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Ship-based lidar evaluation of Southern Ocean low clouds in the storm-resolving general circulation model ICON and the ERA5 and MERRA-2 reanalyses

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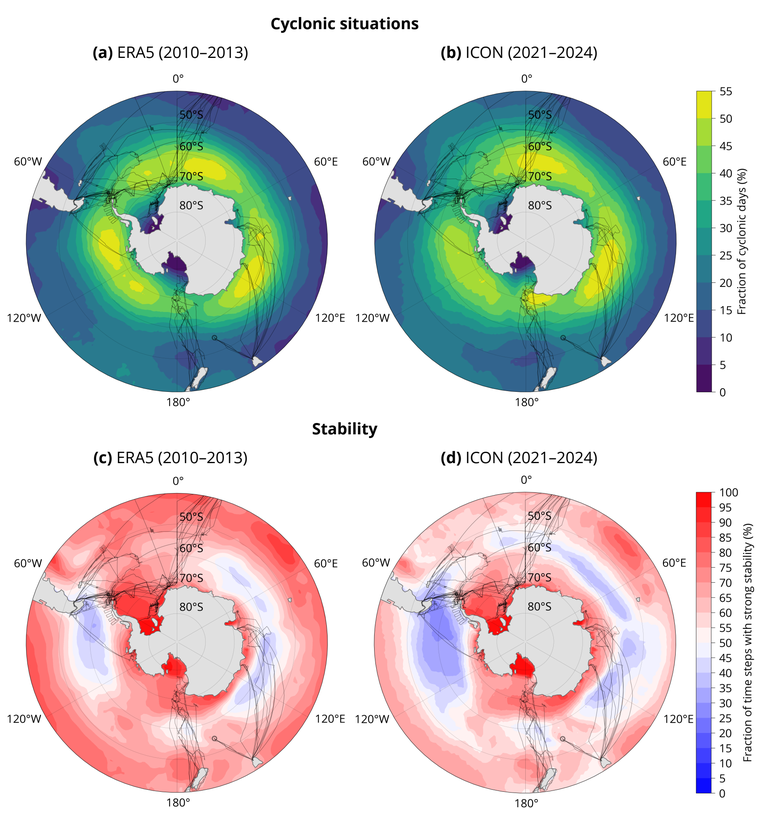
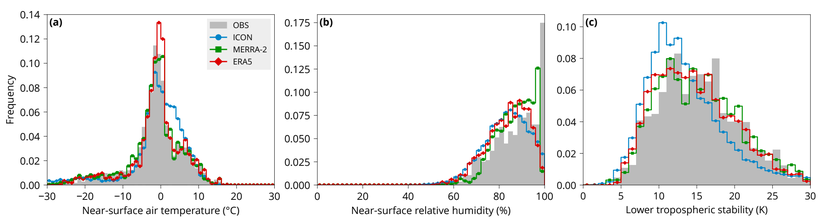
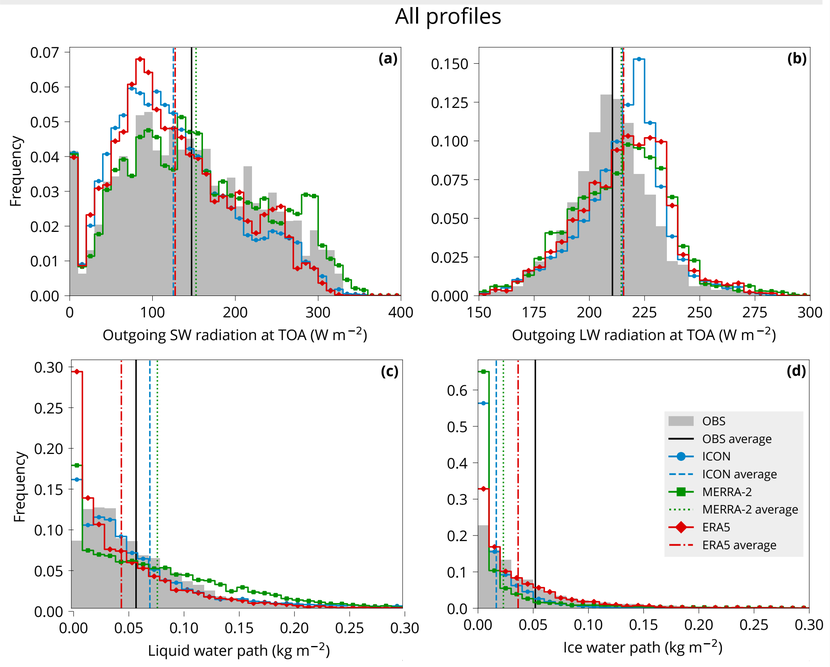
Partitioning by cyclonic sitation and stability



