Representation of Arctic mixed-phase clouds in the ECMWF Integrated Forecasting System during MOSAiC

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The Model

The ECMWF Integrated Forecasting System (IFS) is a global **numerical weather prediction** model, which is also used for **climate predictions** and the reanalysis **ERA5**. The representation of clouds is important because of their radiative impact, but uncertain (e.g. Morrison et al., 2020).

Cloud processes are parametrised based on grid-box mean quantities with separate prognostic variables for liquid and ice cloud mass (see references for full documentation).

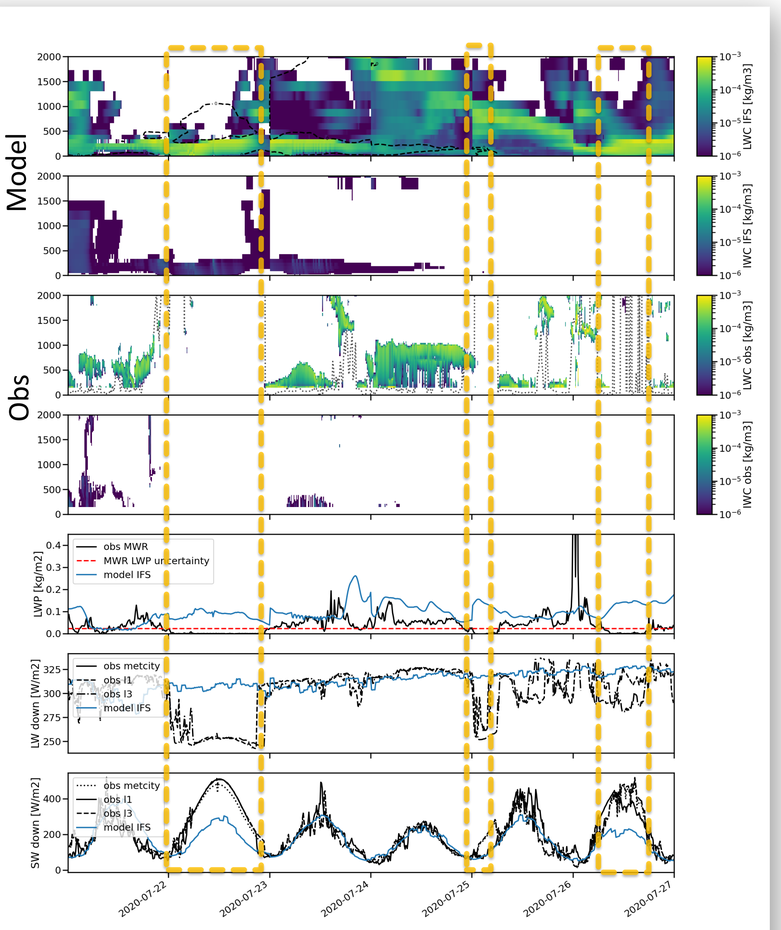
The IFS **Single Column Model (SCM)** simulates one atmospheric column using the same parametrisations as the 3D model.
The column is initialised and forced with profiles and advective tendencies from a 3D model run.

The Observations

The MOSAiC campaign provides atmospheric observational data from the central Arctic for a **full year** (Shupe et al., 2022). Arctic mixed-phase clouds are common and have a large radiative forcing compared to ice-only clouds (Shupe and Intrieri, 2004).

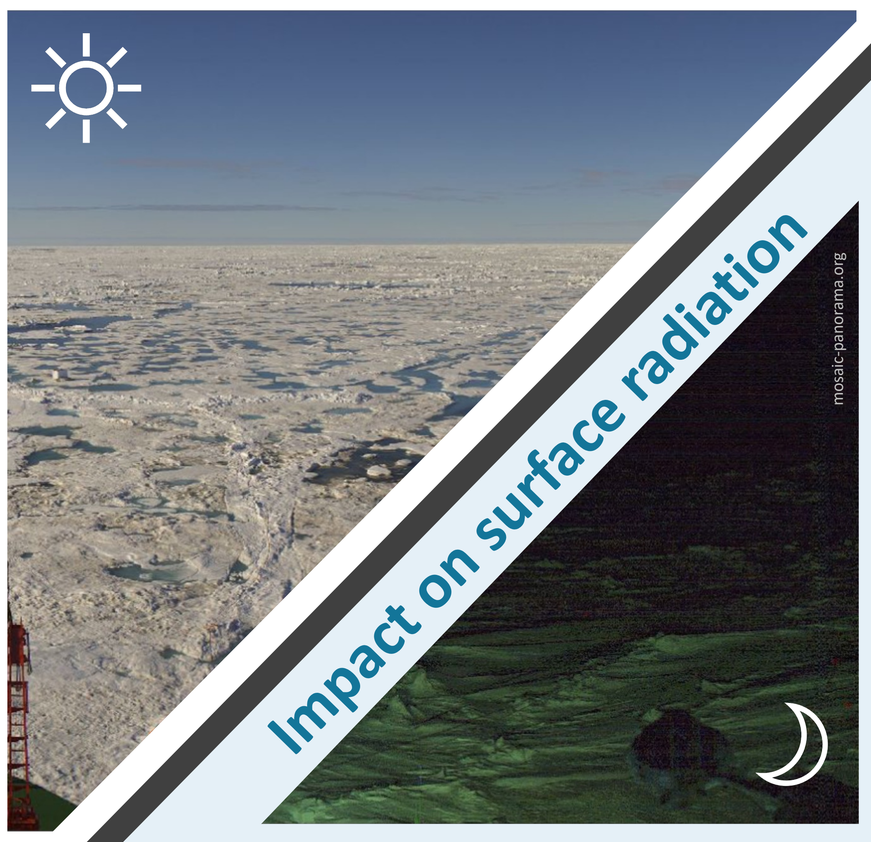
Data used for the evaluation:

