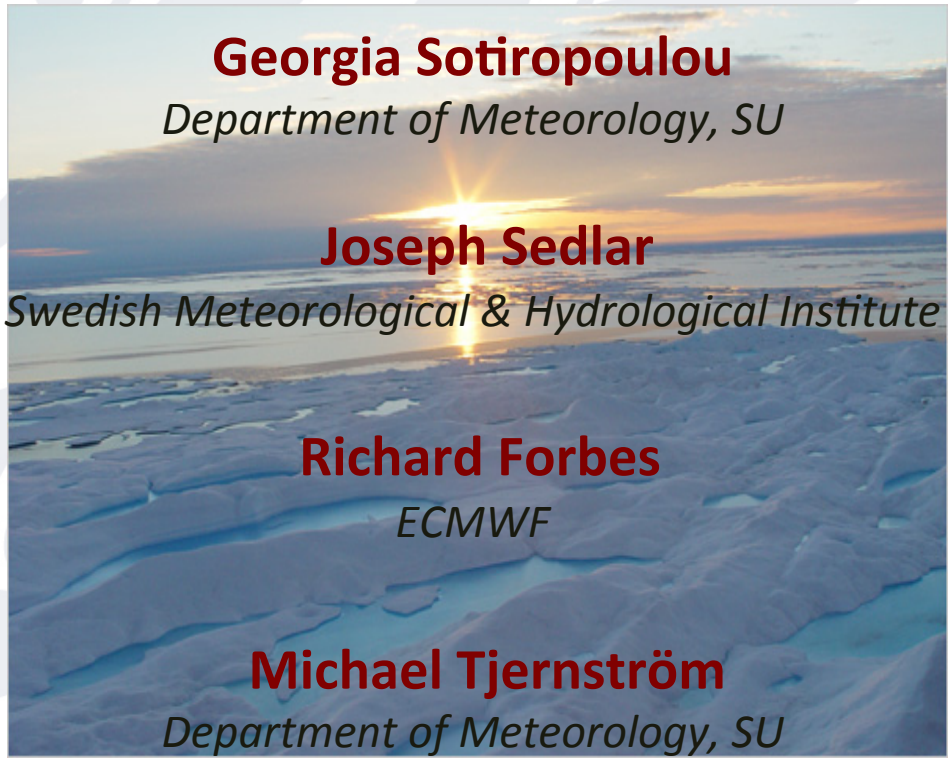
Summer Arctic clouds in ECMWF forecast model:
an evaluation of cloud parameterization schemes



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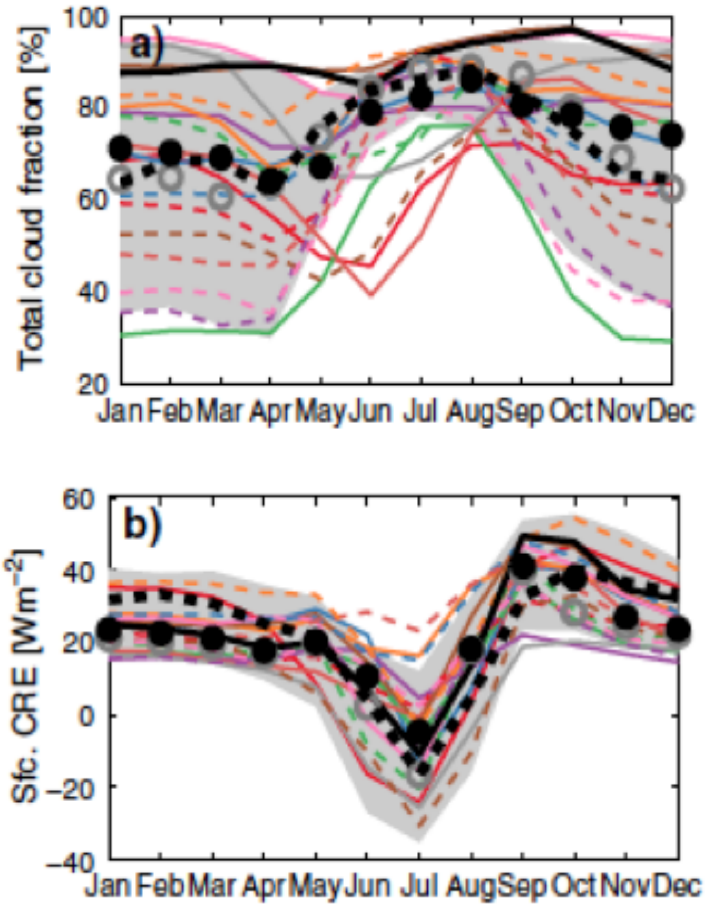
Motivation

➢ *Arctic low-level clouds…*

- have large impact on the surface energy budget

- models exhibit large deviations in Arctic cloud representation

CMIP5 GCM spread in Cloud Fraction & surface Cloud Radiative Effect



Karlsson and Svensson (2013)

Stockholm University

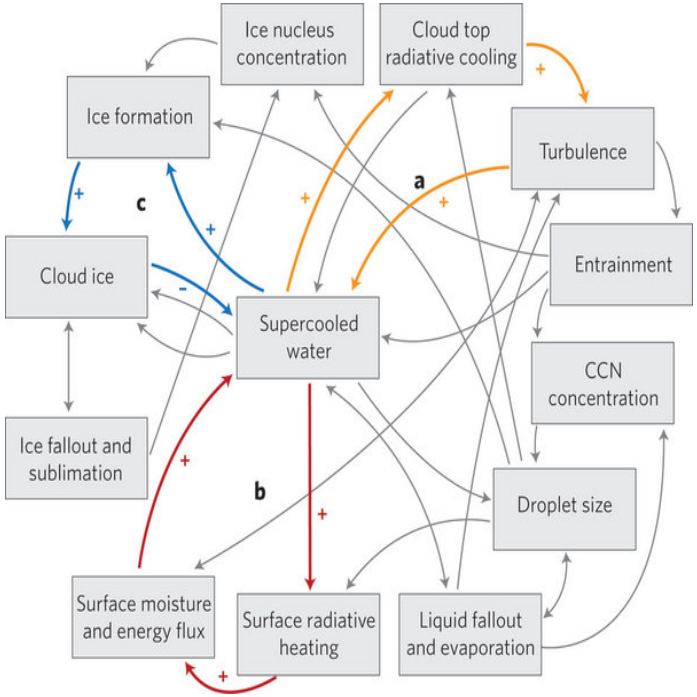
Motivation

➢ *Mixed-phase clouds…*

-have unusual structure: composed of both supercooled liquid water and ice

-persist for a long time at sub-zero temperatures

- their resilience depends on several processes, which are poorly handled by models



