Simplified physics-based precipitation downscaling for glacierized mountain regions

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The Goals

- To obtain **physics based** and **computationally cheap** high-resolution **precipitation fields** e.g. as input for process-based glacier mass balance models.
- To evaluate the added value of the precipitation fields with data from weather stations located in complex topography over the ERA-Interim reanalysis (ERAI) forcing dataset.

Introduction

Studying the local impact of a changing global climate requires detailed information about the state of the atmosphere. Due to the coarse spatio-temporal grid spacing of global circulation models, climate downscaling is a neccessity.

dynamic downscaling
+ physics-based
− high computational cost

statistical downscaling
+ computationally cheap
− measurements required

intermediate complexity downscaling
+ physics-based
+ computationally cheap (compared to, e.g. WRF)
− disadvantages depend on the method

Methods

Model - The Intermediate Complexity Atmospheric Research Model (ICAR, Gutmann 2016) is based on linear mountain-wave theory, employs Thompson microphysics, numerically advects atmospheric quantities within its wind field (**physics based**) and, in principle, does not rely on measurements. ICAR calculates the wind field within the domain from analytical equations (**computationally efficient**). The model was forced with ERAI and daily accumulated precipitation fields were downscaled to a 4x4 km² spatial grid (Horak 2018).

Domain - The Southern Alps are an alpine range that extends along most of the length of the South Island of New Zealand. They contain the large majority of glaciers of New Zealand. Predominant westerlies and northwesterlies advect moist air from the surrounding ocean towards the alpine ridge and produce a strongly orographically influenced precipitation regime, thus making the South Island of New Zealand an ideal testbed for ICAR.