Temperature & Moisture profiles	Extended radiosonde profiles Dahlke et al., 2023
LWP, IWV	HATPRO & MiRAC-P MWR Walbröl et al., 2022
Broadband radiation (LW/SW down)	Atmospheric Surface Flux Stations at 4 sites Cox et al., 2023 abcd
Liquid water content, Ice water content	ShupeTurner cloud microphysics product Shupe 2022

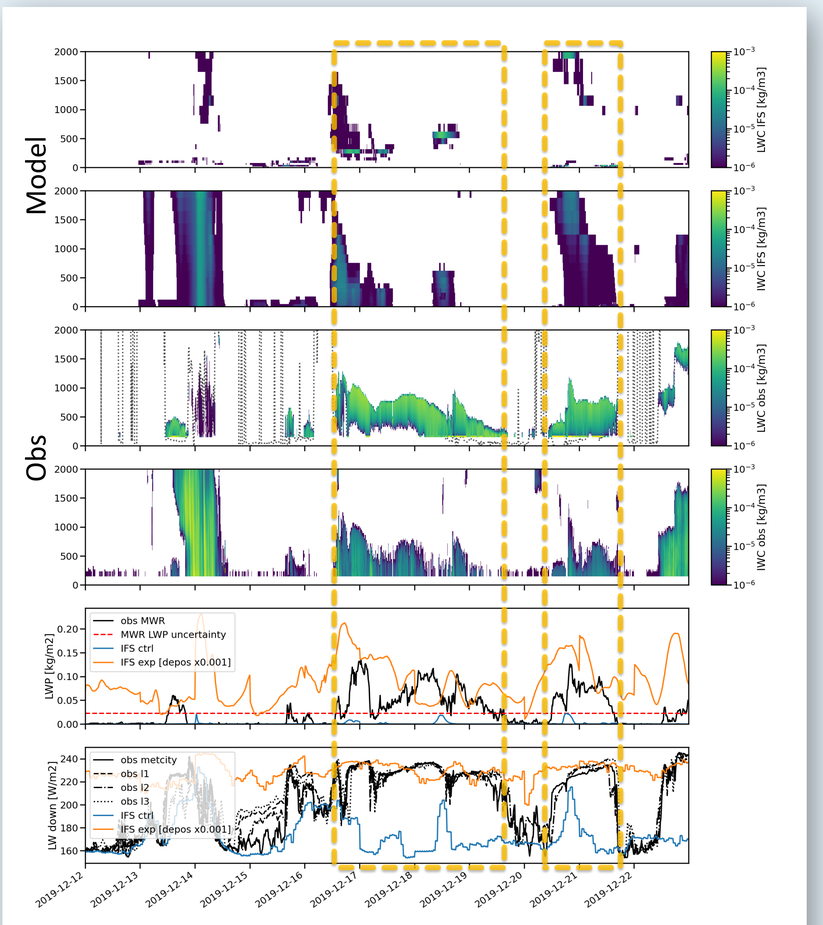


Example case of missed clear-sky periods in July

Too much liquid cloud in summer



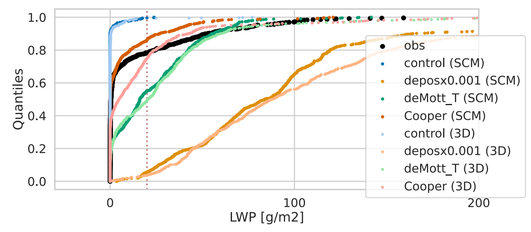
Too little liquid cloud in winter



Example case of missed liquid-containing clouds in December

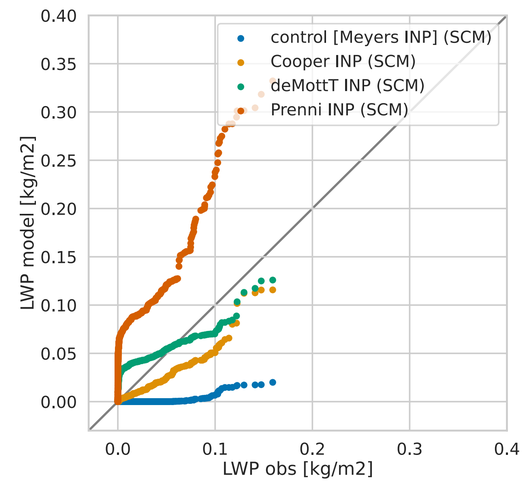
One winter month in a **Single Column Model**

A **setup test** shows comparable sensitivity in 3D Model and SCM.