Morrison et al. 2012

Question

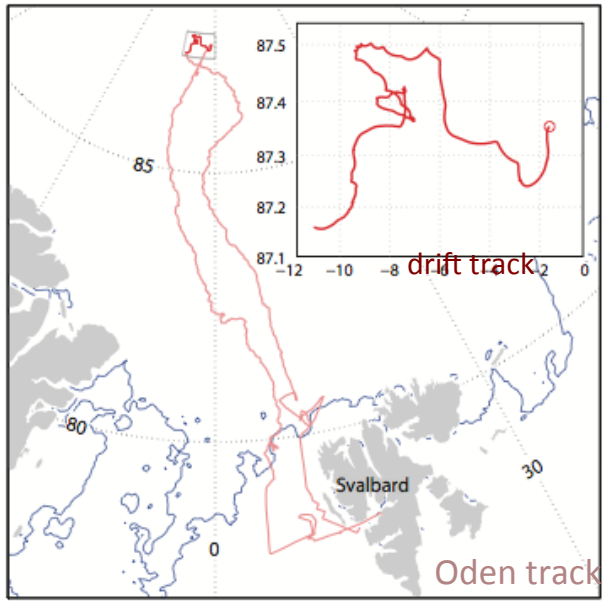
- **Model evaluation:**

How well does ECMWF Forecast Model (IFS), **with a relatively new cloud scheme,** represent Arctic low-level clouds?

Comparison with **ASCOS** (Arctic Summer Cloud Ocean Study, 2008)

ASCOS (Arctic Summer Cloud Ocean Study)

- 2 Aug – 9 Sept 2008 (~40 days)
- North Atlantic sector of Arctic Ocean
- Icecamp established at ~87.5N (~21 days) and drifted with the ice-floe



ECMWF Forecast Model (IFS) – cloud parameterizations

Previous cloud scheme :

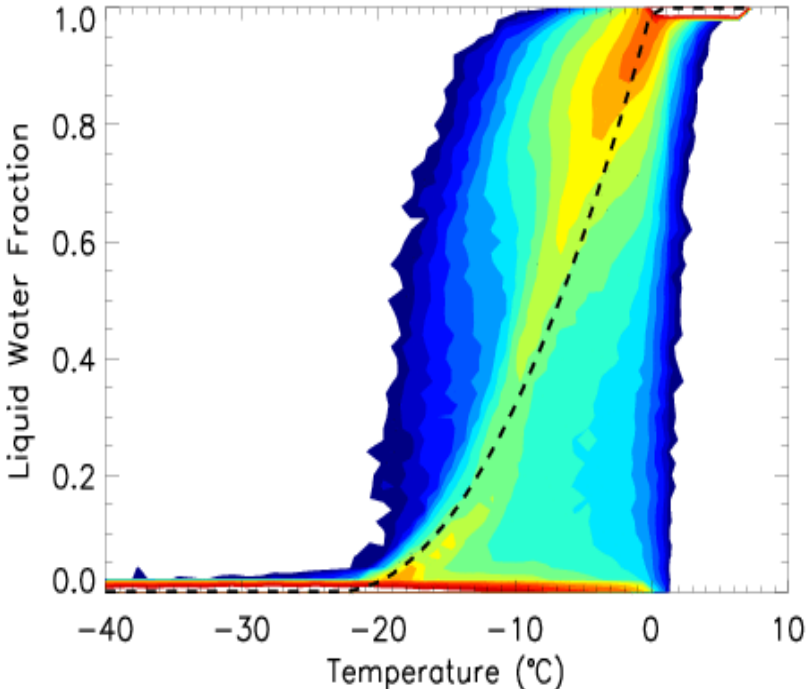
(prior Nov. 2010)

- Prognostic condensate & cloud fraction
- Diagnostic liquid/ ice split as a function of temperature
- Diagnostic precipitation

New cloud scheme :

(Nov. 2010 – present)

- Prognostic liquid & ice & cloud fraction
- Prognostic snow & rain
- Existing + New sources & sinks



Forbes R.

dashed line: diagnostic liquid/ ice
contours: prognostic liquid/ ice

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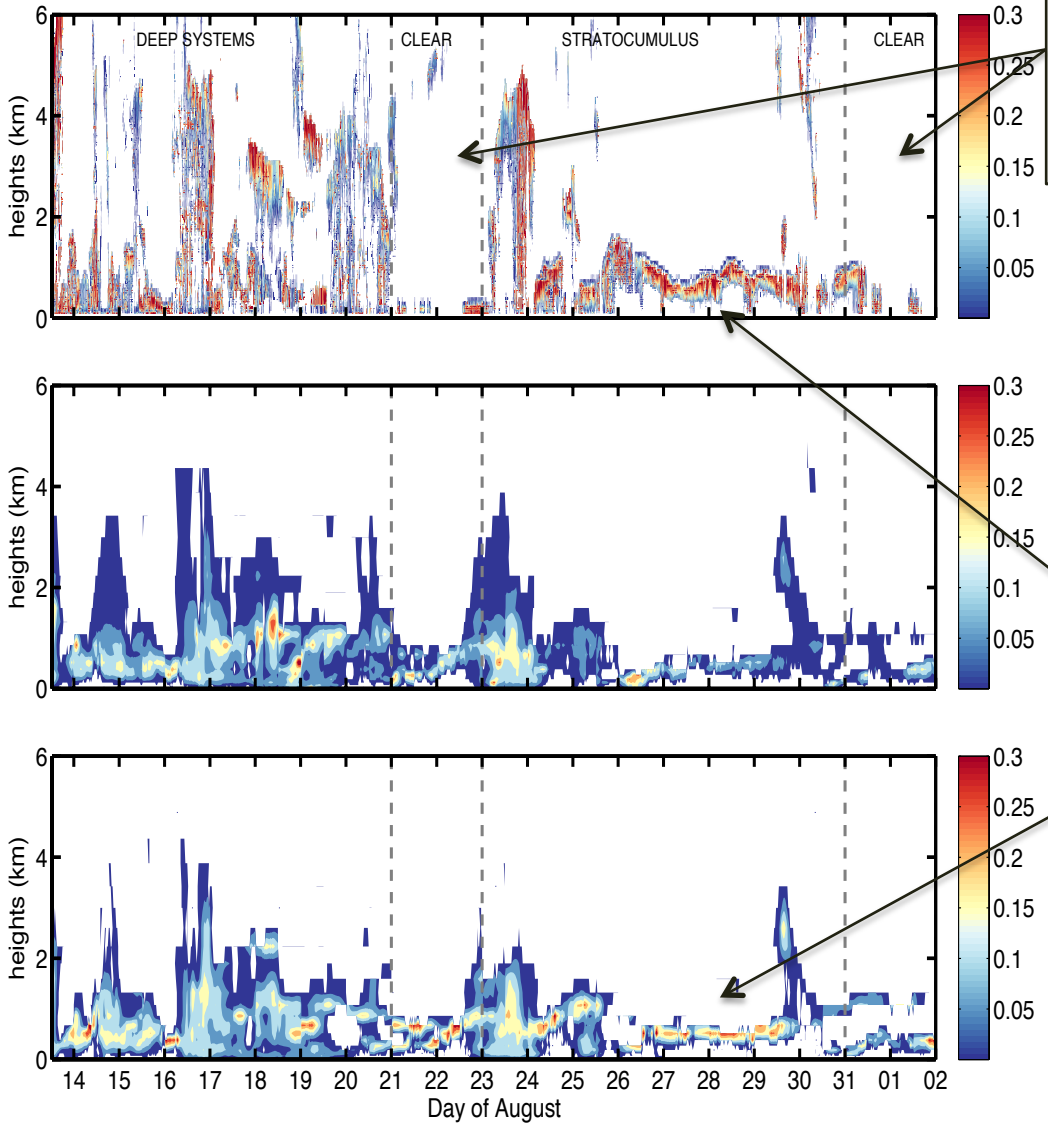
How well does IFS represent summer Arctic clouds?

