Reducing the Southern Ocean Shortwave Bias through Improved Representations of Marine Boundary Layer Mixing: Case Study Analyses

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Motivation

ICON displays a significant **radiative bias** in the **Southern Ocean** (SO), which is attributed to an underestimation of boundary layer clouds. This has been mitigated in the SO mid-latitudes by altering the **triggering** of **shallow convection** (SC) and thus boundary layer mixing in ICON.
Here, we use vertically resolved measurements obtained from SO **field campaigns** to assess the representation of **boundary layer structure** and **cloud radiative properties** for different representations of boundary layer mixing.

Scientific Experiments

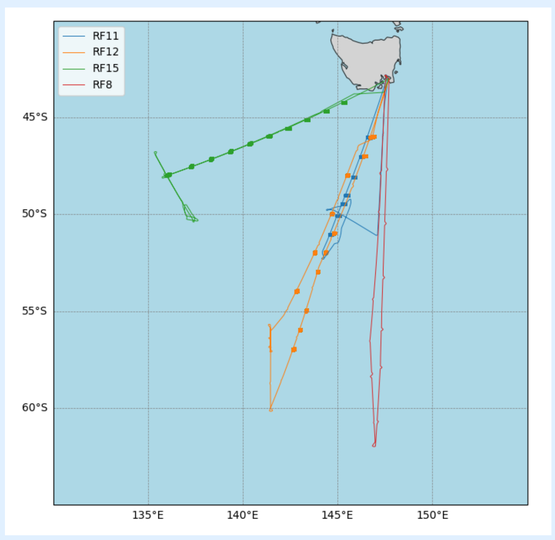
The following experiments will be conducted in global (13 km resolution) and regional limited-area model (LAM; 3.5 km resolution) simulations:

- CONTROL simulation
- SC: change on SC trigger restriction and modified subgrid-scale (SGS) clouds scheme
- AD-HOC: using AD-HOC turbulence scheme
- SC_GUF: alternative formulation of SC without SGS cloud modifications

Comparison to Observations

Cloud distributions and cloud reflectivity will be evaluated with **HIMAWARI**. Boundary layer structures and turbulence measures are obtained from field campaign data (McFarquhar, 2021):

SOCRATES	**MARCUS**
When: 15.01.2018 - 24.02.2018	When: 21.10.2017 - 23.03.2018
Where: South of Tasmania	Where: from Hobart to Mawson, Davis, Casey
Aircraft: NSF/NCAR G-V HIAPER	Ship: RSV Aurora Australis
Instruments: radar, lidar, in-situ, dropsondes	Instruments: radar, lidar, radiosondes



4 flights are considered for SOCRATES:
stratocumulus: RF8, RF12
cumulus: RF11, RF15

33 dropsondes launched

Fig1.: Flight trajectories from SOCRATES (solid line) with dropsonde positions (dots)

RF11 in SOCRATES: cumulus

Simulation Setup:
Version: icon-2024.01-dwd-2.0
Scientific Experiment: SC, global
Initialisation date: 20180216 0000UTC
Initial conditions: ERA5
Simulation type: “free” forecast
Analysis period: 20180216 2338UTC – 20180217 0616UTC

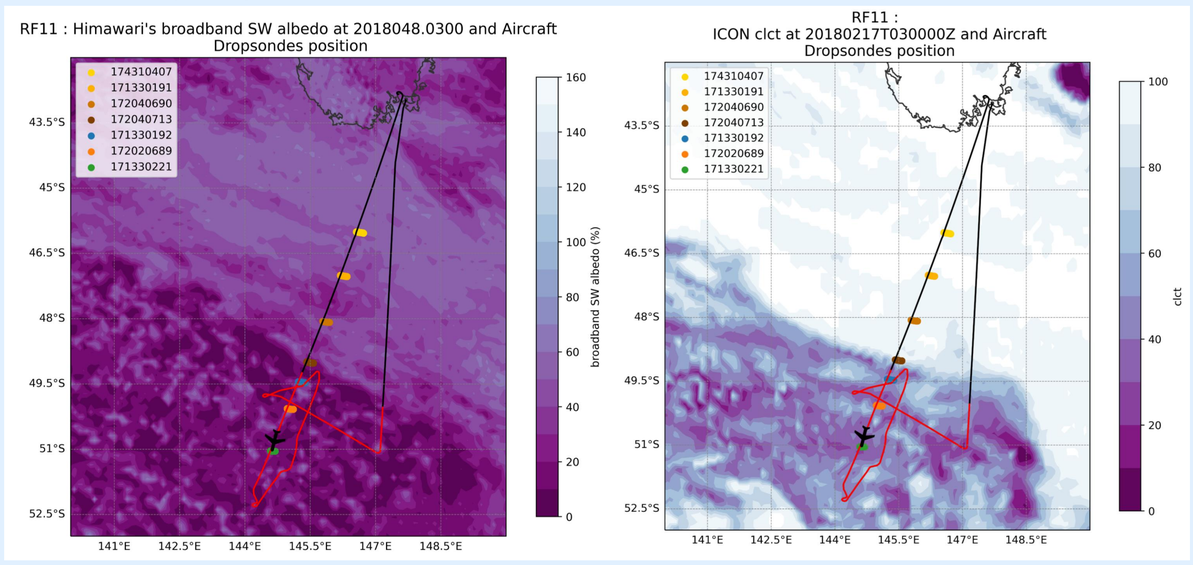


Fig.2: HIMAWARI albedo and ICON total cloud cover at 20180217 0300UTC, aircraft trajectory (black/red line) and dropsonde positions (coloured dots)