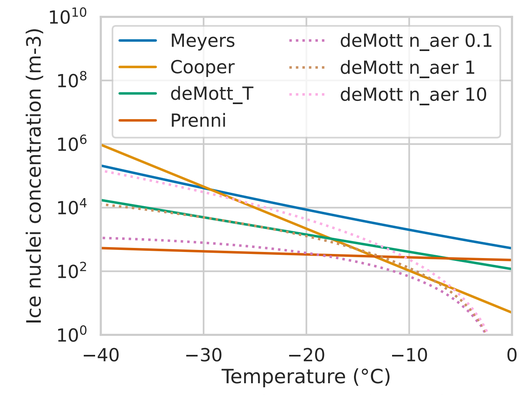
Setup test: LWP quantiles for sensitivity tests in 3D model and SCM for December 2019

The modelled LWP shows a strong **sensitivity** to the parametrisation of the **Wegener-Bergeron-Findeisen (WBF) process** in winter – from underestimation to overestimation.

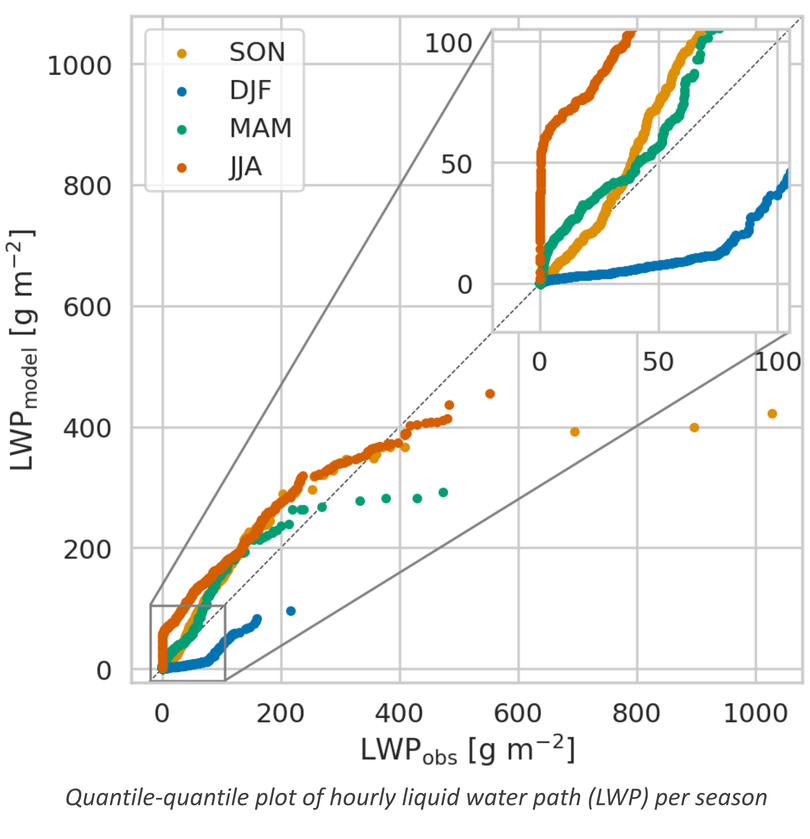


Quantile-quantile plot of LWP in December for different parametrisations in the SCM

The WBF efficiency depends on assumptions of the **ice particle number concentration.**



Parametrisations of ice particle number concentration



Quantile-quantile plot of hourly liquid water path (LWP) per season

One year in the ice

Conclusions

- The IFS underestimates the occurrence of winter Arctic mixed-phase clouds and misses summer clear-sky periods during the MOSAiC campaign, both with clear impact on surface radiation.
- The maintenance of cloud liquid water in cold temperatures is sensitive to the parametrisation of the WBF process; a reduction within the uncertainty range is sufficient to maintain cloud liquid water in winter.
- The parametrisation of mixed-phase microphysical processes needs adjustments to allow for maintaining winter Arctic mixed-phase clouds. Any adjustments must be evaluated globally.

Open questions

The representation of **ice mass** in Arctic mixed-phase clouds and its sensitivity to the WBF parameterisation remains to be investigated. Is the total amount of cloud water correctly represented? What is the partitioning between liquid and ice?

References

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