LWC (kg m^{-3})

ASCOS

IFS old cloud scheme

IFS new cloud scheme

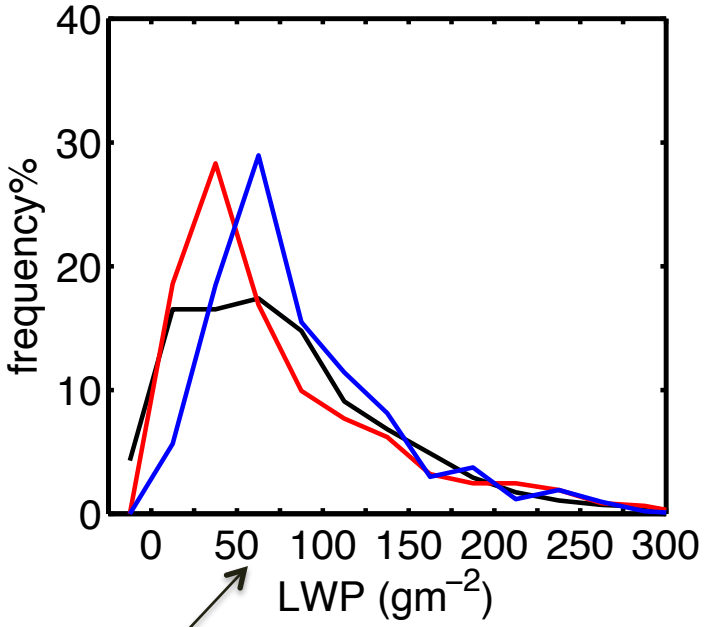


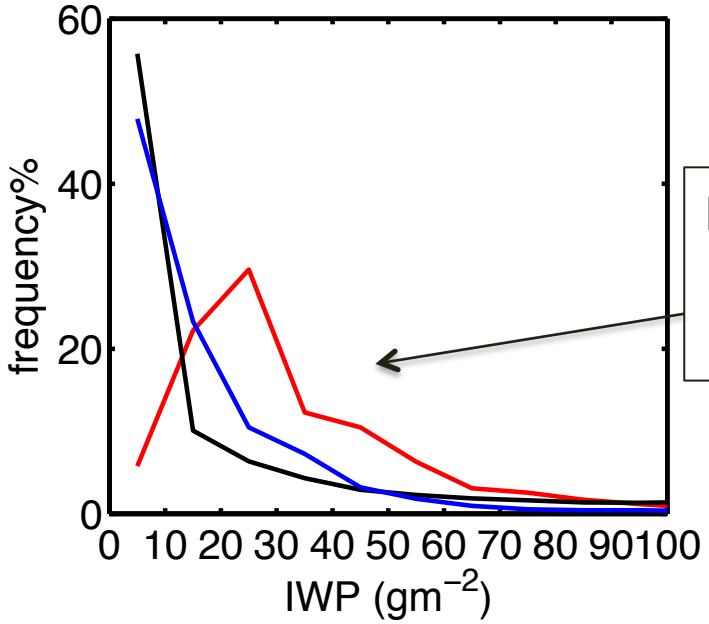
cloud-free periods not captured by both schemes

stratocumulus period better captured by the new scheme

How well does IFS represent summer Arctic clouds?

