Exploring model hierarchies for large-eddy simulations of observed Cold Air Outbreaks in the Arctic

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The $(AC)^3$ project

ArctiC Amplification:
Climate Relevant Atmospheric and SurfaCe Processes
and Feedback Mechanisms $(AC)^3$

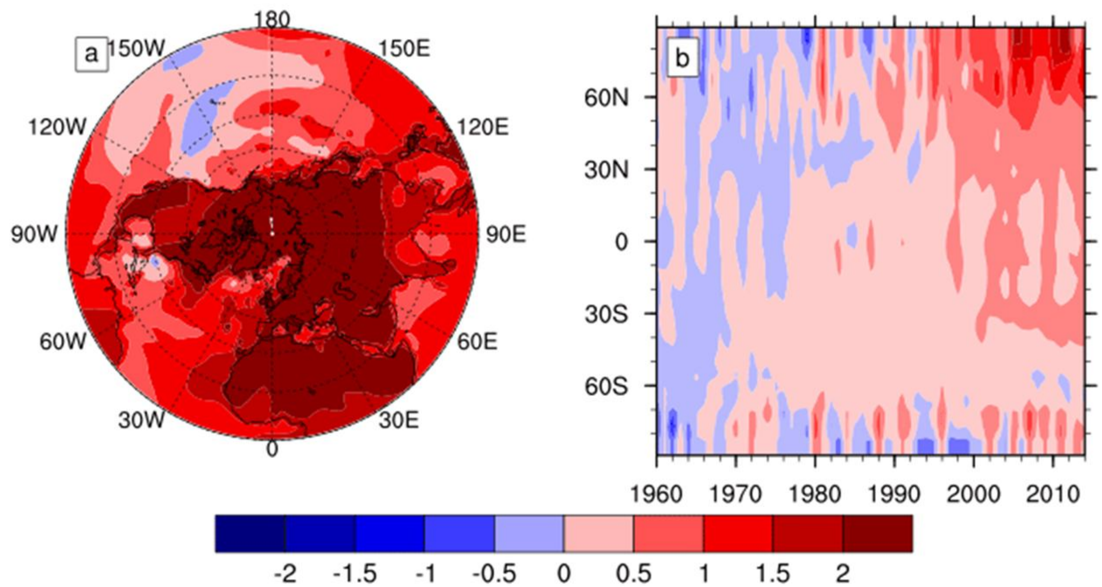
DFG funded, 1st phase ongoing

Consortium of universities and research institutes in Germany

Field campaigns

Strong modeling component

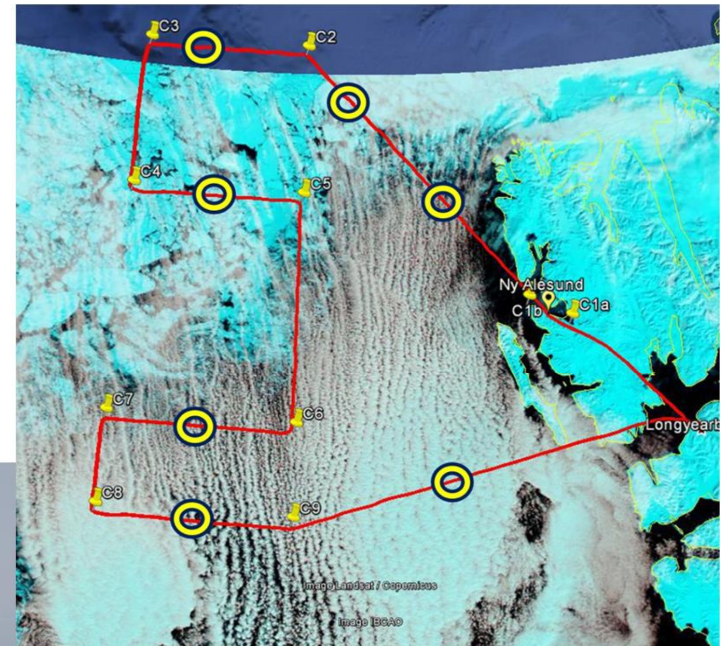
http://ac3-tr.de

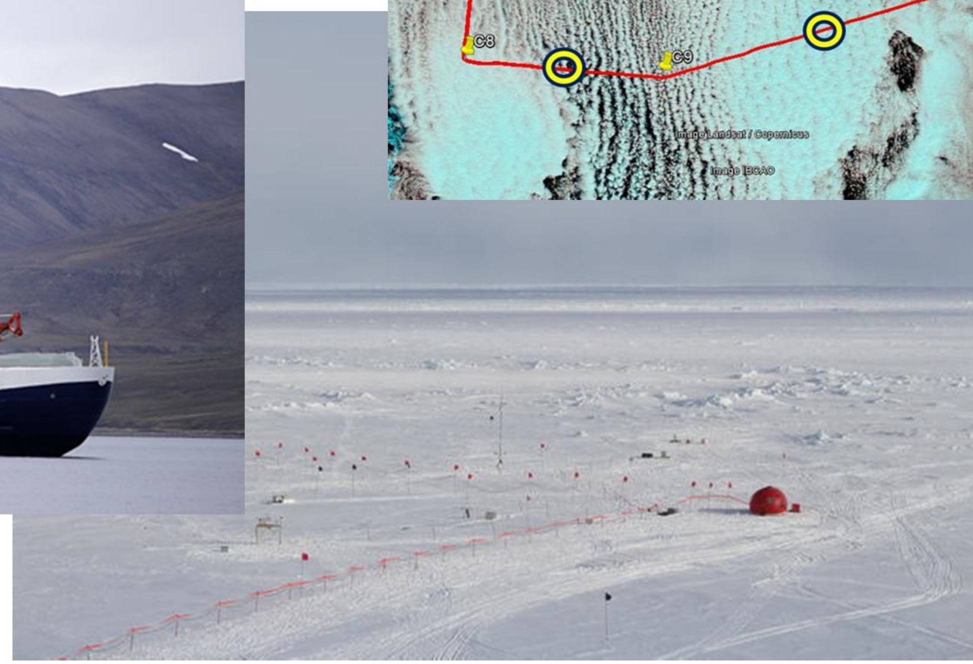


$(AC)^3$ field campaigns: ACLOUD, PASCAL, Ny Ålesund

Spring/Early summer 2017

Svalbard, Fram Strait, Ice edge and beyond





Our role in $(AC)^3$

To configure fine-scale eddy-resolving simulations to accompany the field campaigns

To provide a high-resolution realistic guess of the smaller-scale variability surrounding the measurement platforms

To research low level clouds in the Arctic at process level, and improve parameterizations for LES and GCMs

We face some difficulties:

Potential problems

- How to deal with complex terrain?
- Are initial and boundary conditions derived from GCMs good enough?
- What about uncertainty in the prescribed forcings?
- How do we make optimal use of sparse measurements?
- Where do we get CCN and IN information?
- What domain size is large enough?
- Are our microphysics good enough?

Exploring model hierarchies

Designed to at least partially address these problems

Building on results from other recent CAO LES studies

A 3-level approach:

- Level I: GCM at ~10km resolution
- Level II: Nested regional simulation at 600m resolution
- Level III: Lagrangian LES at ~25m resolution

Level I: EMCWF IFS

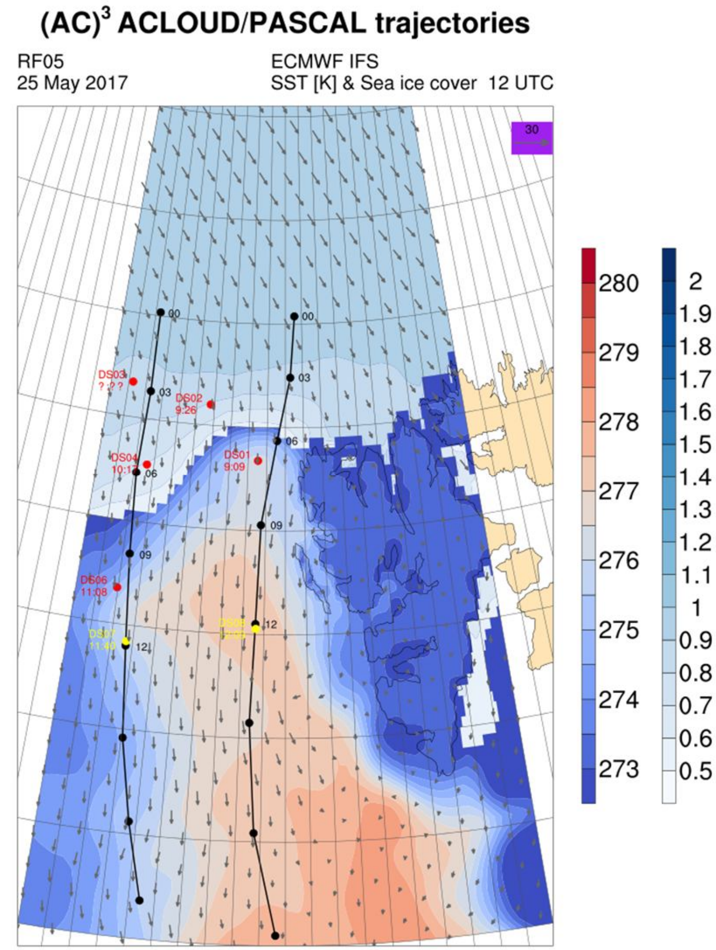
Integrated Forecasting System

Aim: Provide info on the **Large-scale synoptic situation**

Domain configuration:

- Global
- 0.1x0.1 deg resolution

IFS provides boundary fields for ICON, and can also be used to directly drive Lagrangian LES



Level II: ICON

Icosahedral Non-hydrostatic model (ICON)

Aim: **Realistic convection-permitting simulation of low level flow off the ice-shelf**

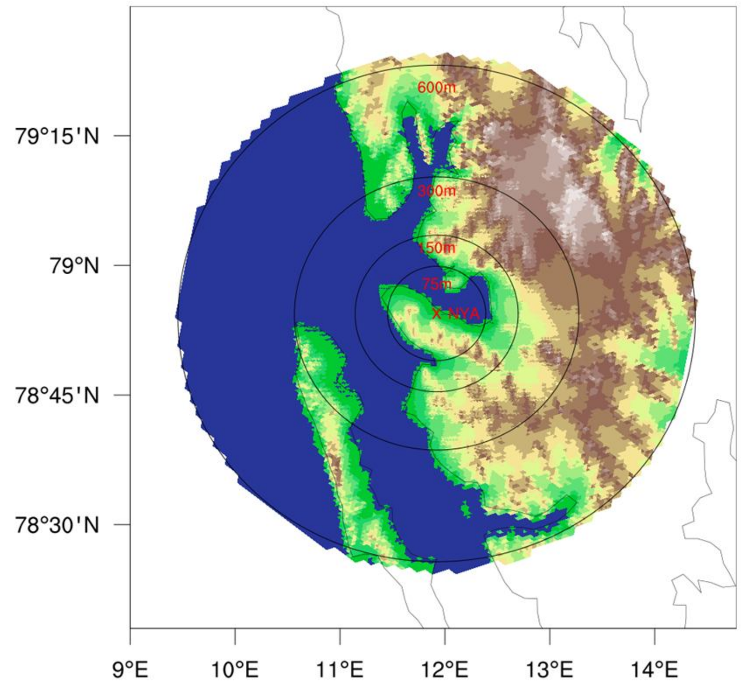
Domain configuration:
- Eulerian, regional (area around Svalbard), nested, open boundaries
- 600m resolution

Large-scale forcing:
- Inflow at boundaries

Terrain:
- Detailed, realistic orography

Microphysics:
- Seifert and Beheng (2006): Mixed phase

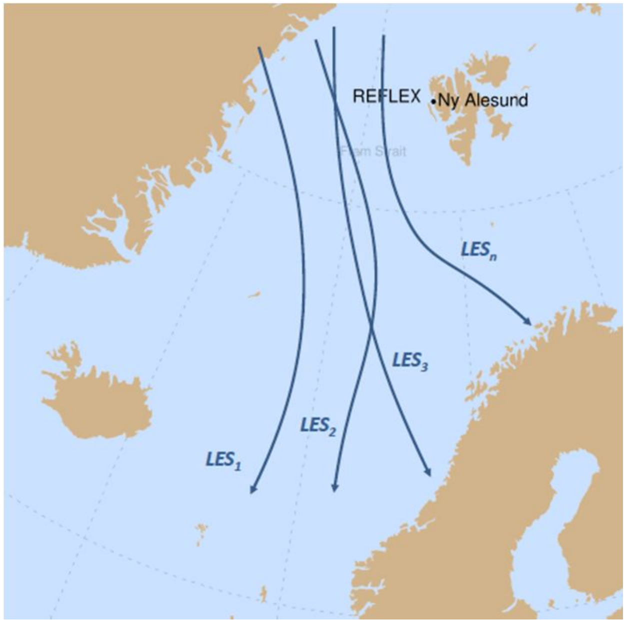
ICON grids, 4x nesting (1-way)



Level III: DALES

Dutch Atmospheric Large-Eddy Simulation model (DALES)

Aim**: Idealized Lagrangian LES**



Domain configuration:

- Lagrangian, periodic boundaries
- High resolutions ~25m

Large-scale forcing:

- Spatially homogeneous

Terrain:

- Flat, homogeneous (open water / solid pack-ice)

Microphysics:

- Seifert and Beheng (2006): Mixed phase. (newly implemented)

Two simulation modes:

1. small (a **swarm** of 8x8 micro-LES realizations) for constructing the case
2. large (a **single** 1000x1000 composite case simulation) for doing science

ACLOUD/PASCAL cases of interest

ACLOUD RF05	25 May 2017	Weak CAO
PASCAL/ACLOUD RF13	5 June 2017	Rendez-vous with PS / Ice Station
PASCAL	6-7 June 2017	Arctic ML at the Ice Station
ACLOUD RF22	23 June 2017	Profiling at Ny Ålesund

Case 1: ACLOUD RF05

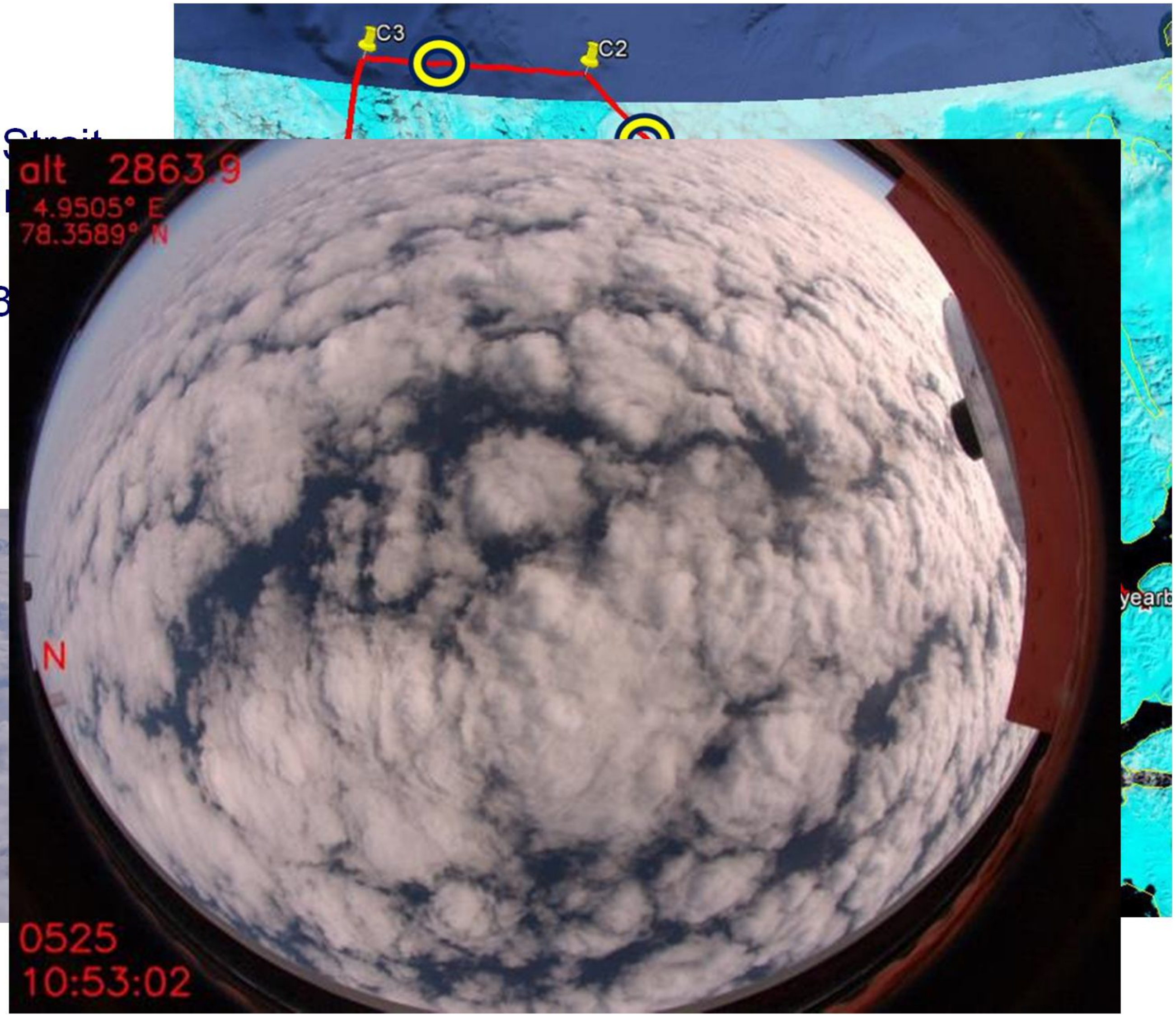
Figures from RF05 flight report by André Ehrlich

