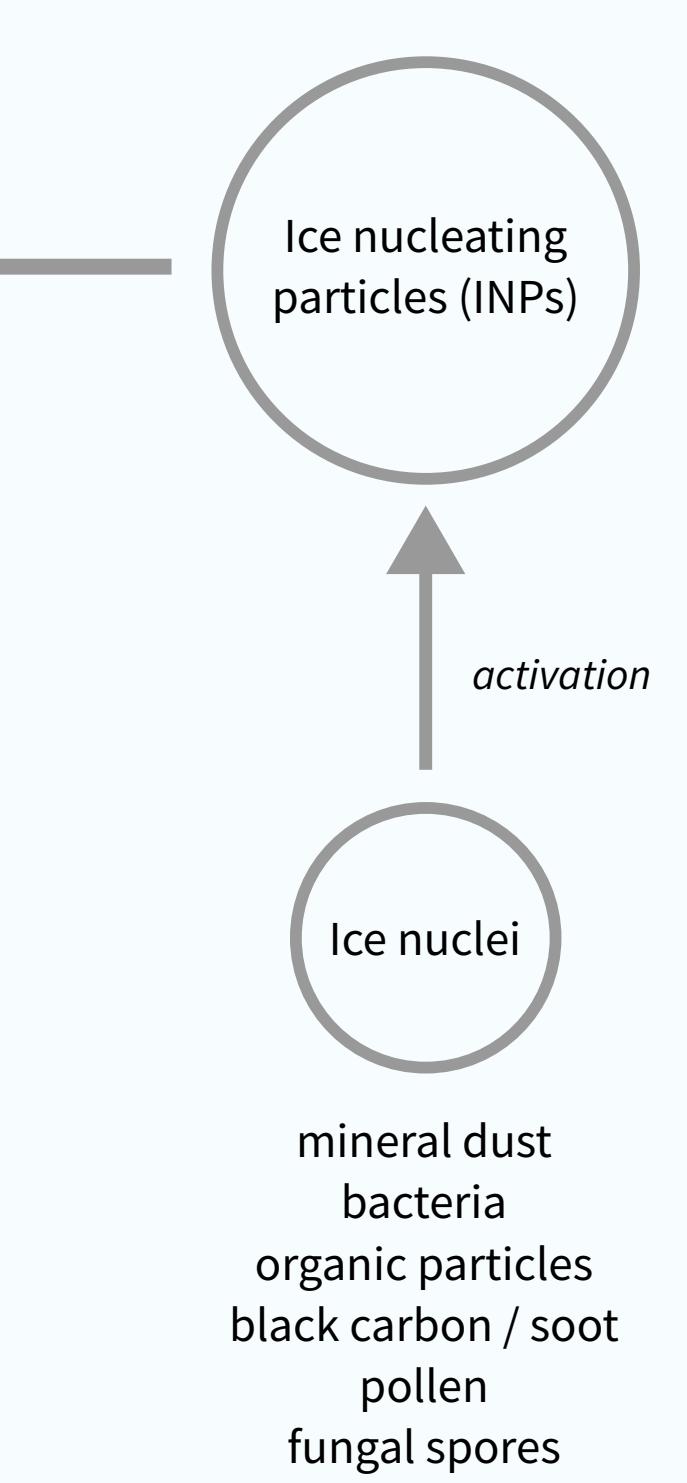
Secondary ice

Rime splintering (RS) / Hallett–Mossop (HM) (-3 to $-8°C$)
Droplet shattering (DS)
Collisional breakup (BR)
Sublimation fragmentation

Ice nuclei — *activation* →

mineral dust
bacteria
organic particles
black carbon / soot
pollen
fungal spores

Ny-Ålesund – Bjørnøya (Bear Island) – Andenes, 28 March 2020

LES track — 2020-03-28

Sea ice concentration (%)

MODIS IR

Band 31.0 Black Body Temperature (K)

Instruments at Andenes and Bjørnøya

scanning and profiling radars
surface radiance
microwave radiometer
lidars
ceilometer
disdrometer
AWS
wind profiler
Aerosol Observing System
radiosondes
micro rain radar
eddy correlation
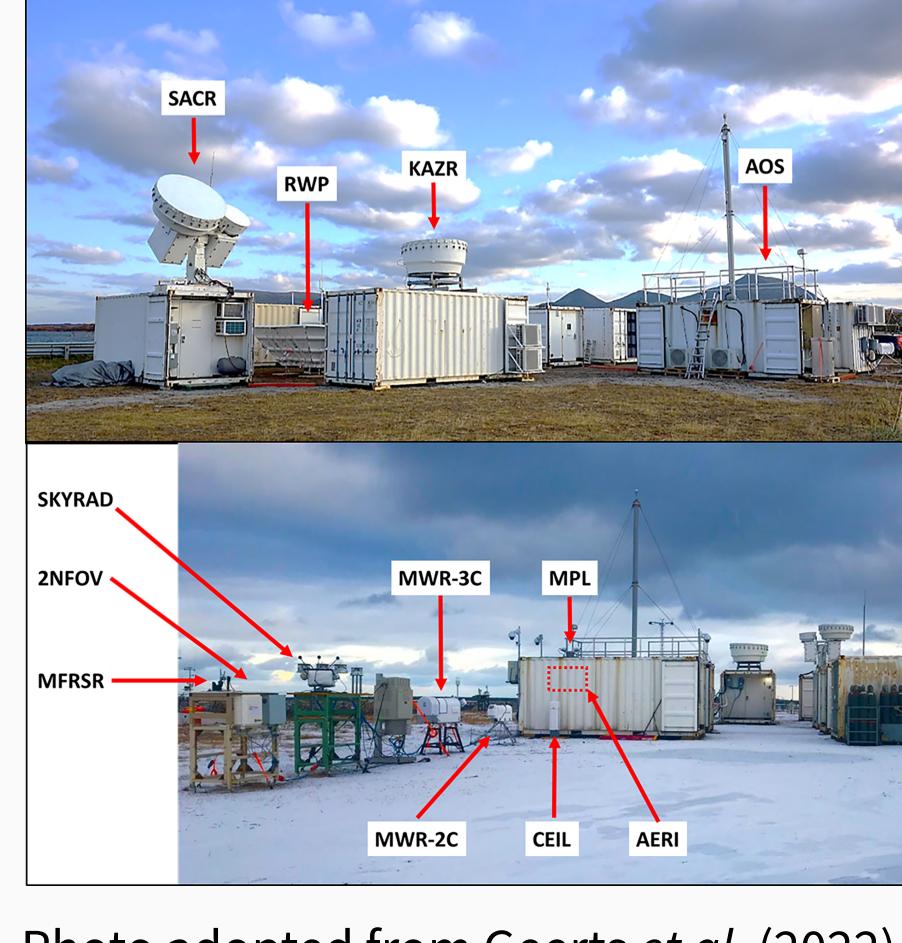
Photo adopted from Geerts *et al.* (2022), DOI: 10.1175/BAMS-D-21-0044.1.

COMBLE-MIP FixN experiment; # cloud droplets $N_d = 20$ cm^{-3}, # cloud ice $N_i = 25$ L^{-1}, only homogeneous ice formation