Cloud water properties





Ice improves with the new scheme

More cloud liquid in the new scheme

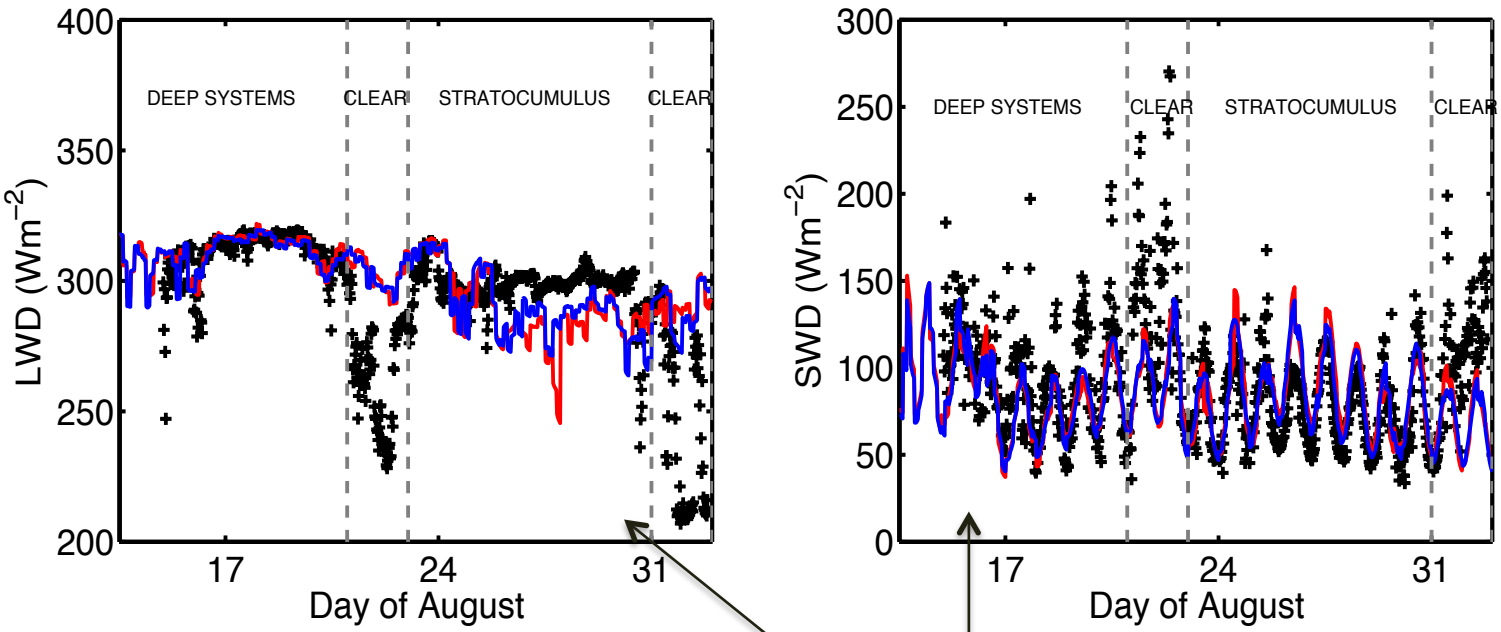
ASCOS

IFS old scheme

IFS new scheme

How well does IFS represent summer Arctic clouds?

Surface downward longwave & shortwave radiation



+++ ASCOS

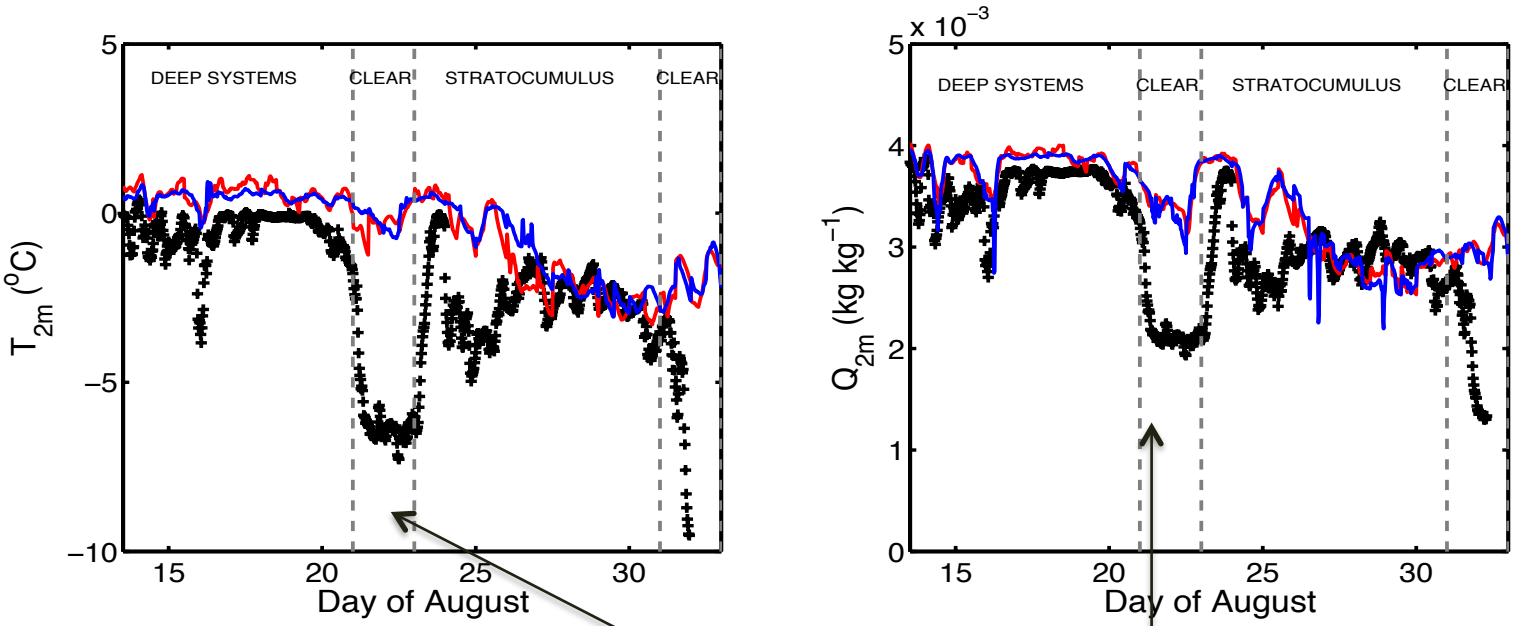
IFS old scheme

IFS new scheme

surface radiations do not improve with the new scheme

How well does IFS represent summer Arctic clouds?