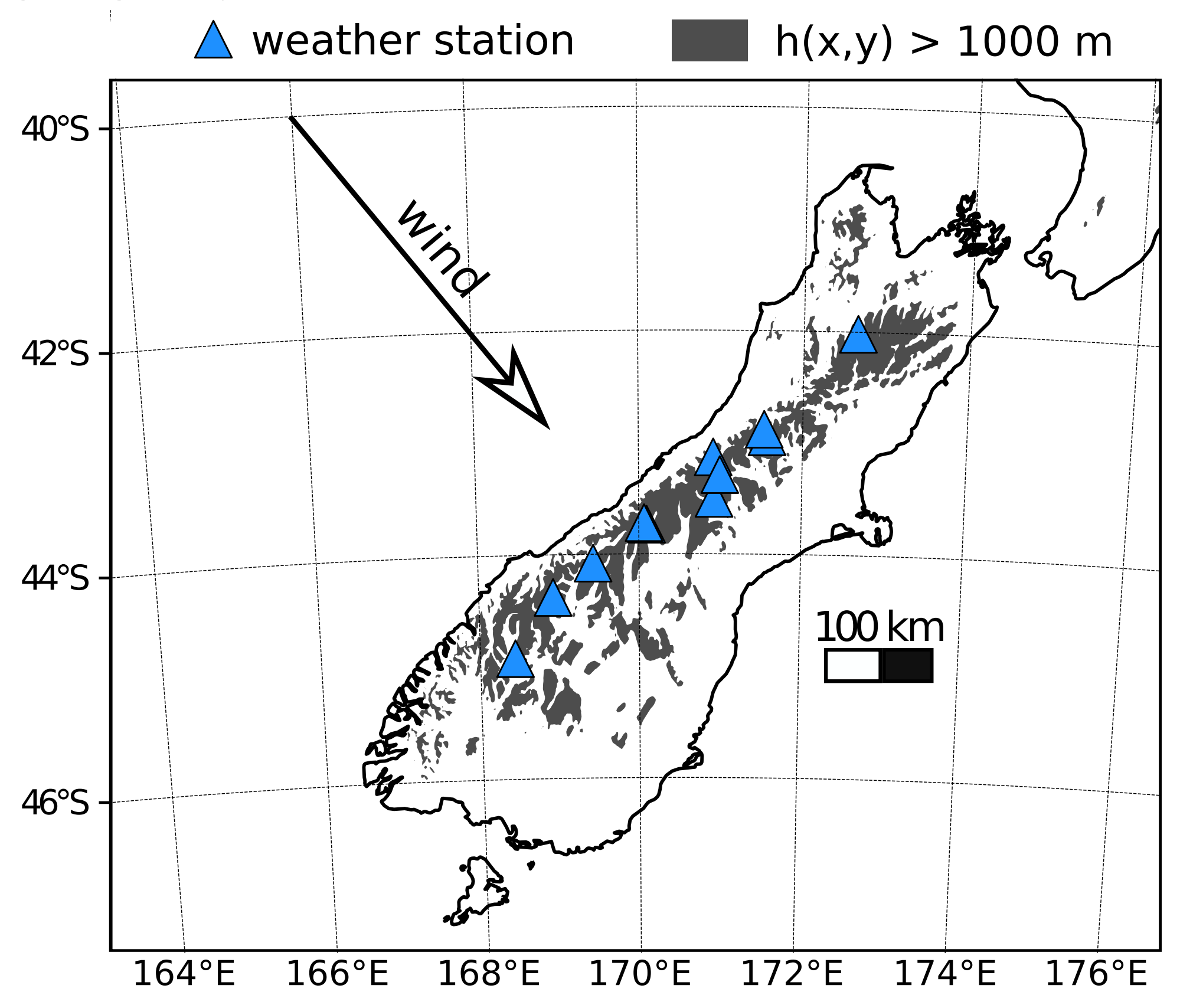

Figure 1 - The South Island of New Zealand.

References

Gutmann, Ethan, et al. "The intermediate complexity atmospheric research model (ICAR)." Journal of Hydrometeorology 17.3 (2016): 957-973.

Horak, Johannes, et al. "Assessing the Added Value of the Intermediate Complexity Atmospheric Research Model (ICAR) for Precipitation in Complex Topography."