Surface-level observations and LTS



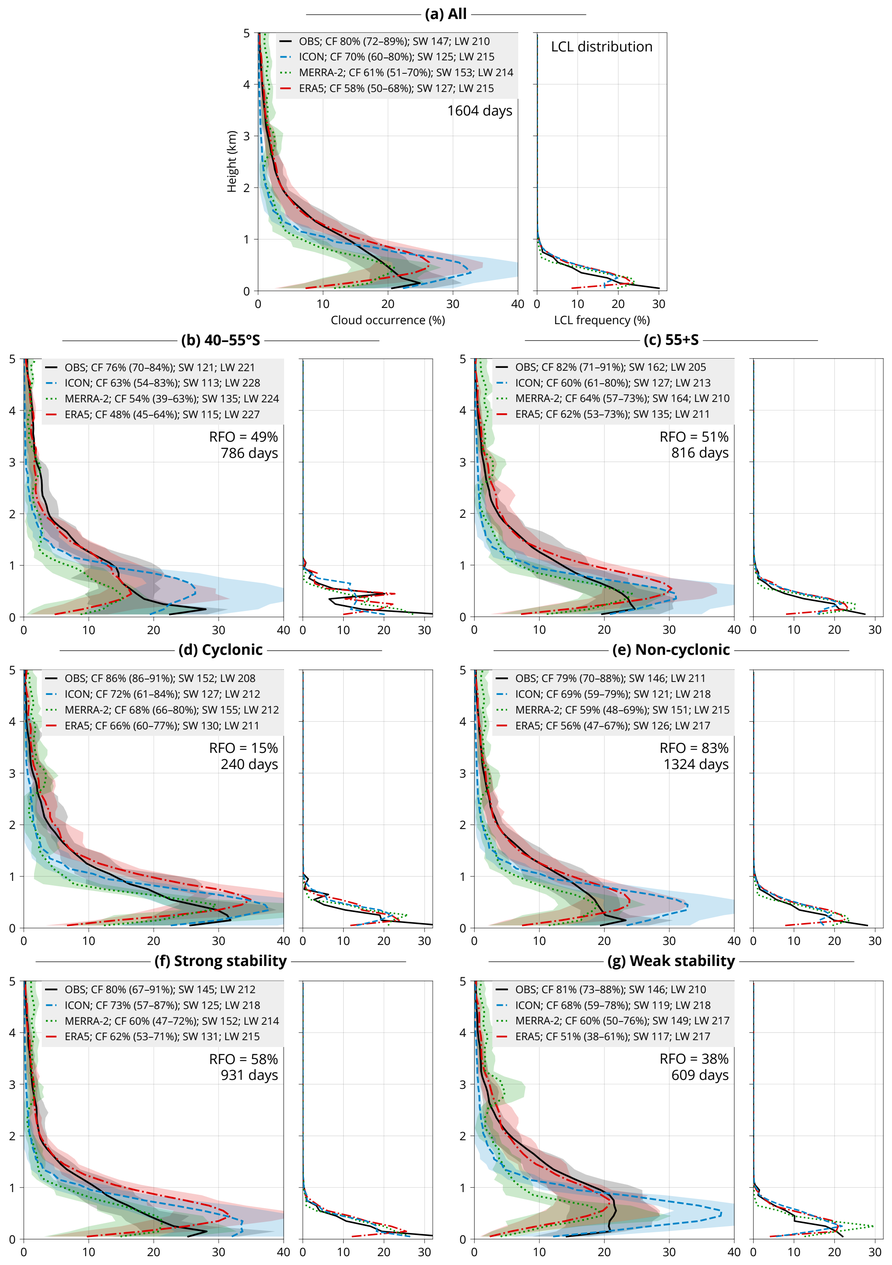
Radiation and phase comparison with CERES