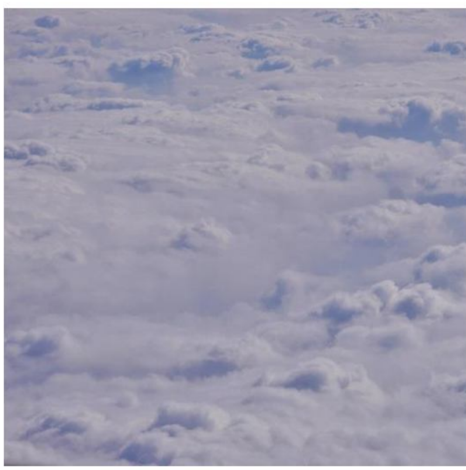
25 May 2017

Weak CAO in Fram S
probed by Polar 5 ai

Low level flight (~2-3

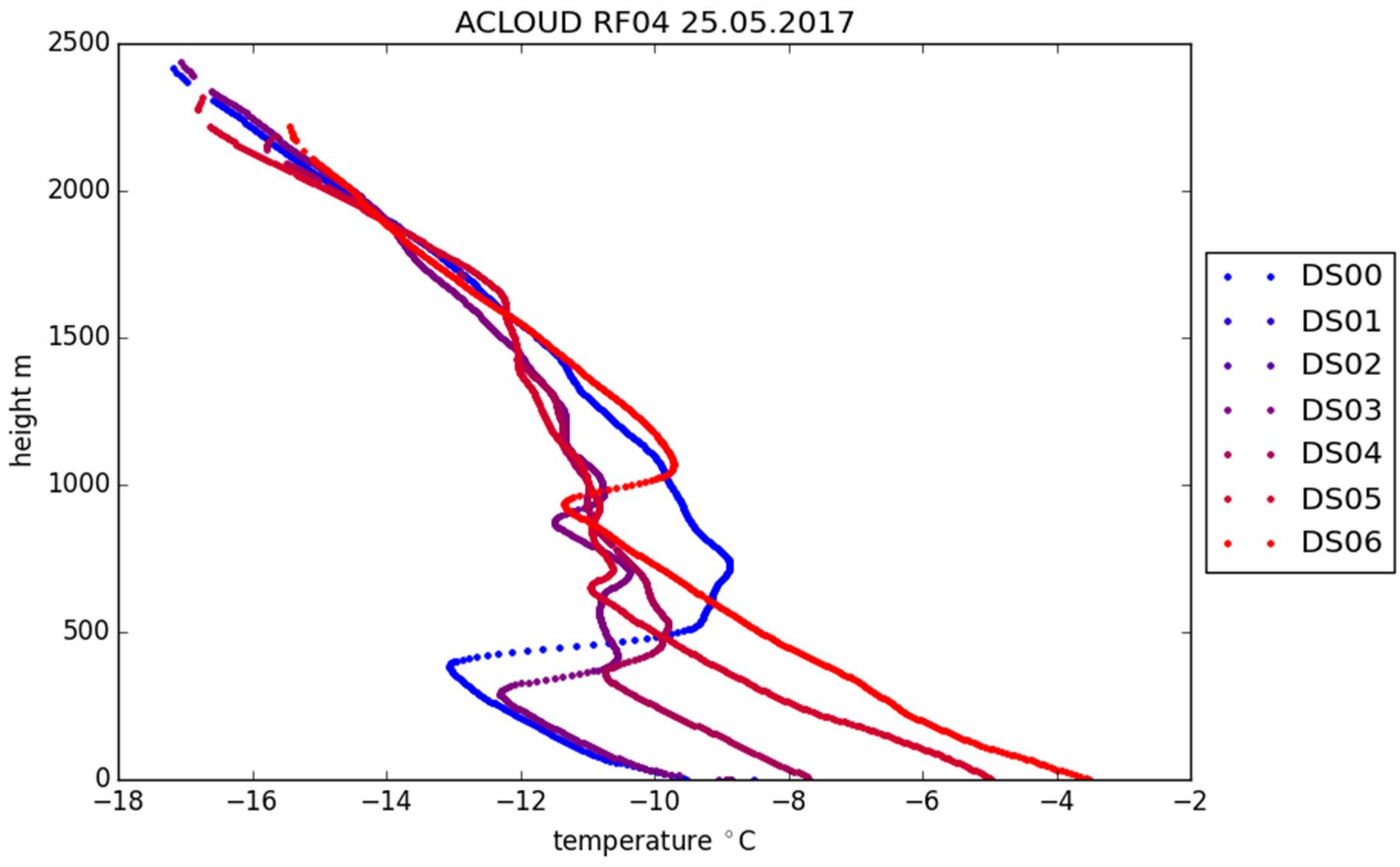
8 Dropsondes





Case 1: ACLOUD RF05

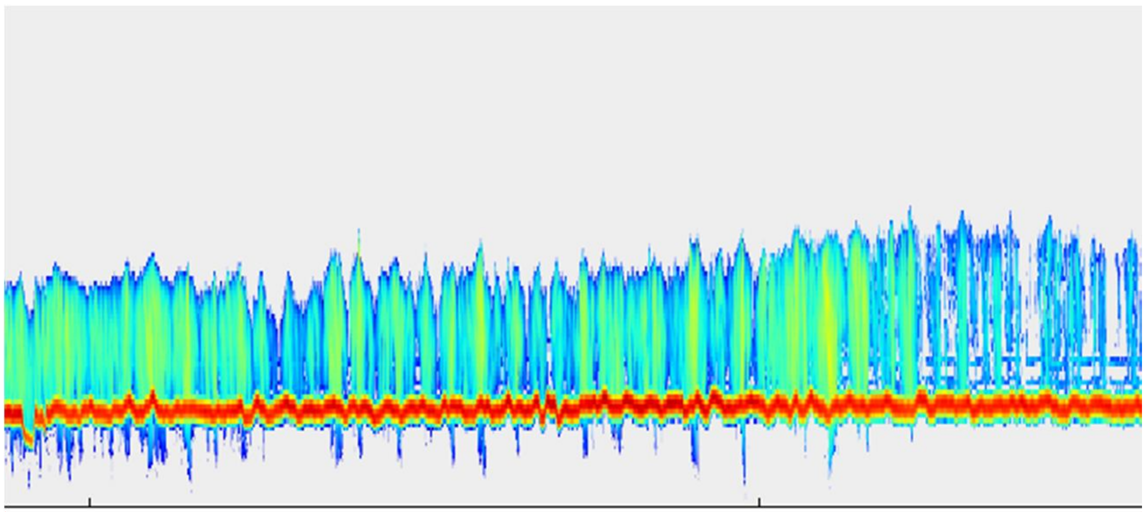
Dropsonde profiles

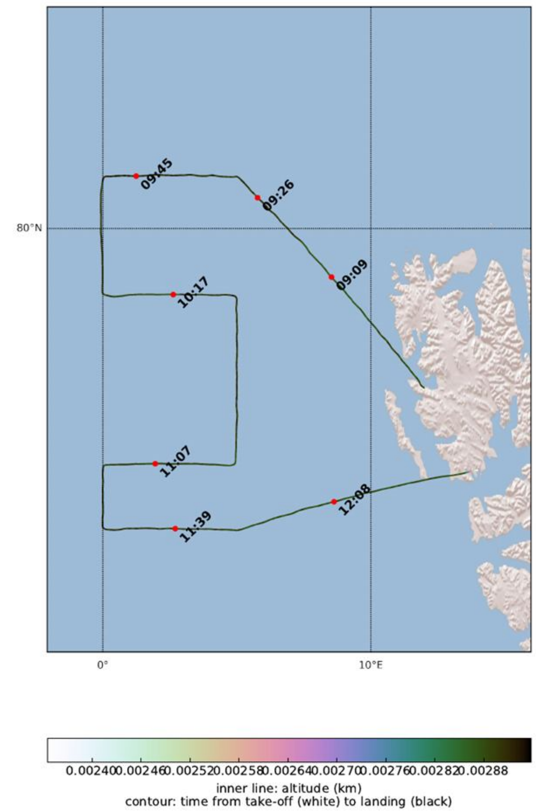


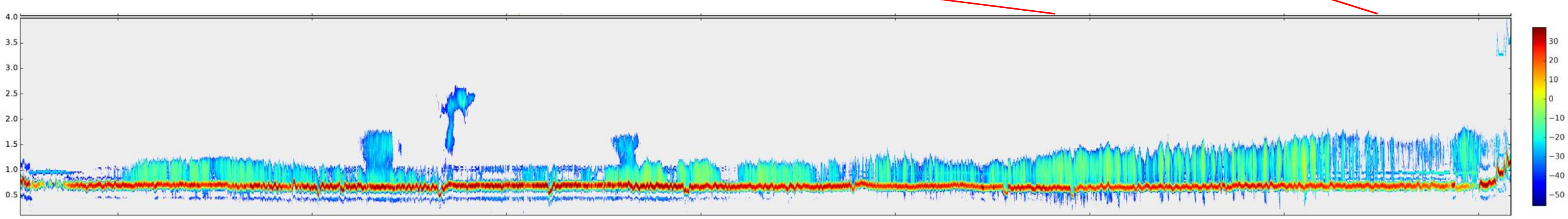
Polar 5 radar measurements of cloud street structure