2m- temperature & humidity



+++ ASCOS

IFS old scheme

IFS new scheme

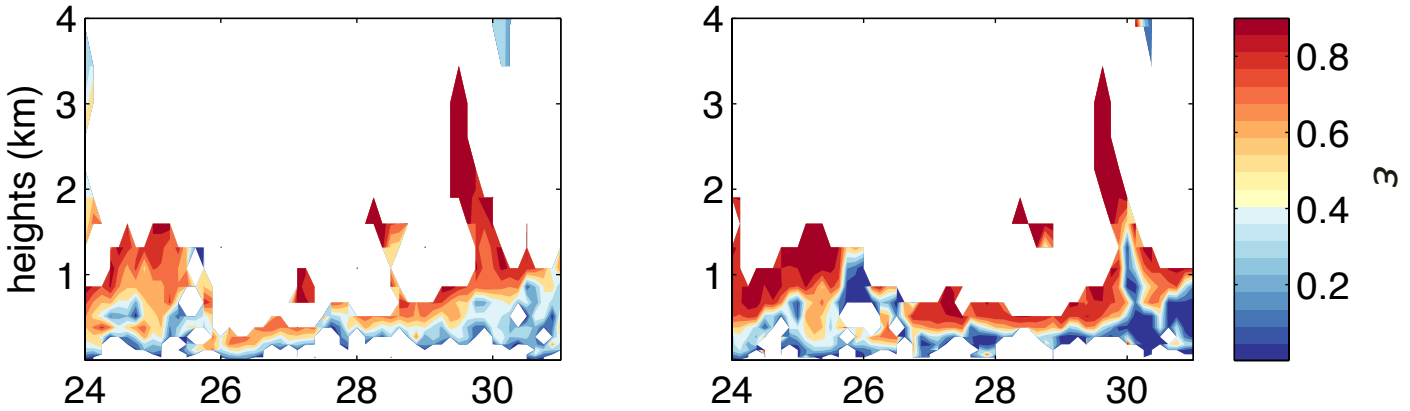
A **warm** and **moist bias** present in both schemes

Why sfc radiations do not improve with improved cloud water properties?

IFS old scheme **IFS new scheme**

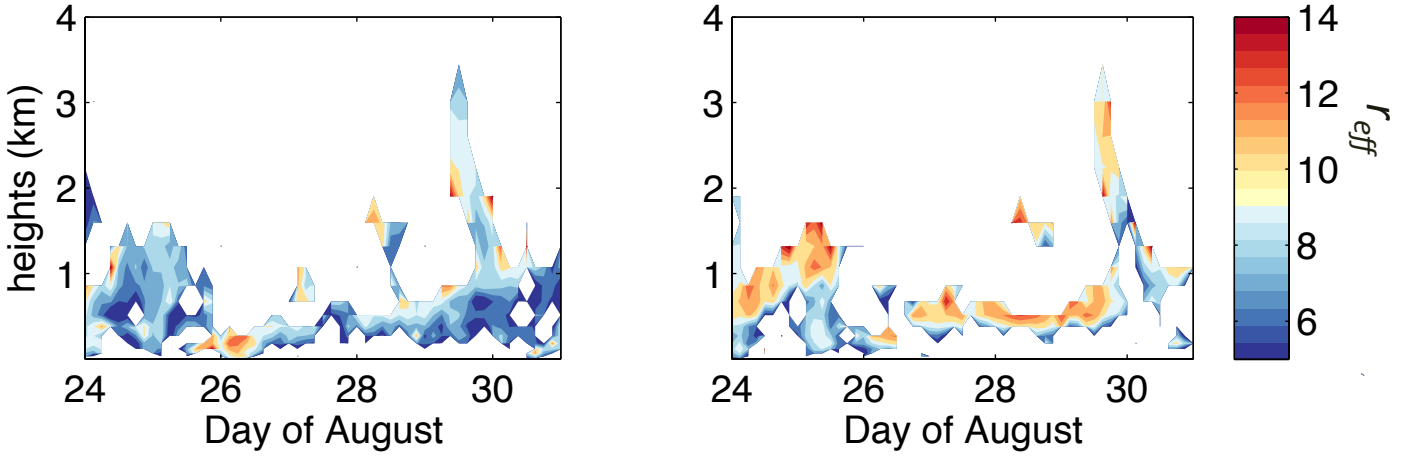
long-wave cloud emissivity (ε) at 10.5µm

ε ~ 1 in both schemes



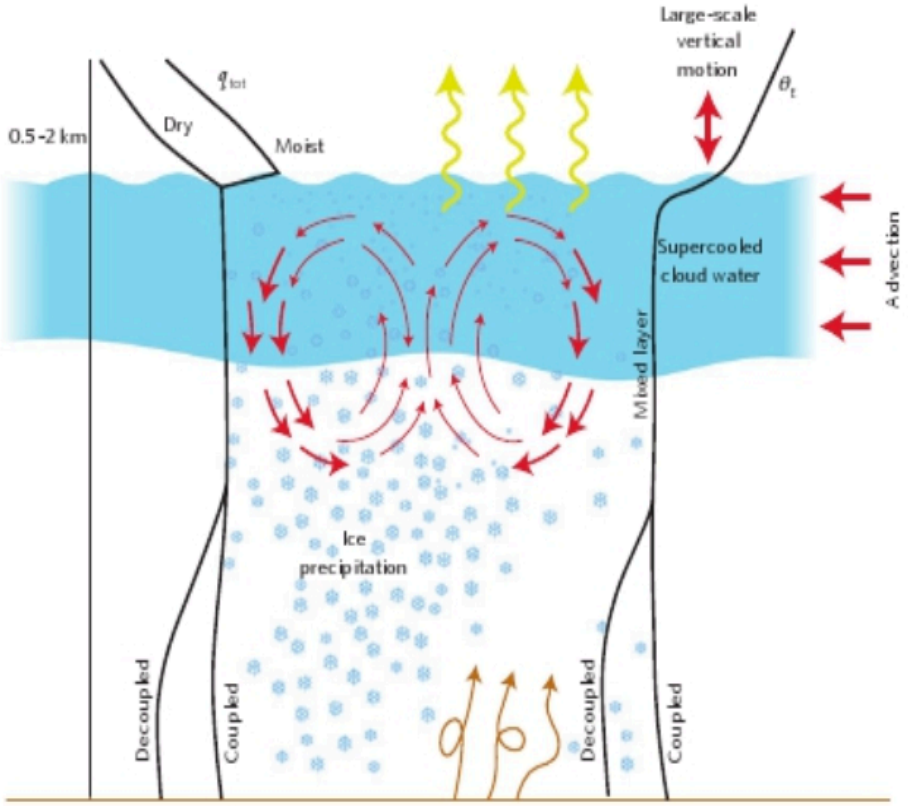
cloud droplet effective radius (r_{eff}, µm)

r_{eff} increases in new scheme; less SW reflection



Processes sustaining mixed-phase clouds:

- large-scale advection
- microphysics
- surface sources

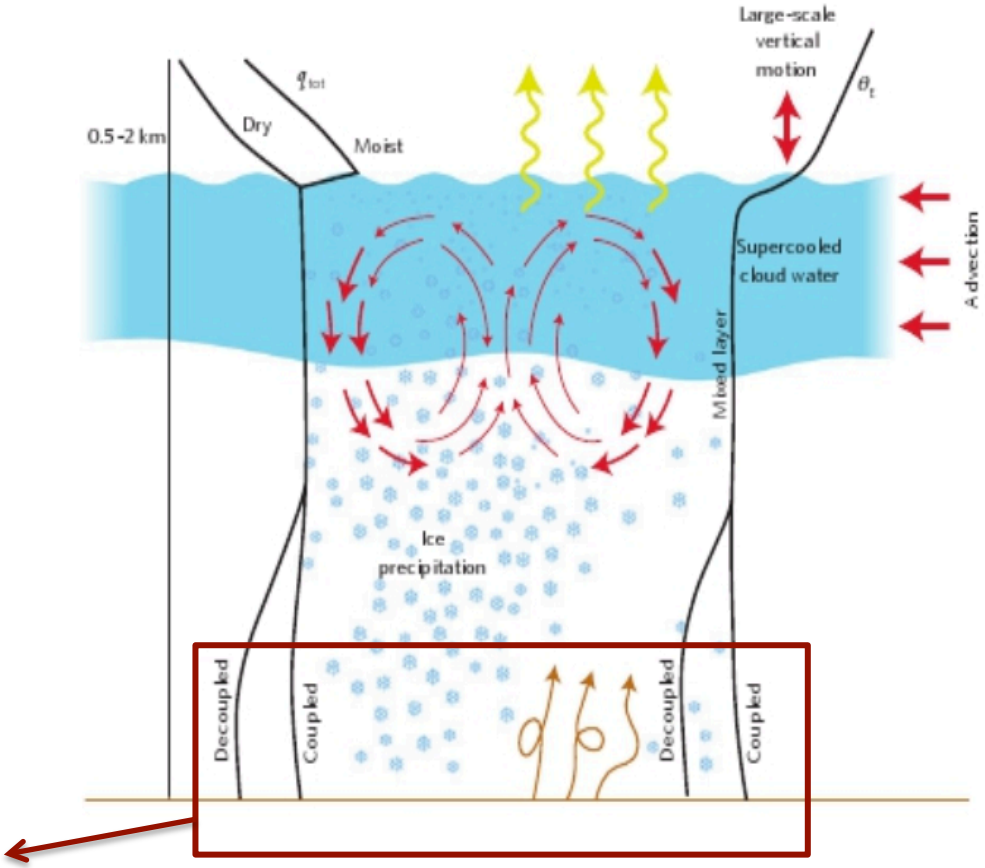


Morrison et al. 2012

Processes sustaining mixed-phase clouds:

- large-scale advection
- microphysics
- surface sources

how well are cloud-surface interactions represented in IFS ?



Morrison et al. 2012

Cloud-surface interactions:

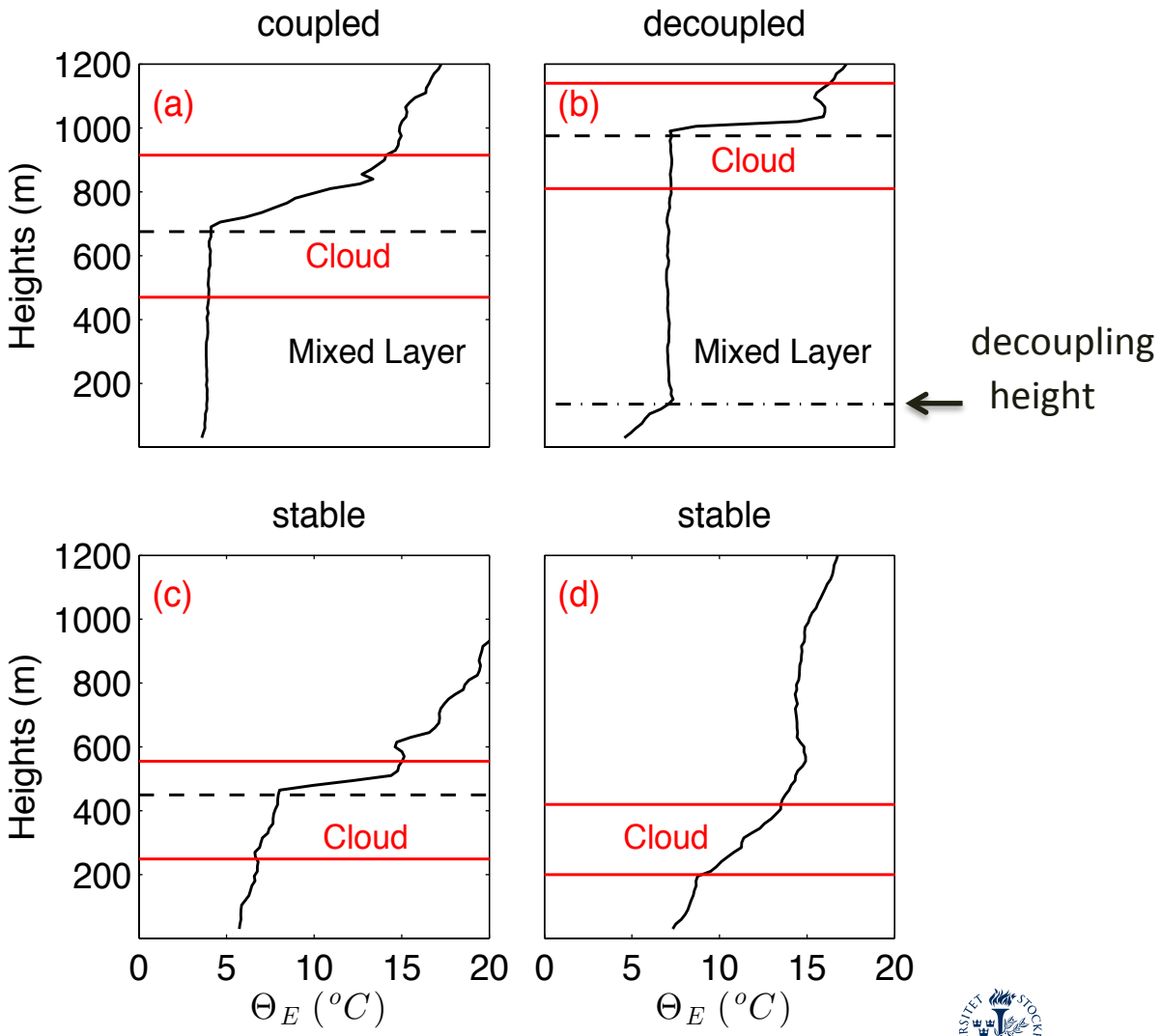
Cloud profiles categorized, using Θ_E , as :