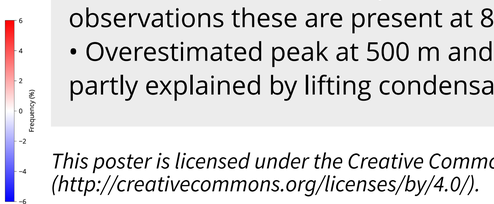
Introduction

- We compared cloud observations from 31 voyages and a subantarctic ground-station with ICON, MERRA-2, and ERA5
- 4 km-scale version of ICON developed by nextGEMS, globally atmosphere-ocean coupled
- ICON: no subgrid-scale cloud parameterisations except for microphysics
- We focus on cloud biases over the Southern Ocean 40+°S, which are a long-standing problem in climate models
- Large dataset of 2400 days of lidar observations compared using the lidar simulator ALCF and 2300 radiosonde profiles
- Ceilometers Vaisala CL51 and CT25K (910 nm) and Lufft CHM 15k (1064 nm)
- CERES satellite instrument observations of radiation fluxes, liquid and ice water path
- The lidar simulator calculates backscatter, cloud mask, and cloud fraction from model and reanalysis data

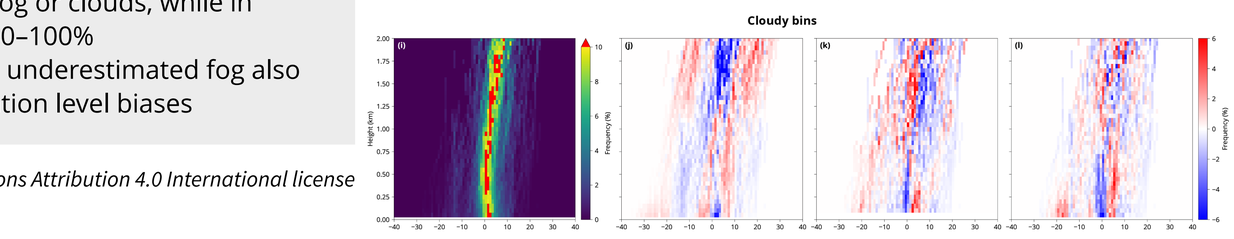
Cloud occurrence by height



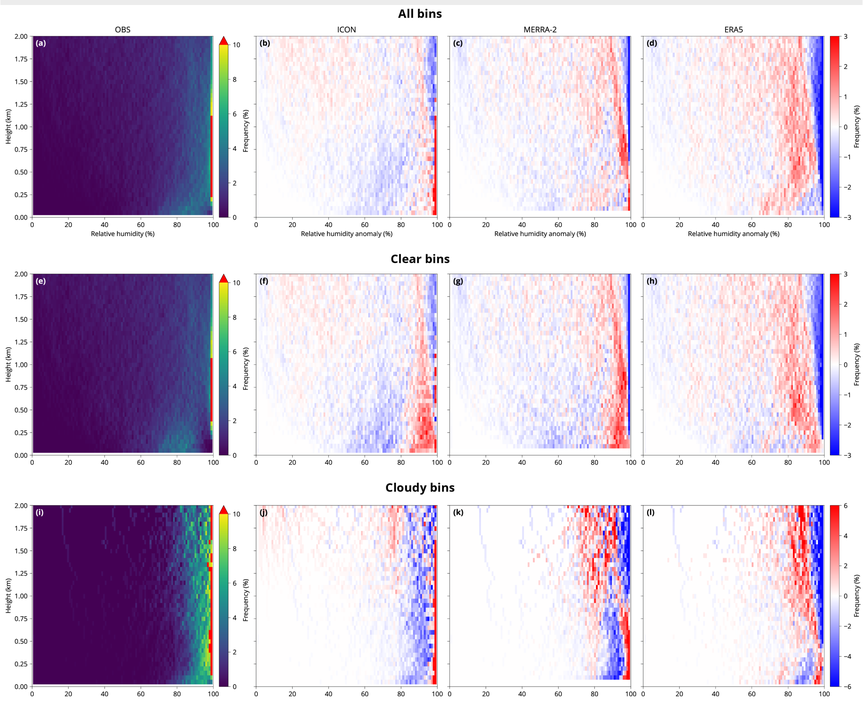
The lidars



Thermodynamic profiles by cloud type



Relative humidity distribution



Conclusions

- Total cloud fraction underestimated in the model and reanalyses by 10–20%
- Error due to underestimated fog or very low-level cloud, overestimated cloud peak at 500 m, and underestimated cloud occurrence above 1 km
- MERRA-2 exhibits the 'too few, too bright' problem
- ICON is too weakly stable due to both higher near-surface temperature and lower virtual potential temperature at height
- Near-surface relative humidity and lower tropospheric stability are underestimated in the model and reanalyses, and the lifting condensation level overestimated, causing less fog and higher cloud base
- The model and reanalyses require relative humidity close to 100% near the surface to produce fog or clouds, while in observations these are present at 80–100%
- Overestimated peak at 500 m and underestimated fog also partly explained by lifting condensation level biases