Figures by Mario Mech, University of Cologne

MiRAC

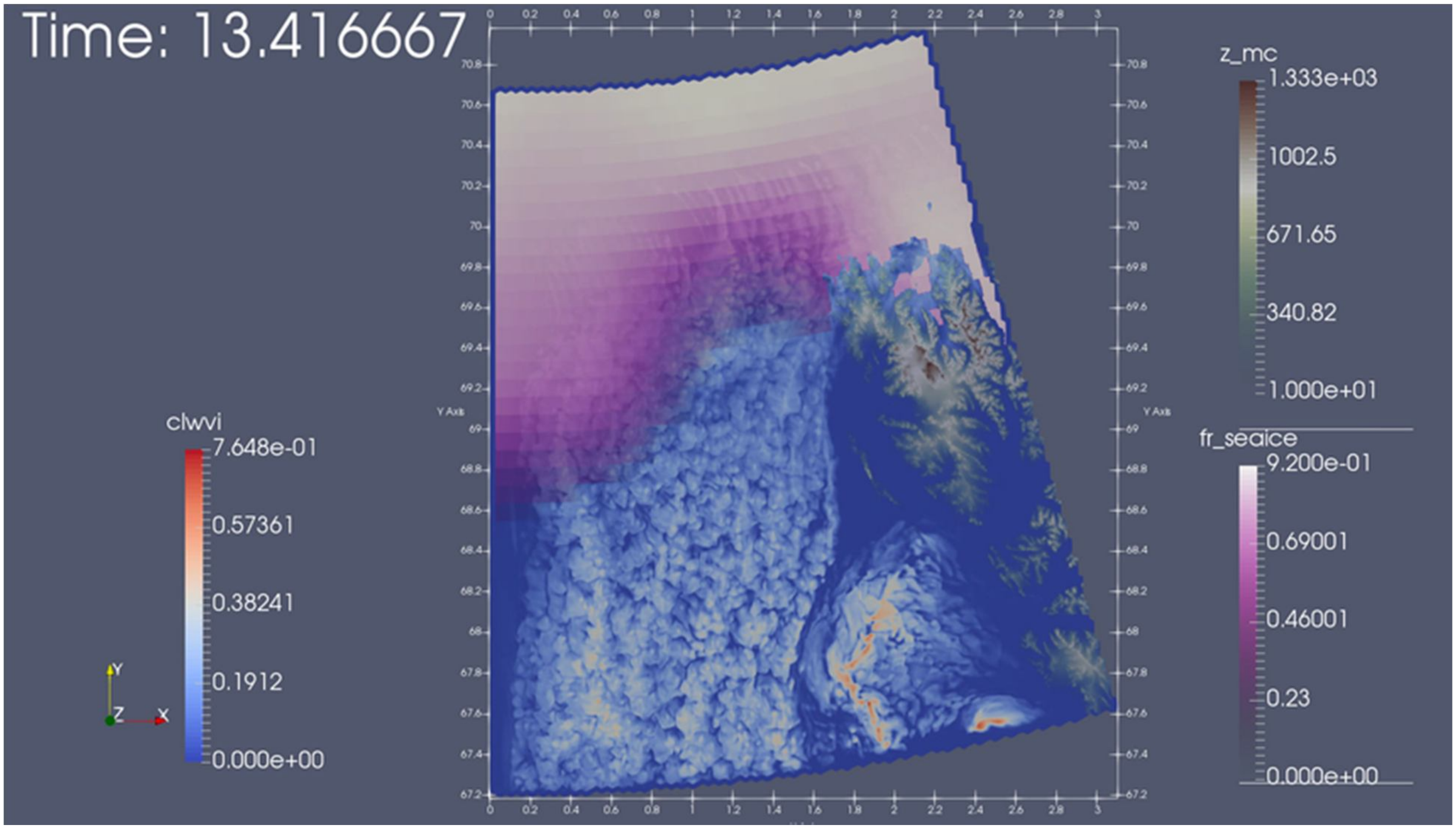






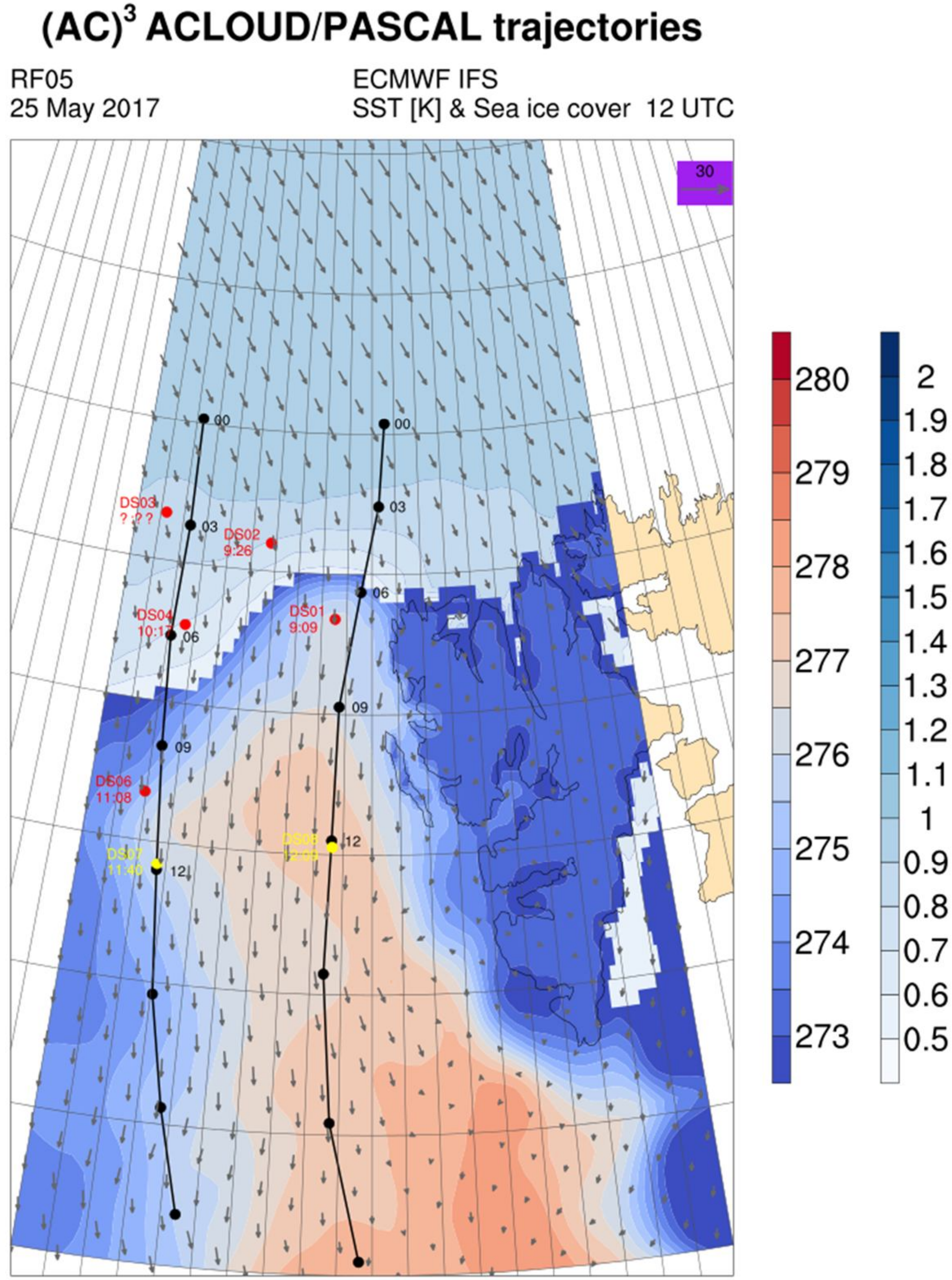
ICON results at Δx = 600m

Simulation and Figures by Vera Schemann



Lagrangian LES case setup:

Trajectories intersecting with dropsondes of interest

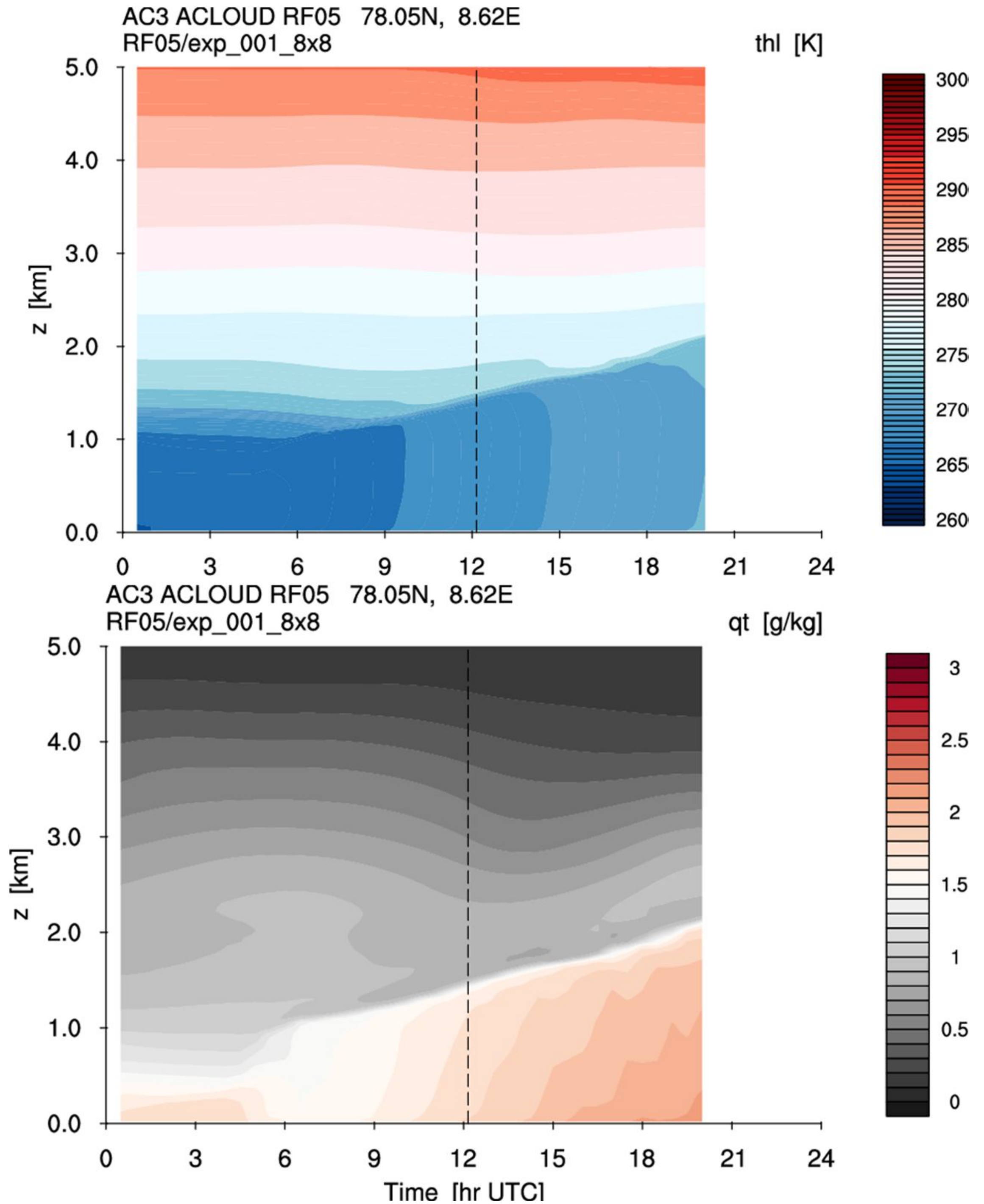


DALES results for the DS08 trajectory

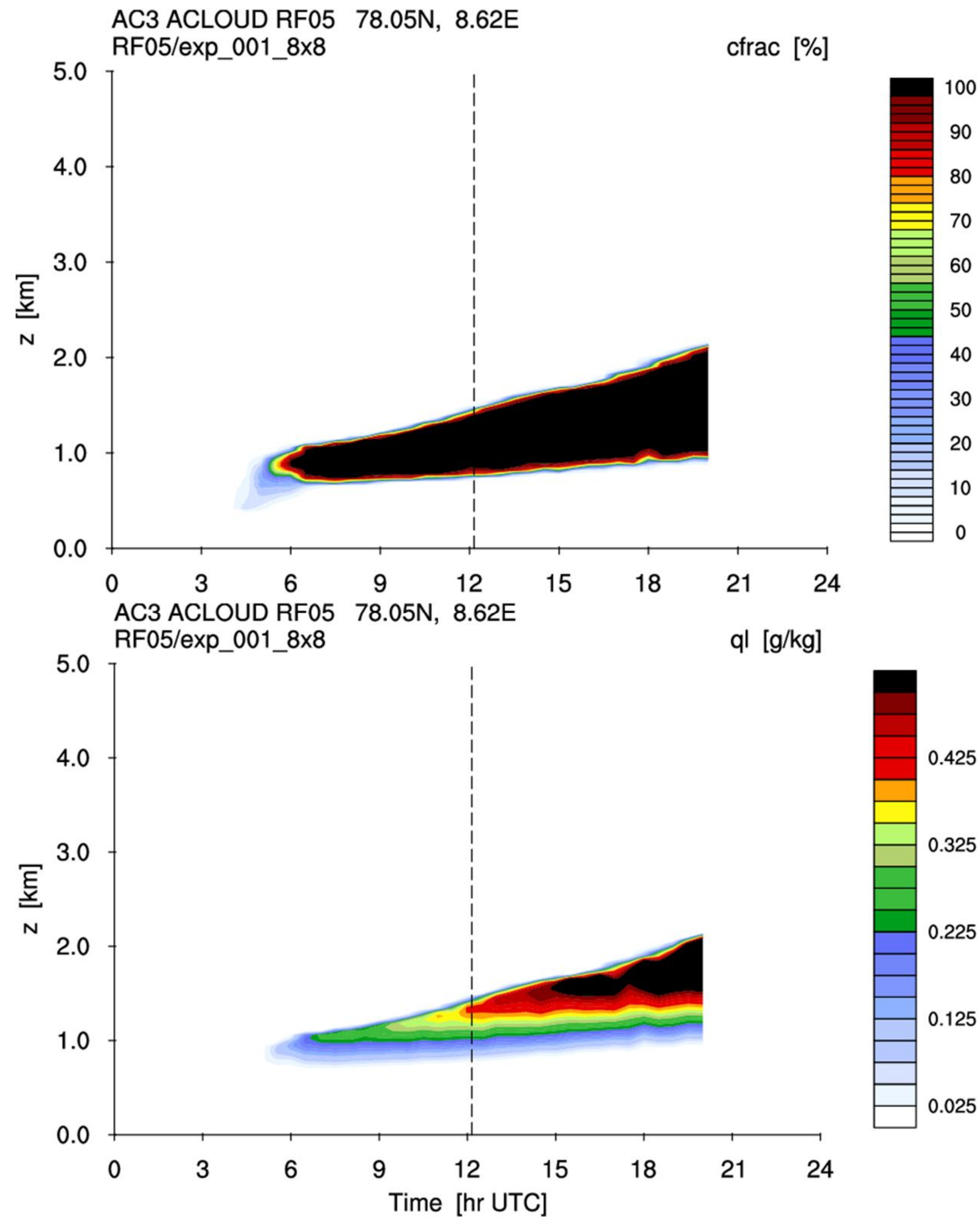
8x8 grid, Δx = Δy = 100m

Mini-LES: Cheap & quick to run, perfect for testing the case setup before doing any big runs

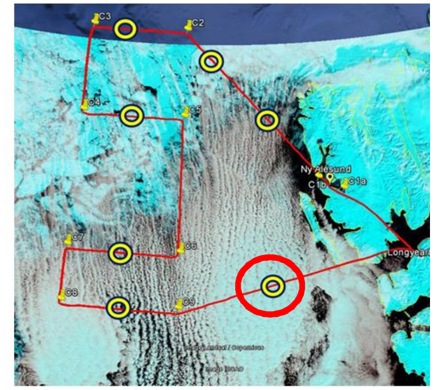
Used as a “glorified mixed layer model”