→ Good agreement between HIMAWARI and ICON

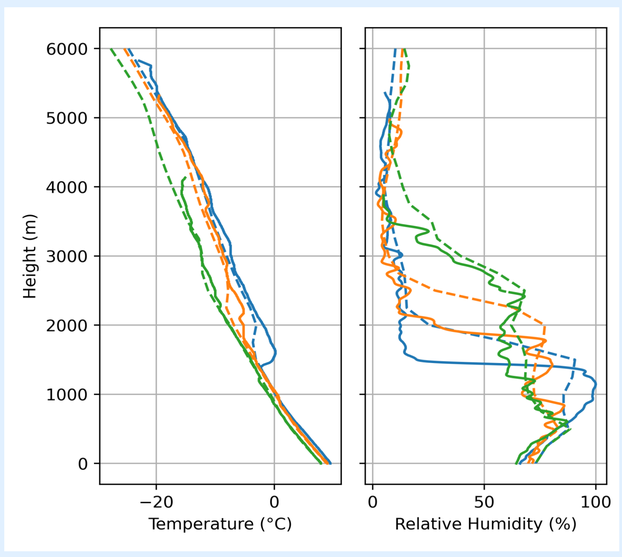


Fig.3: Vertical profiles of temperature and relative humidity for the 3 selected dropsondes located in the cold sector (cumulus area):
observations are in solid line and ICON nearest grid point is in dashed line

→ too deep boundary layer simulated

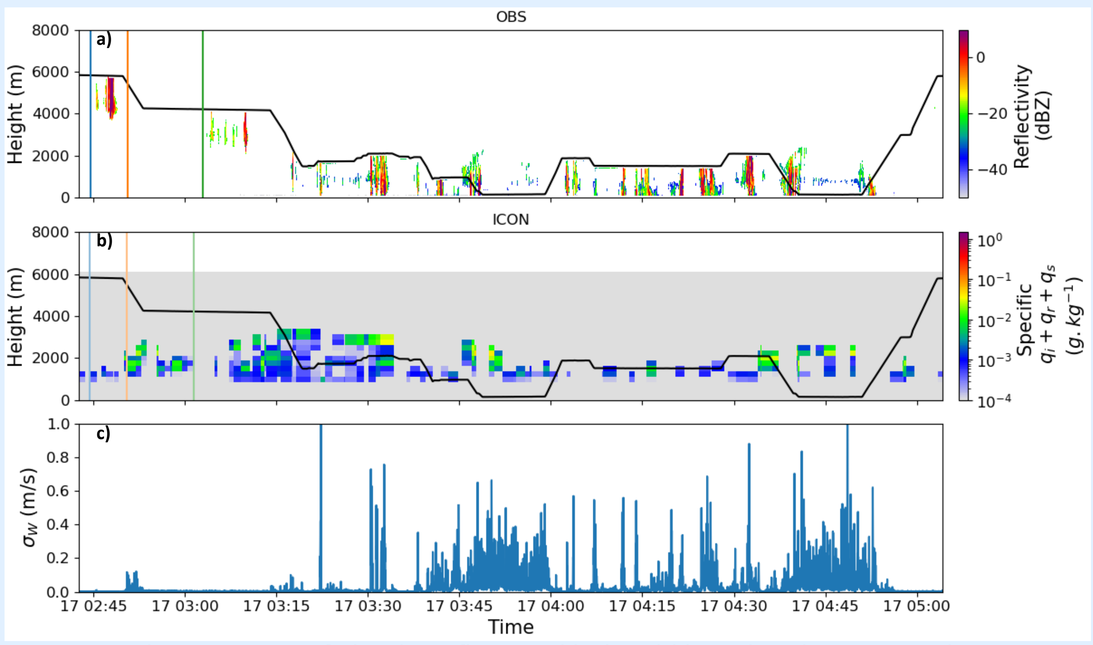


Fig.4: Vertical cross-section of a) radar reflectivity (dBZ) and b) combined ice, rain and snow water content ($g.kg^{-1}$). Aircraft altitude is shown in black. c) Vertical wind variance measured from in-situ probes (Atlas et al. 2020), along flight time in cold sector (red line in Fig.2). Vertical coloured lines in a) and b) correspond to time of dropsondes launching.

References

Atlas, R. L., et al. (2020). How well do large-eddy simulations and global climate models represent observed boundary layer structures and low clouds over the summertime Southern Ocean? Journal of Advances in Modeling Earth Systems, 12, e2020MS002205. https://doi.org/10.1029/2020MS002205

McFarquhar, G. M., et al. (2021): Observations of Clouds, Aerosols, Precipitation, and Surface Radiation over the Southern Ocean: An Overview of CAPRICORN, MARCUS, MICRE, and SOCRATES. Bull. Amer. Meteor. Soc., 102, E894–E928, https://doi.org/10.1175/BAMS-D-20-0132.1.

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Perspectives

- Configure LAM setup
- Test different MBL mixing representations in ICON
- Expand analysis to other SOCRATES flights
- Use of radar simulator (PAMTRA, Mech et al. 2020) to better compare radar observations and ICON
- Expand analysis to MARCUS

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