(a) **coupled** to the surface

(b) **decoupled** from surface

(c, d) stably-stratified or **stable**

(No cloud-driven mixing)

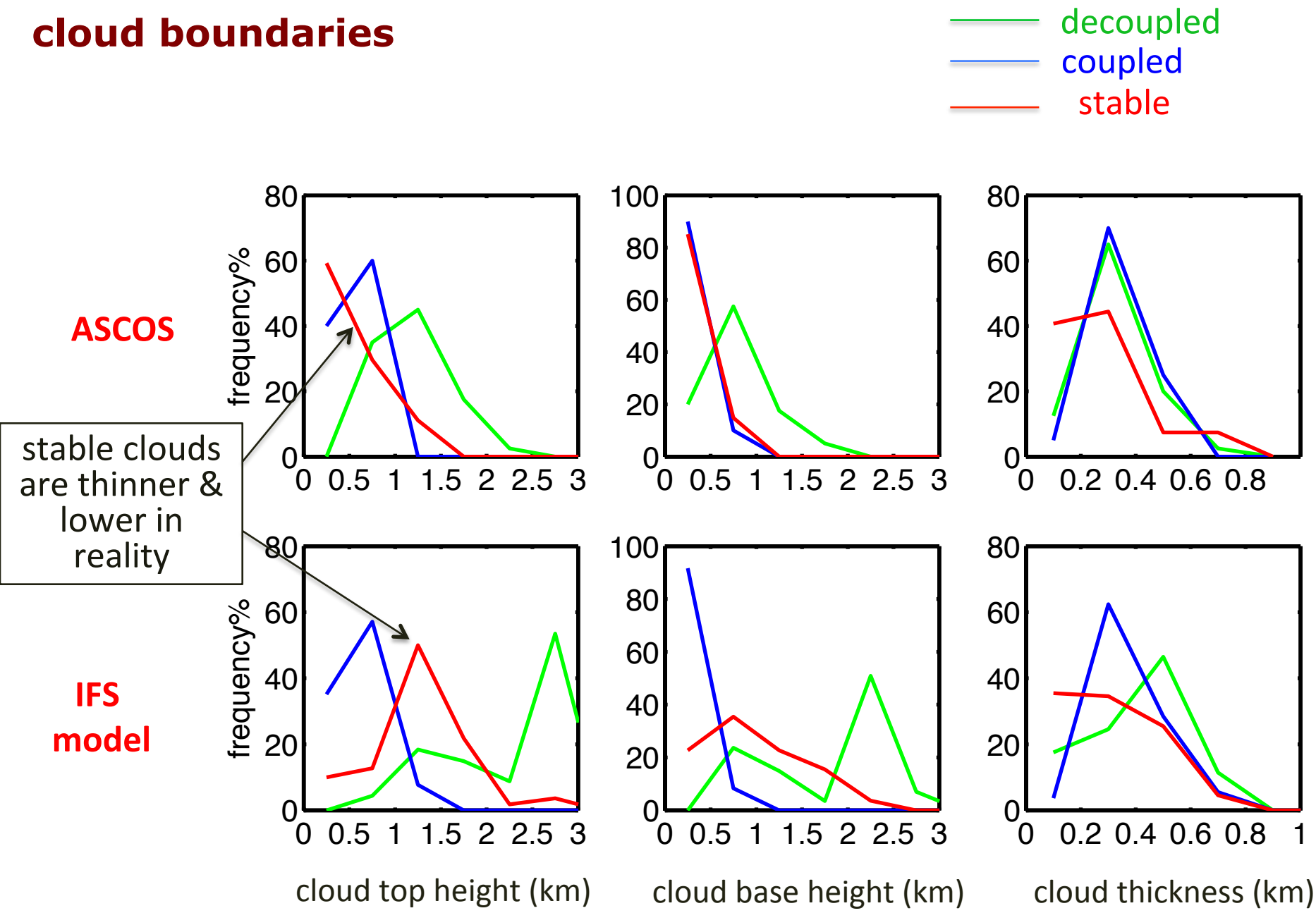


How well does IFS represent the cloud-surface interactions?

	Decoupled	Coupled	Stable
ASCOS	**50%**	20%	30%
IFS - 60 levels (new scheme)	1%	**66%**	33%
IFS - 137 levels (new scheme)	16%	**69%**	15%

surface turbulence parameterization in IFS: **in stratocumulus-topped boundary layers the mixed layer spans from the 1st model level to the PBL top.**