Results

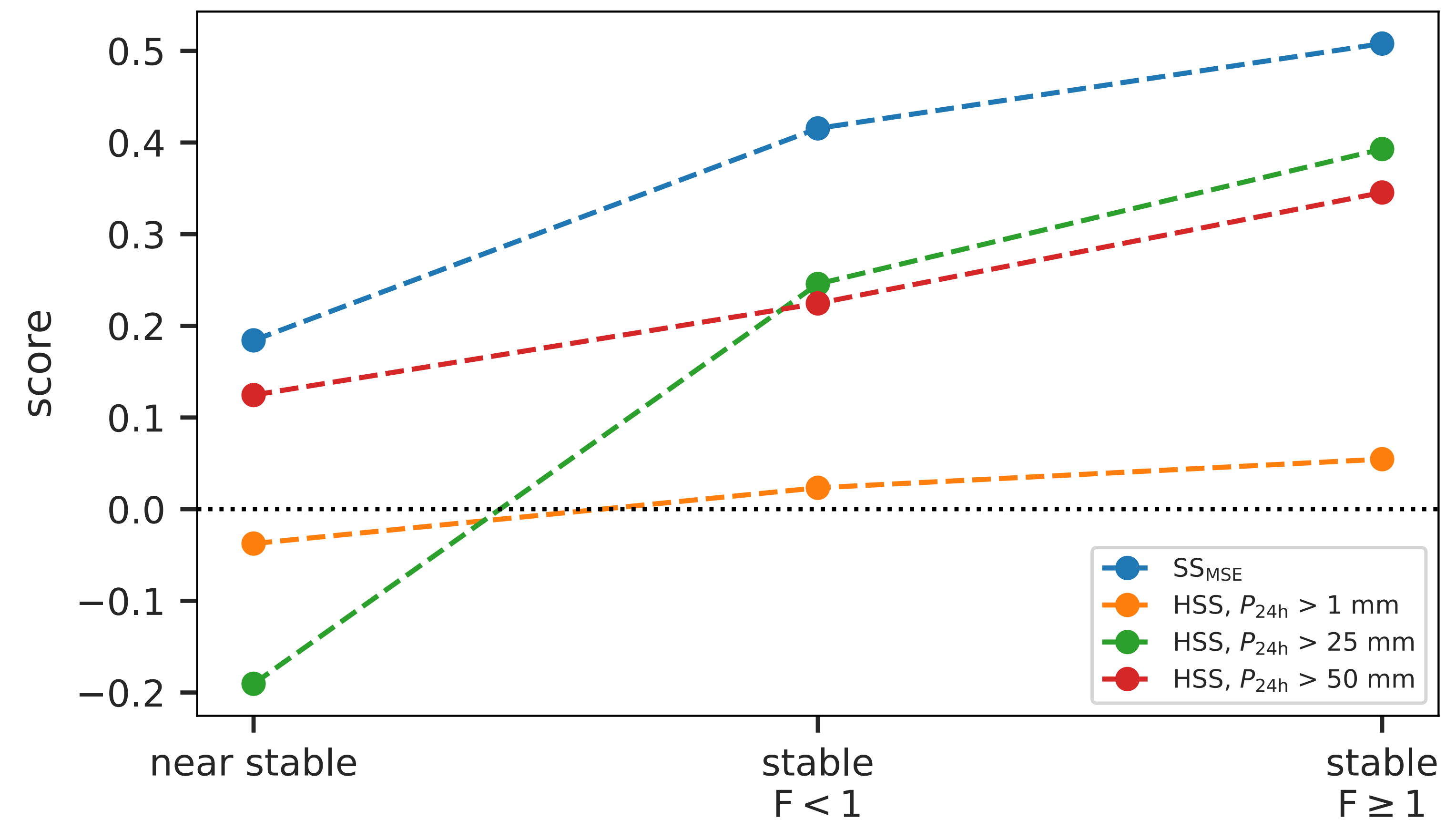

Figure 2 - Model performance increases with higher flow linearity and atmospheric stability. Model performance was quantified with standard skill scores in dependence of flow linearity characterized by the inverse, non-dimensional mountain height F.

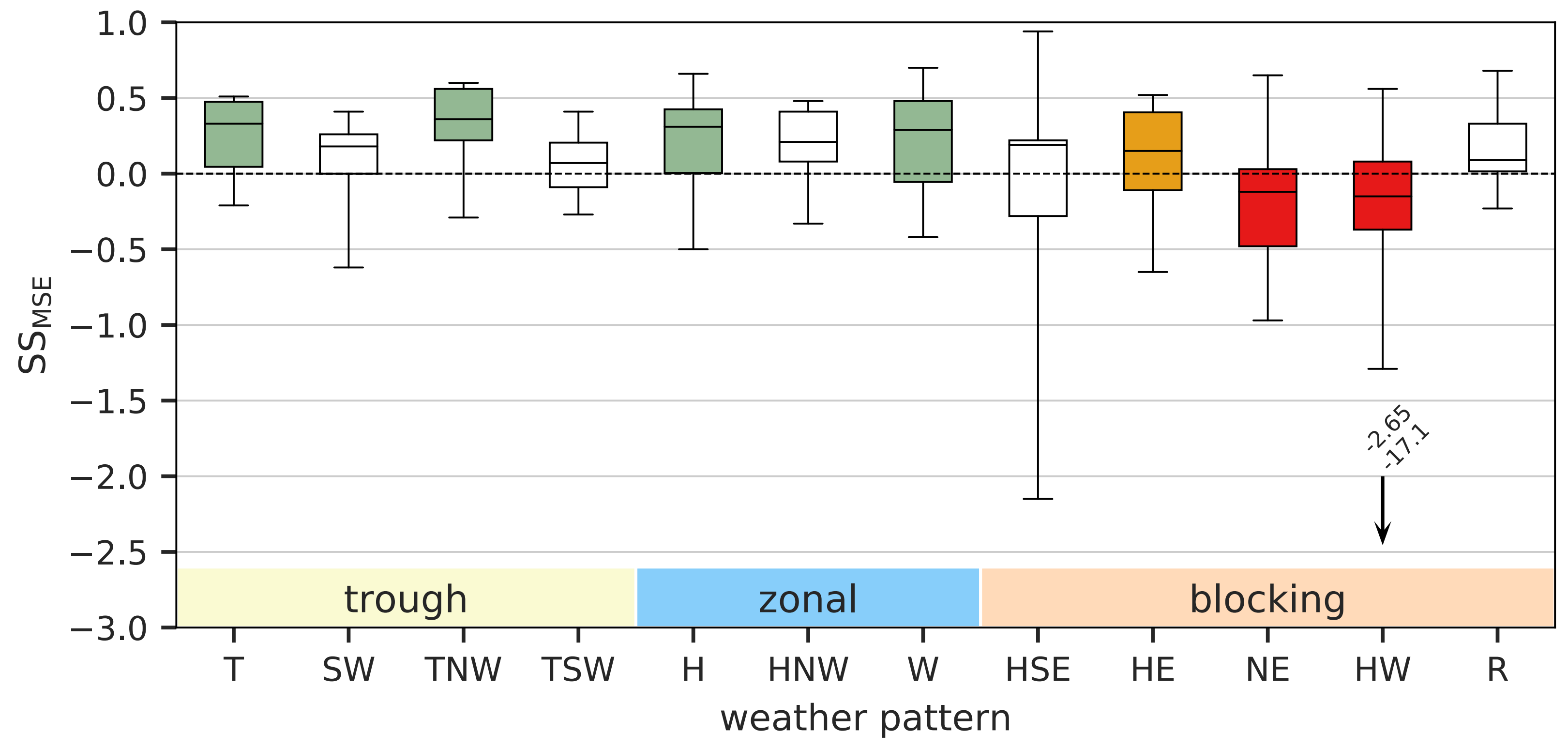

Figure 3 - ICAR performance in dependence of synoptic weather pattern. Patterns with cross-alpine flow yield the highest scores (green shaded boxes), those with parallel flow the lowest (red shaded boxes).