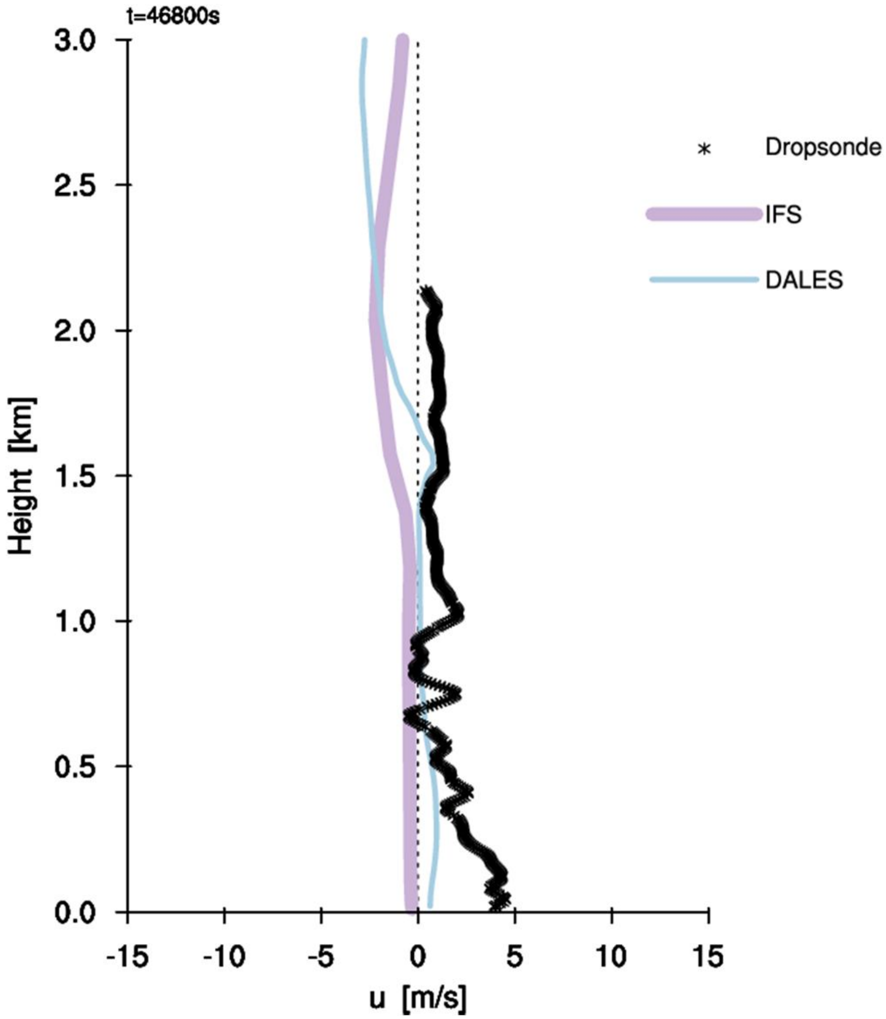


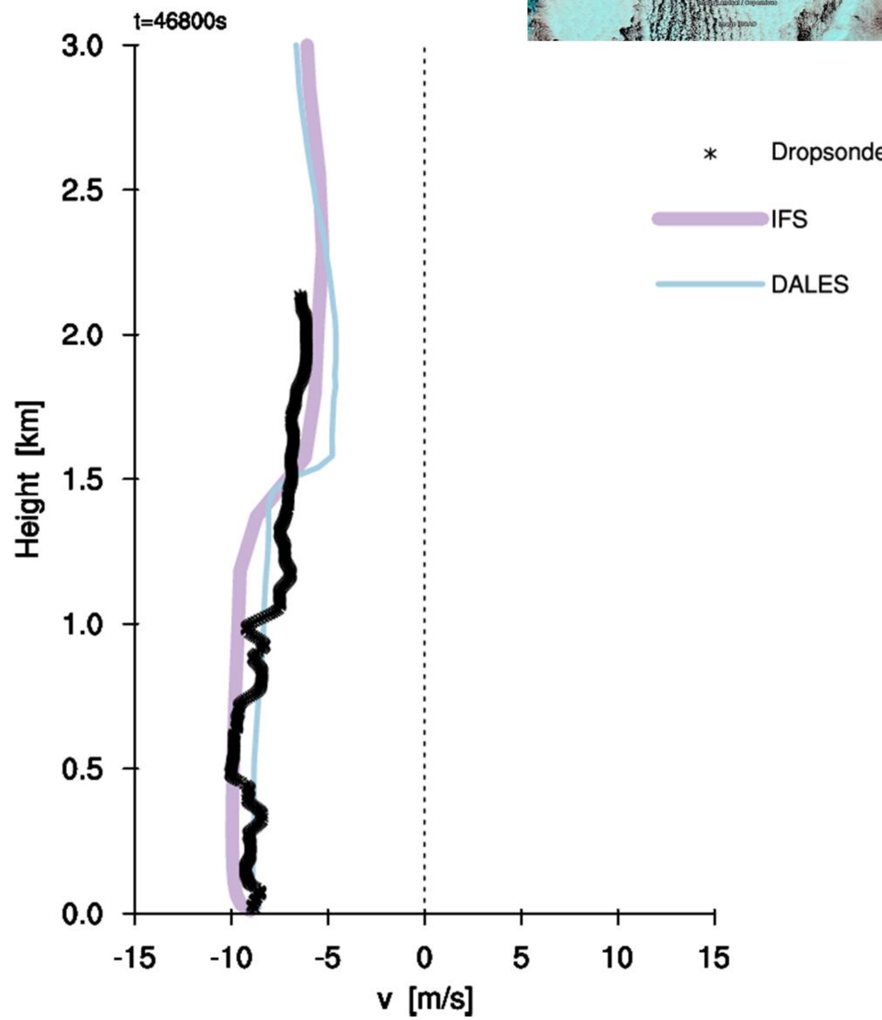
DALES Clouds



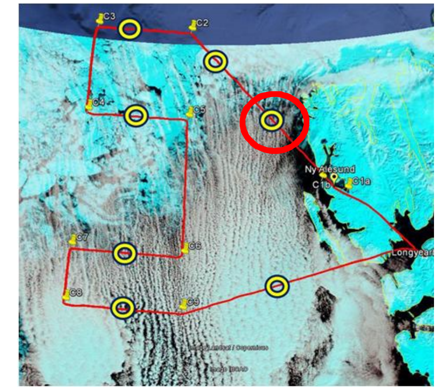
ACLOUD RF05: Comparing DALES to dropsonde DS08