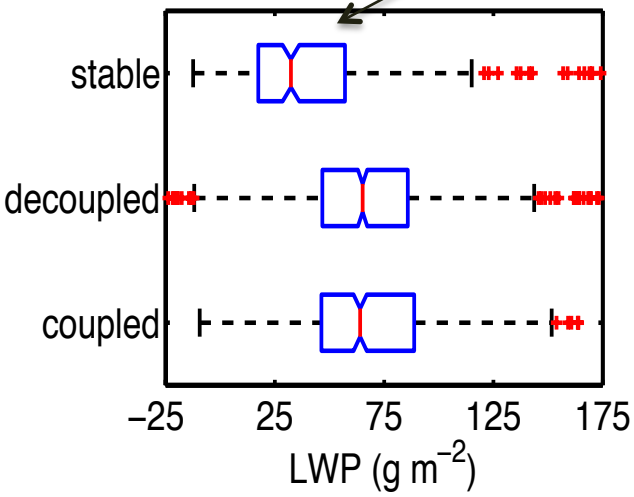
cloud boundaries

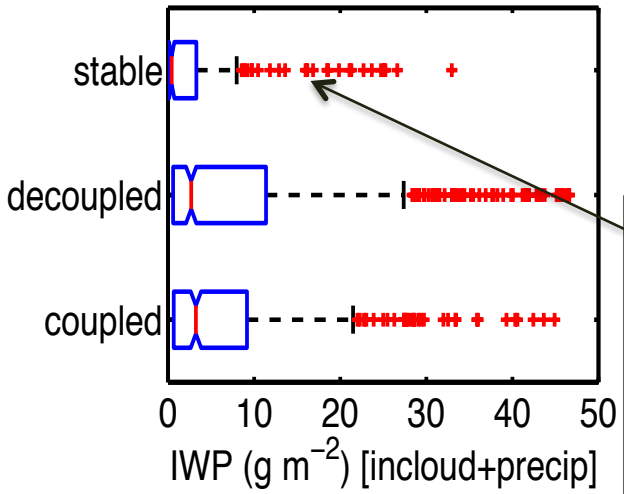


cloud water properties

Stable clouds are optically-thinner

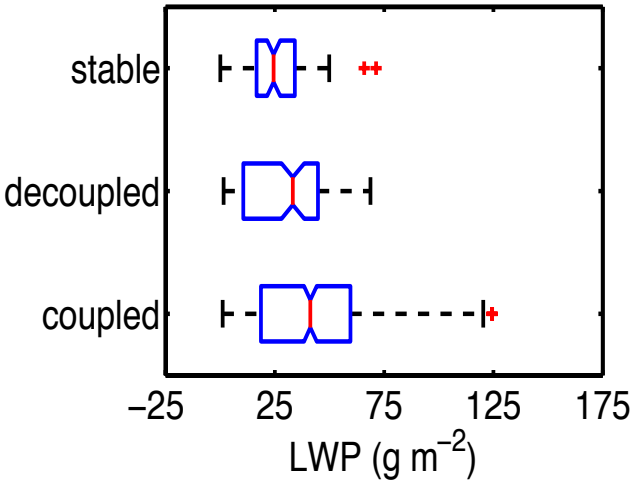
ASCOS

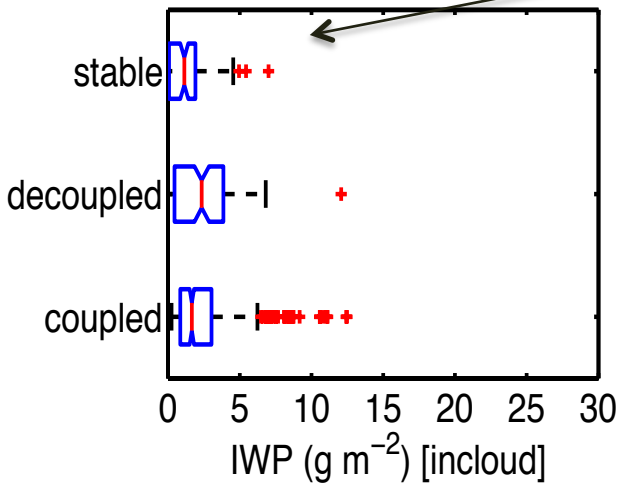




stable clouds are single-phase liquid in reality ≠ mixed- phase in the model

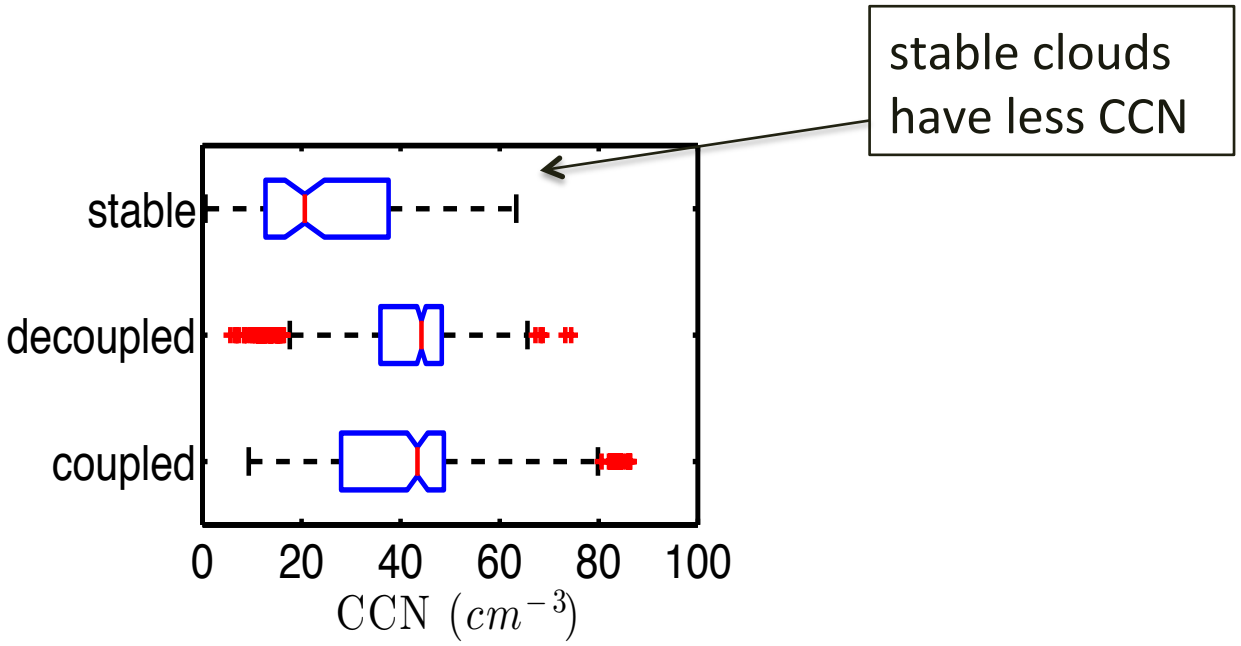
IFS model





CCN concentration

ASCOS



IFS model

two CCN values; one over land and a lower value for all marine conditions

Conclusions

- The new prognostic cloud scheme produces clouds with more liquid and less ice ⟶ *more realistic mixed-phase clouds with the new scheme*

- Surface radiations and hence near-surface variables (T_{2m} ,Q_{2m}) are **not improved** in the new scheme ⟶ *issues related to cloud radiative properties, surface albedo and surface emissivity.*

- IFS fails to reproduce cloud-free periods, and it also does not reproduce correctly stable clouds : **low-CCN conditions are not handled by the model**. *a more adaptive parameterization for cloud/ aerosol interactions is required*

- IFS fails to represent correctly the cloud-surface interactions. ⟶ *A turbulence mixing scheme that allows for local turbulence production at cloud-top is needed*

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REFERENCE:

Sotiropoulou, G., J. Sedlar, R. Forbes, and M. Tjernström, 2016: Summer Arctic clouds in the ECMWF forecast model: an evaluation of cloud parameterization schemes. *Quart. J. Roy. Meteorol. Soc.*, **142**, 387–400, doi: 0.1002/qj.2658.