ICAR simulations should **cover the troposphere** and **apply** a **zero value boundary condition** at the model top.

An evaluation of linear theory based downscaling with ICAR in complex topography

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INTRO

The Intermediate Complexity Atmospheric Research (ICAR) model is a simplified 3D atmospheric model (linear mountain-wave theory) that advects atmospheric quantities (e.g. moisture) and runs microphysics (e.g. Thompson MP).

- Why ICAR?

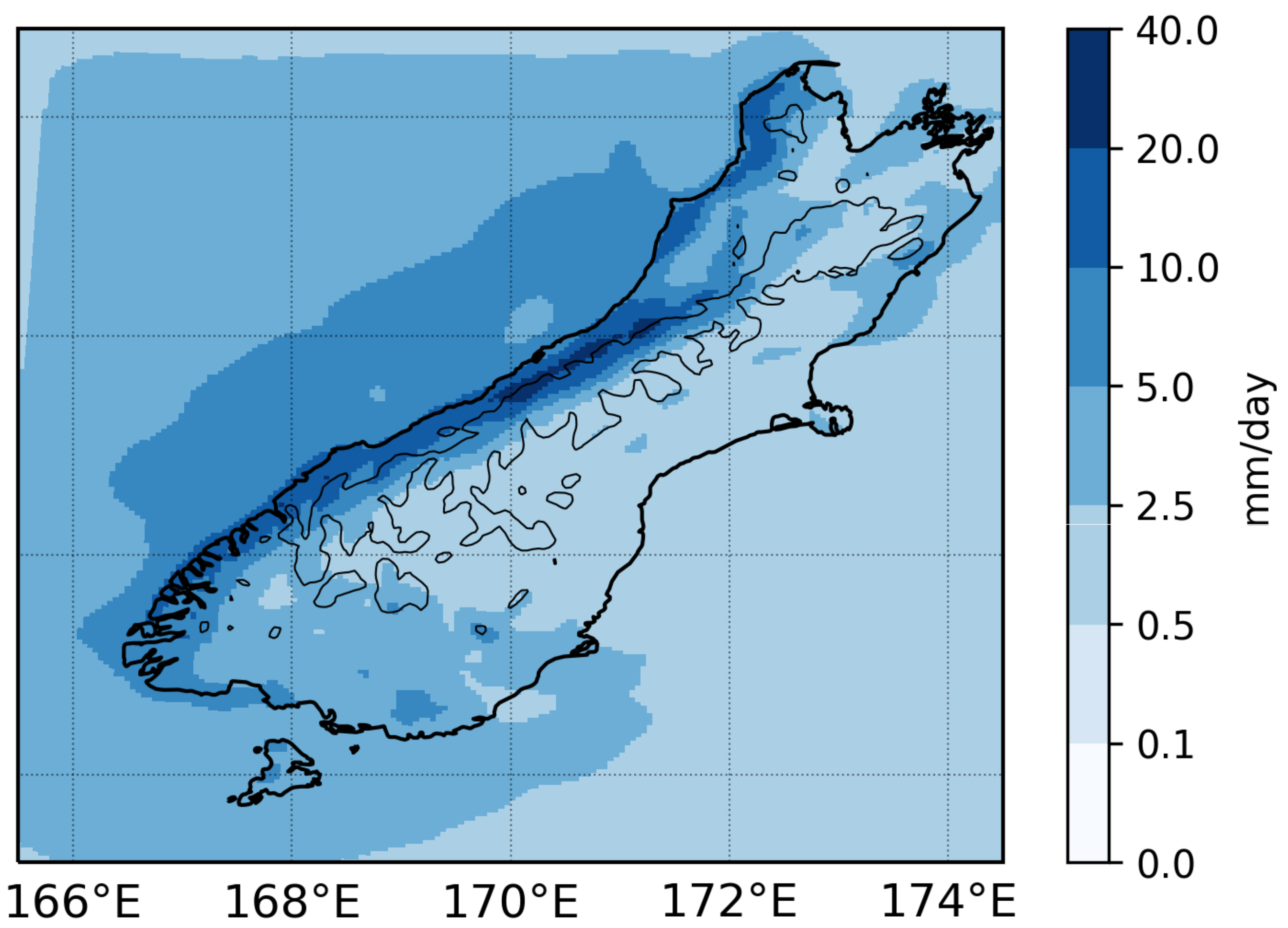

Figure 1. Mean daily precipitation on the South Island of New Zealand as simulated with ICAR. Thin contour line: 1000m MSL. Detailed evaluation in Horak et al. 2019

- physics based (see Fig. 1 and Horak et al. 2019)