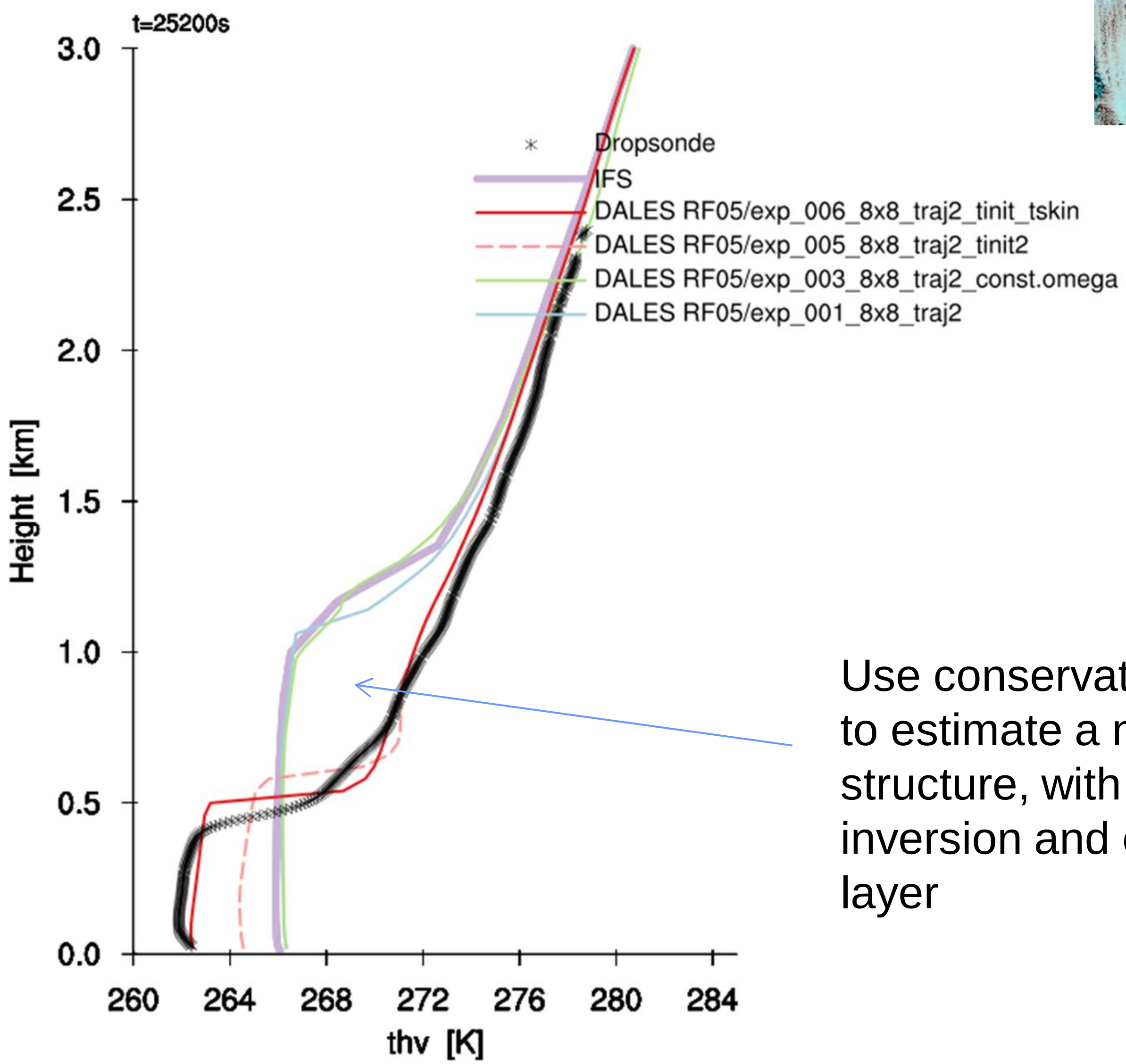






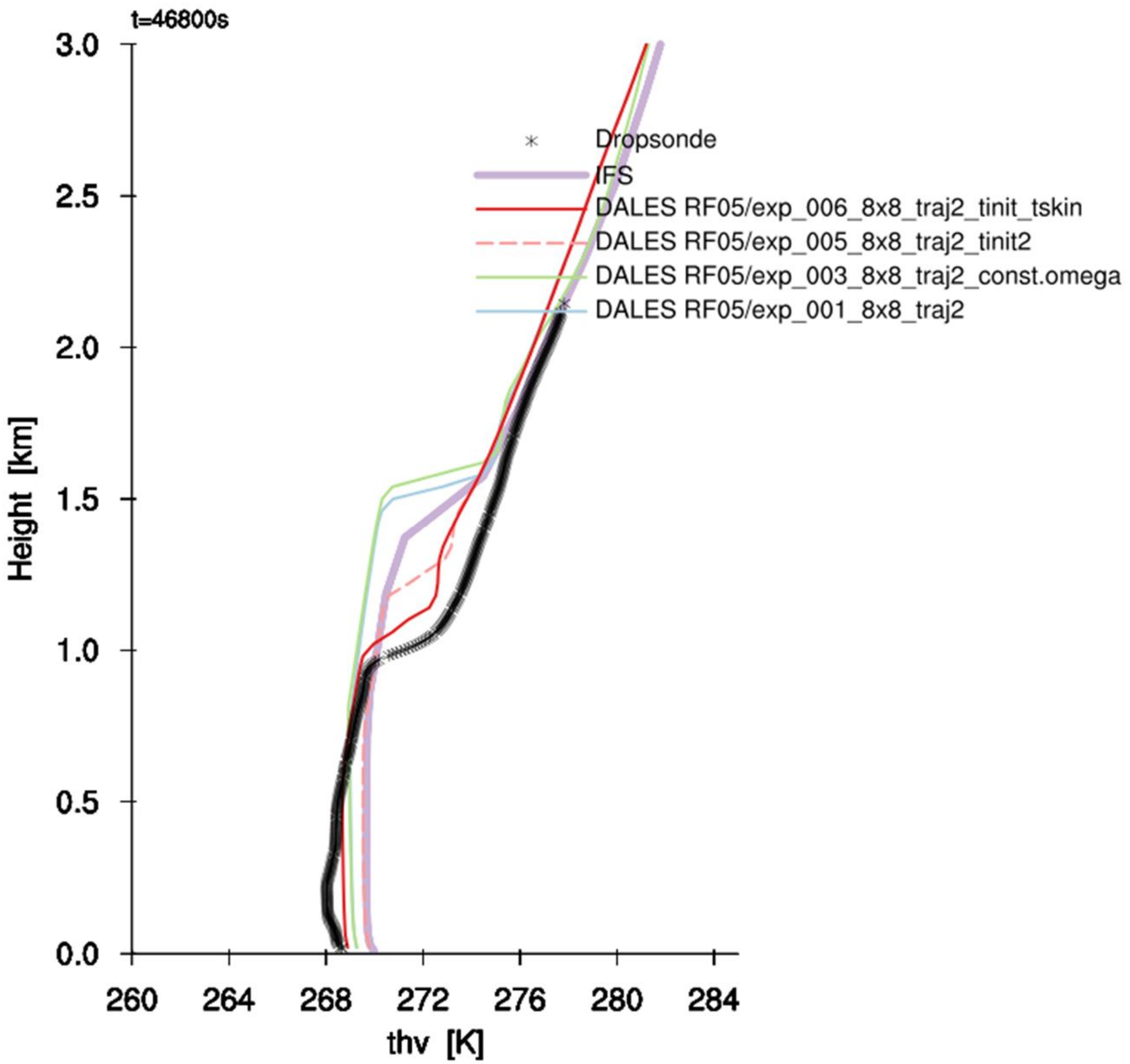
DS01: IFS & DALES are too warm and have a too deep ML
This is already the case at initialization (not shown)

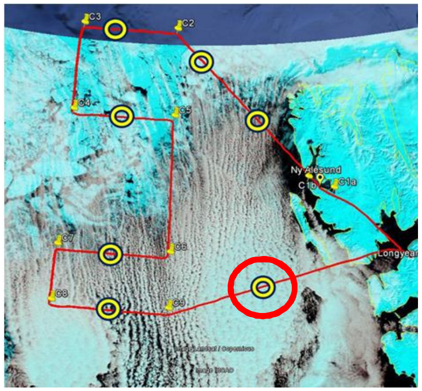




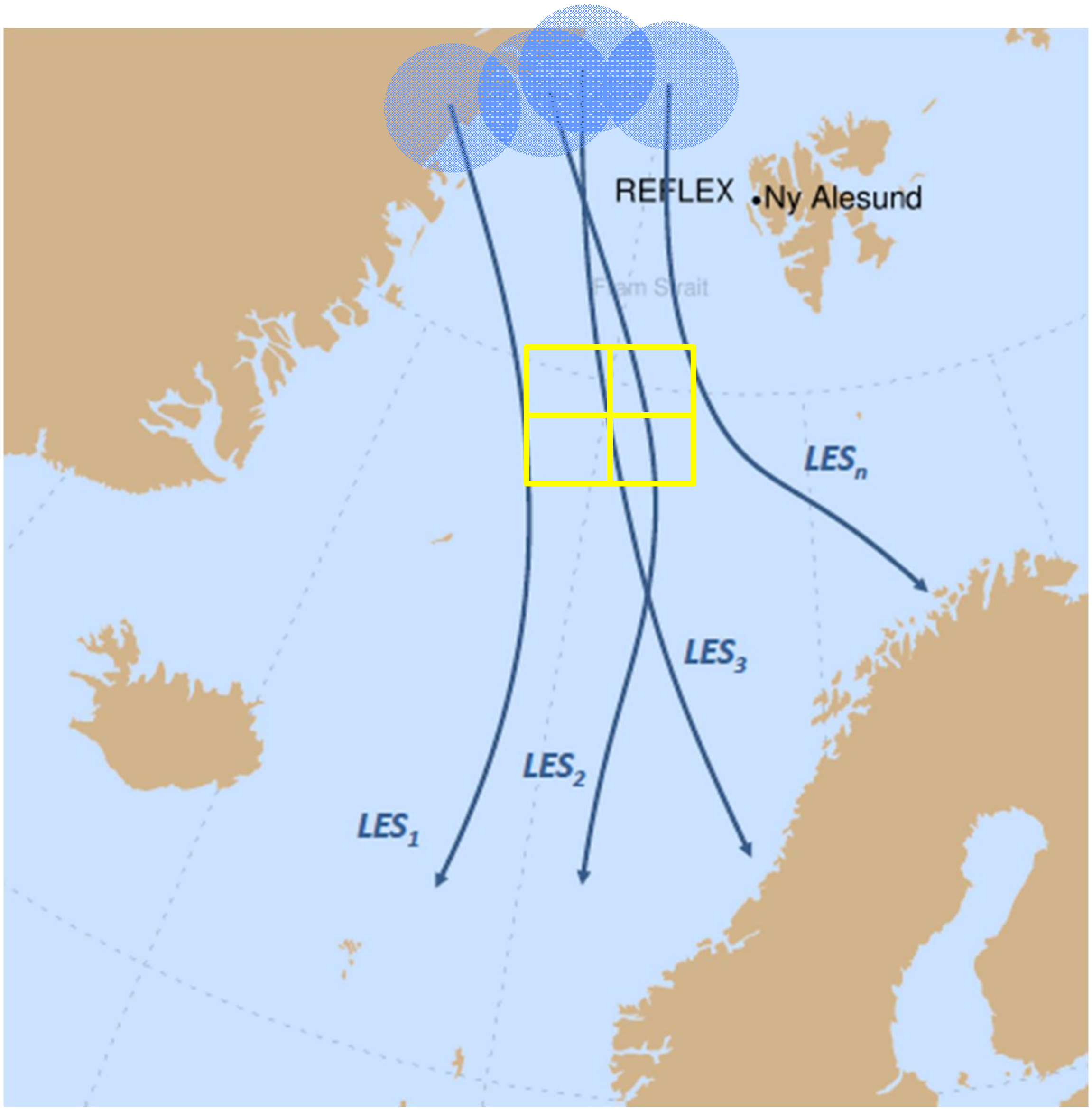
Use conservation of energy to estimate a new vertical structure, with a lower inversion and colder mixed layer