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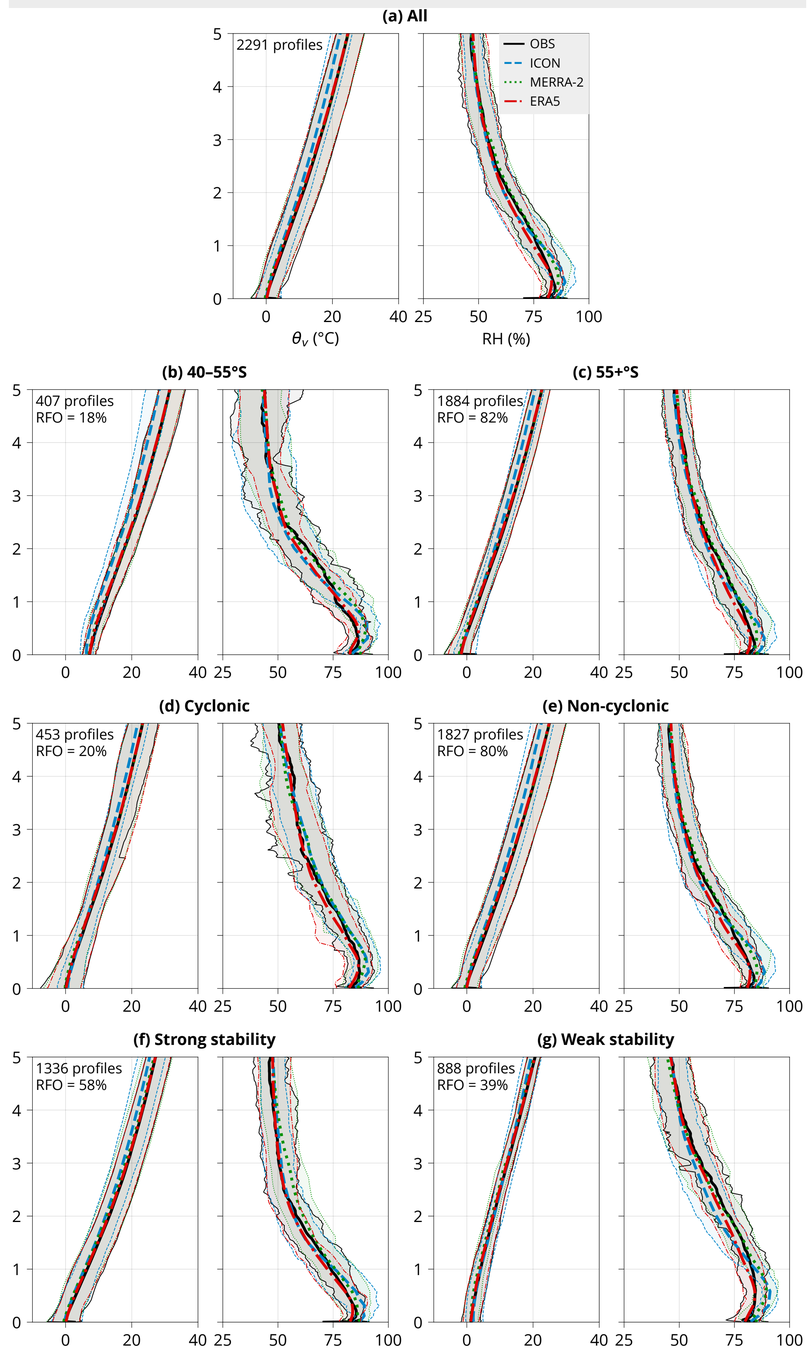
Key Points:
- Large cloud biases are present in the global storm-resolving model but are lower in several key aspects than in the reanalyzes
- The model and reanalyzes underestimate cloud fraction and very low-level cloud and fog, while over-estimating cloud occurrence peak at 500 m
- A "too few, too bright" problem of underestimated cloud fraction, compensated by overestimated cloud albedo, is present in MERRA-2

Supporting Information:
Supporting Information may be found in the online version of this article.

Thermodynamic (radiosonde) profiles



Virtual potential temperature distribution