- computationally cheaper than dynamic. downscaling: ≈ factor 100 faster than WRF.
- does not rely on measurements.
- However: preliminary studies revealed potentially unrealistic hydrometeor distributions in the topmost vertical layers → investigate!

METHODS

1) idealized simulations with ICAR at different model top settings and a WRF control run (right column).
2) Mean squared errors between WRF and ICAR (MSE) calculated for each quantity.
3) Reduction of error (RE) quantifies improvements.

RESULTS

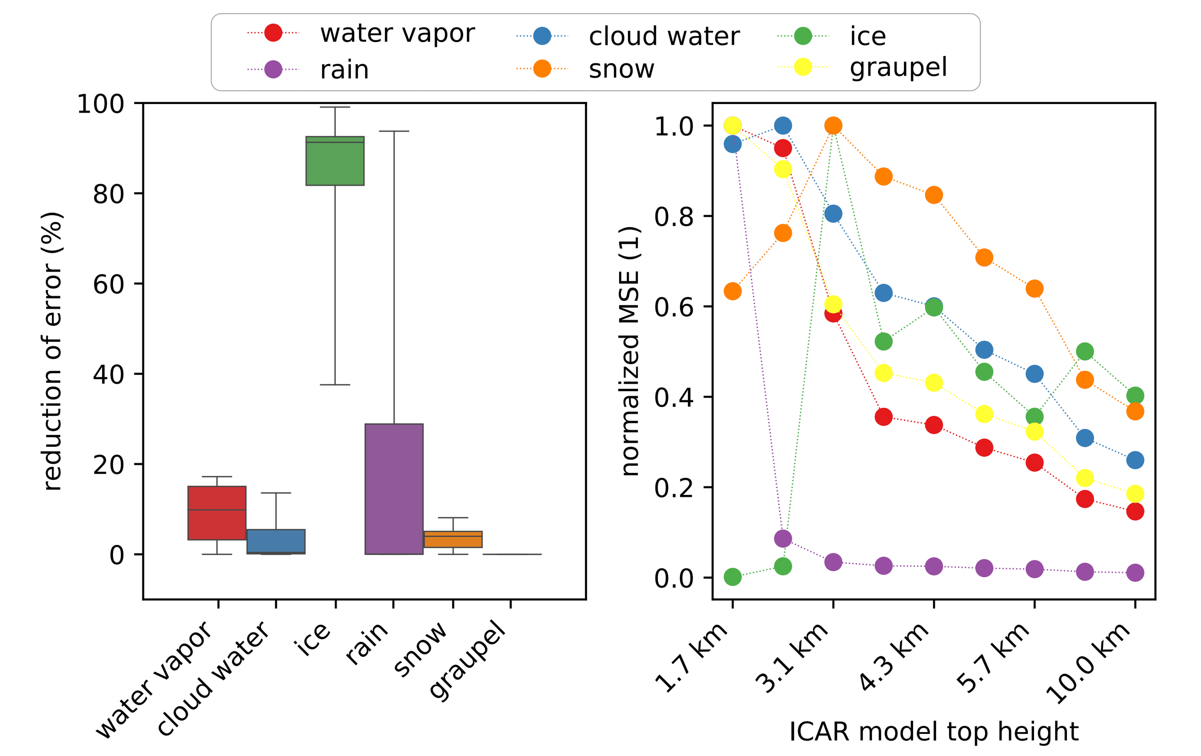

Figure 2. Left: Reduction of error by employing a zero value boundary condition compared to a zero gradient boundary condition for model tops ≤ 5.7 km. Right: MSE decrease with model top height.