Lowering the initial inversion and decreasing T_ice by 3K gives a much better match (solid red line), also at **DS08**:





“Swarm LES” for improving initial conditions

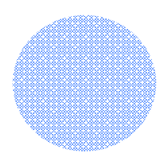


Global: IFS
(analyses & short-range fcasts)

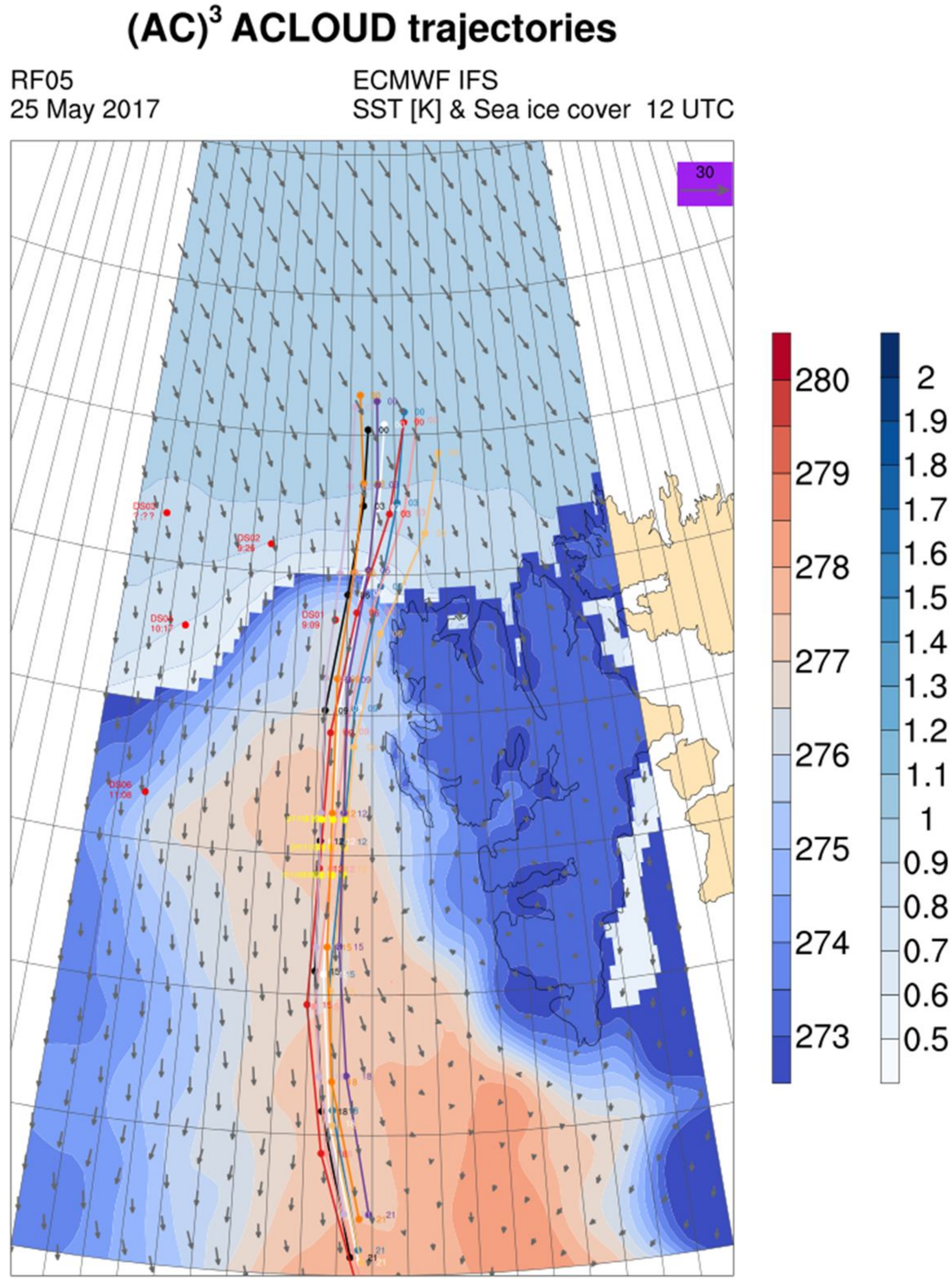
Regional: ICON
(nested, incl. orography)

Lagrangian: LES
(microLES swarm)
(single big-domain LES)

Area of interest
(dropsonde)



Adjustment area
(initial conditions)


(AC)^3 ACLOUD trajectories
RF05
25 May 2017
ECMWF IFS
SST [K] & Sea ice cover 12 UTC
30
280
279
278
277
276
275
274
273
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5

Summary

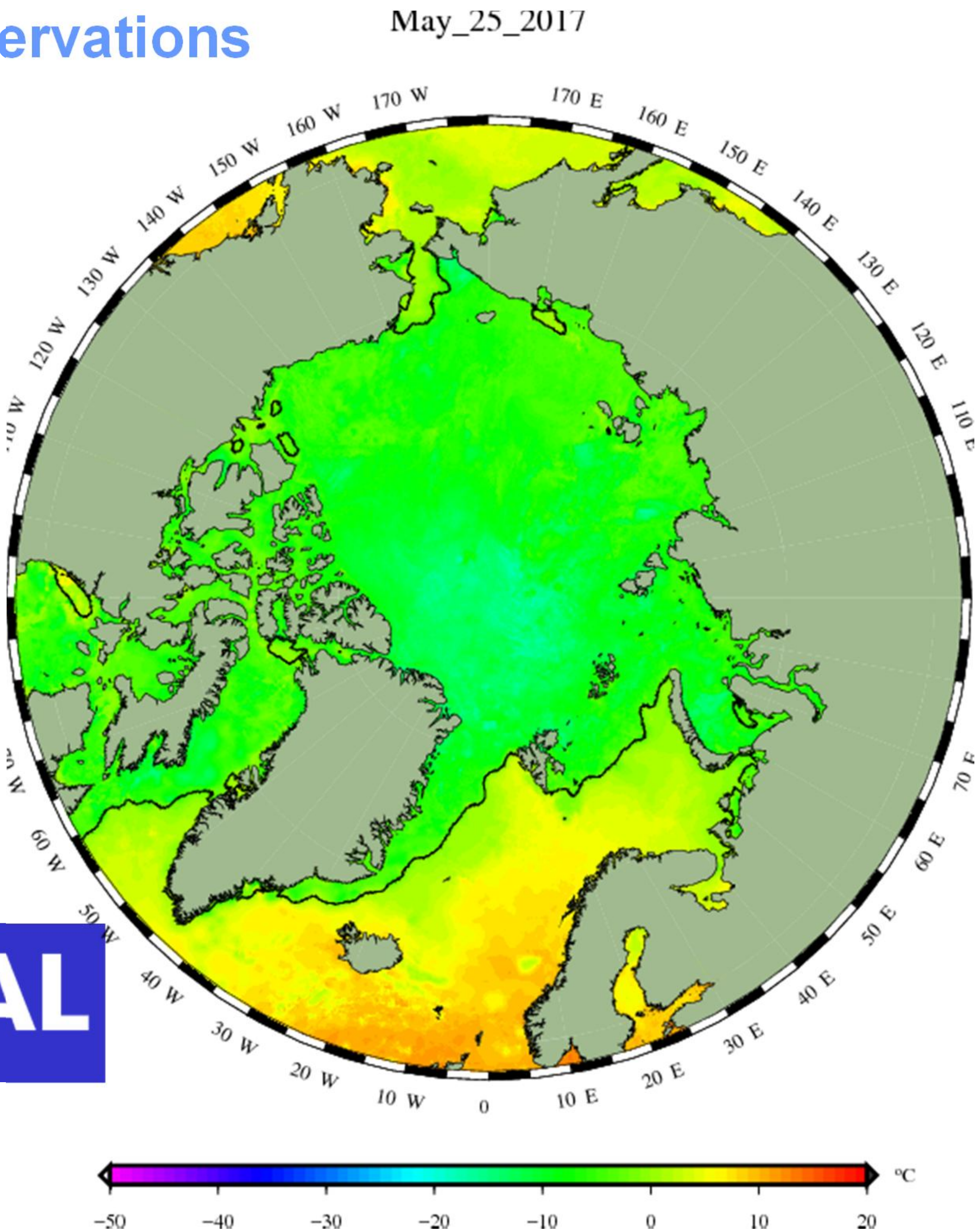
Global, regional and local simulations are combined in constructing a CAO case.

Information about the upstream vertical structure is crucial

Swarm microLES can help in optimizing the initial conditions, and for estimating the internal variability of the domain in Lagrangian simulations

Sea ice temperature observations

http://polarportal.dk



POLAR PORTAL
MONITORING ICE AND CLIMATE IN THE ARCTIC