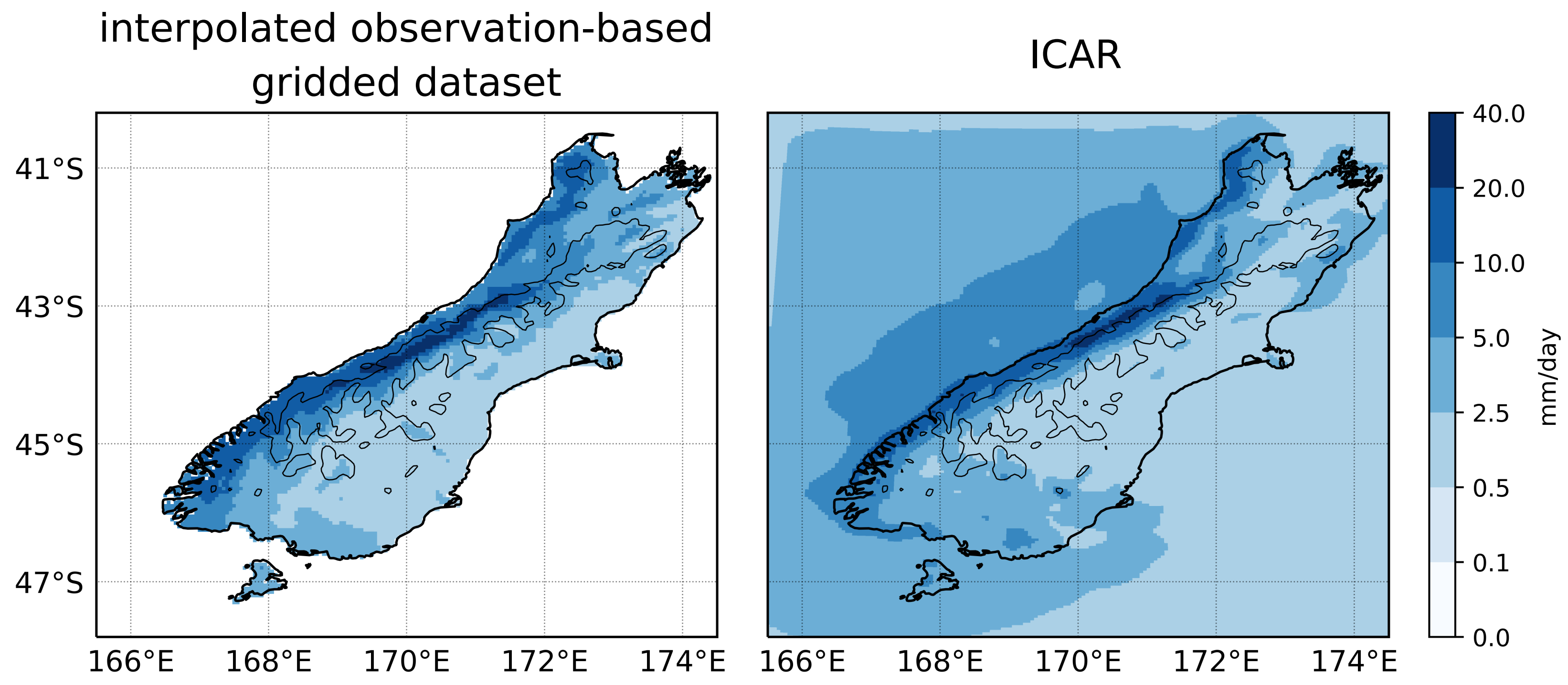

Figure 4 - Average 24h precipitation from 2007-2016. left: dataset based on measurements and expert judgement, right: ICAR.

Conclusions

- ICAR performs best during
  - stable atmospheric conditions
  - flow of high linearity
  - cross-alpine flow
- worst during
  - near stable conditions
  - flow parallel to alpine range
- ICAR shows potential but underestimates precipitation
- precipitation patterns and seasonality well reproduced
- BUT: choice of model top critical factor(!) ⇒ more research

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