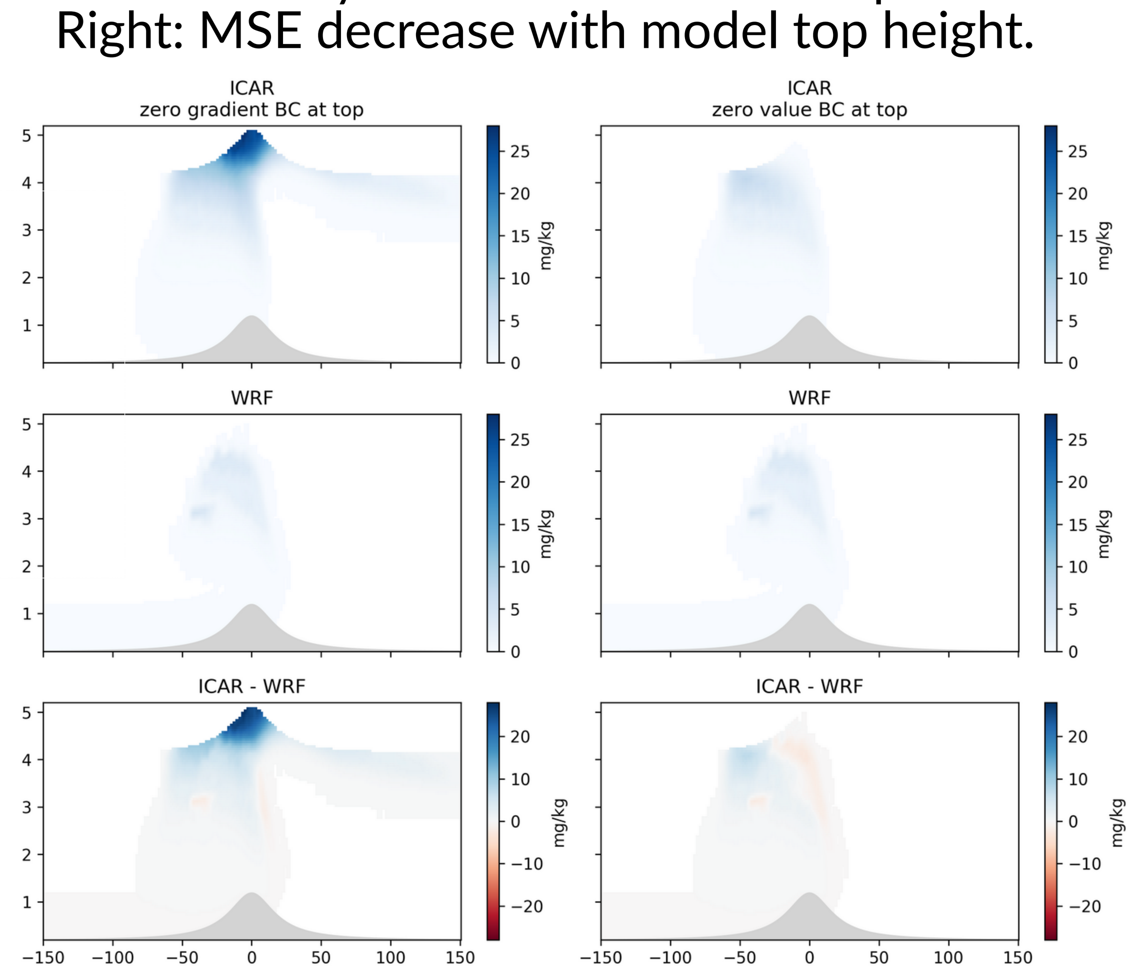

Figure 3. Ice distribution in ICAR with different boundary conditions at the model top (top row), WRF control run (middle row) and the differences btw. ICAR and WRF (bottom row).

DISCUSSION

- A zero value boundary condition (ZVBC) improves the realism of most hydrometeor fields (Fig. 2, left), but particularly for ice (Fig. 3). This is the case for model tops up to 10 km but especially for those below 5.7 km.
- Applying a ZVBC at the top boundary and covering the troposphere with the model domain (Fig. 2, right) is advised.

Reduction of Error

$$RE = 1 - \frac{MSE}{MSE_R}$$

with the MSE of a modified version of ICAR and MSE_R as the MSE of the unmodified ICAR version, each with respect to a WRF control run.

Idealized Simulation Setup:

U = 20 m/s, N = 0.01 s^{-1}, $\Theta(z=0)$ = 270 K, RH = 100 % and P(z=0) = 1013 hPa resulting in mountain-waves (Fig. 4)

ICAR microphysics, P and Θ fields were initialized with the values of these fields from WRF at t = 6h.

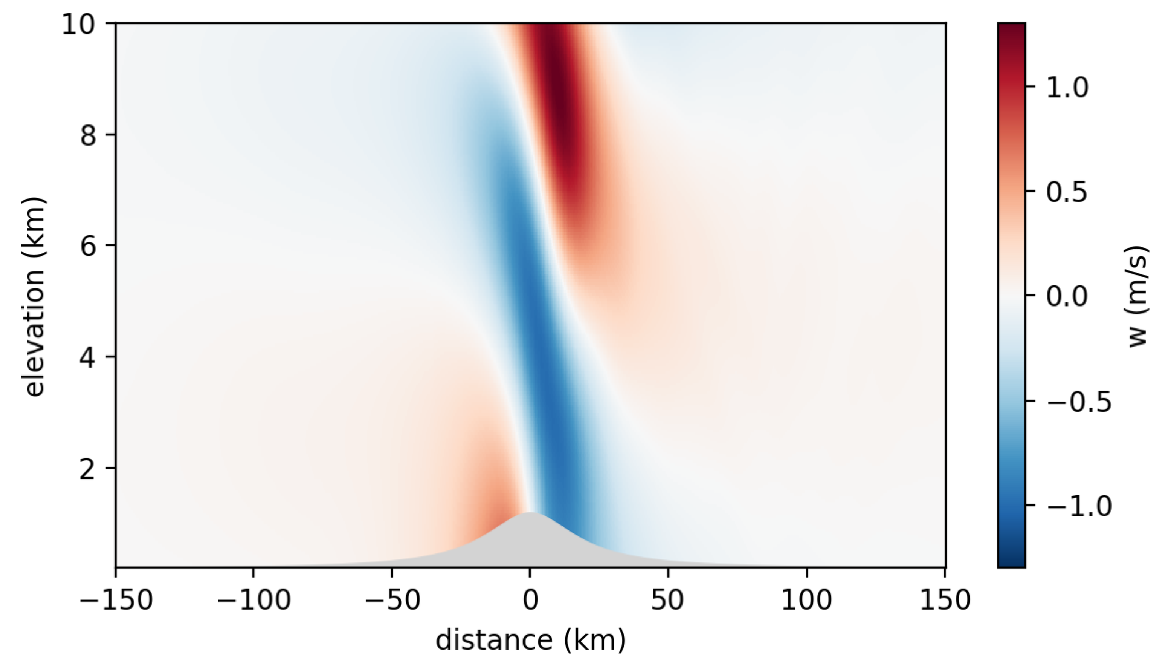

Figure 4. Up- and downdrafts induced by flow over the topography (Queney solution).

Reference

Horak et al., *Assessing the added value of the Intermediate Complexity Atmospheric Research (ICAR) model for precipitation in complex topography*, Hydrol. Earth Syst. Sci., 23, 2715–2734, https://doi.org/10.5194/hess-23-2715-2019, 2019

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