



Supplement of

Brief communication: Reanalyses underperform in cold regions, raising concerns for climate services and research

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S1. Terrain Ruggedness

The terrain roughness is derived largely following Gruber (2012).

$$rug = \frac{E_{std}}{\sqrt{A}} \quad (S1)$$

where E_{std} (m) and A (km^{-2}) is the elevation standard and area for a analysis grid of 0.25° . The elevation is from GTOPO30 with a spatial resolution of 30 arc-second or ~ 1 km.

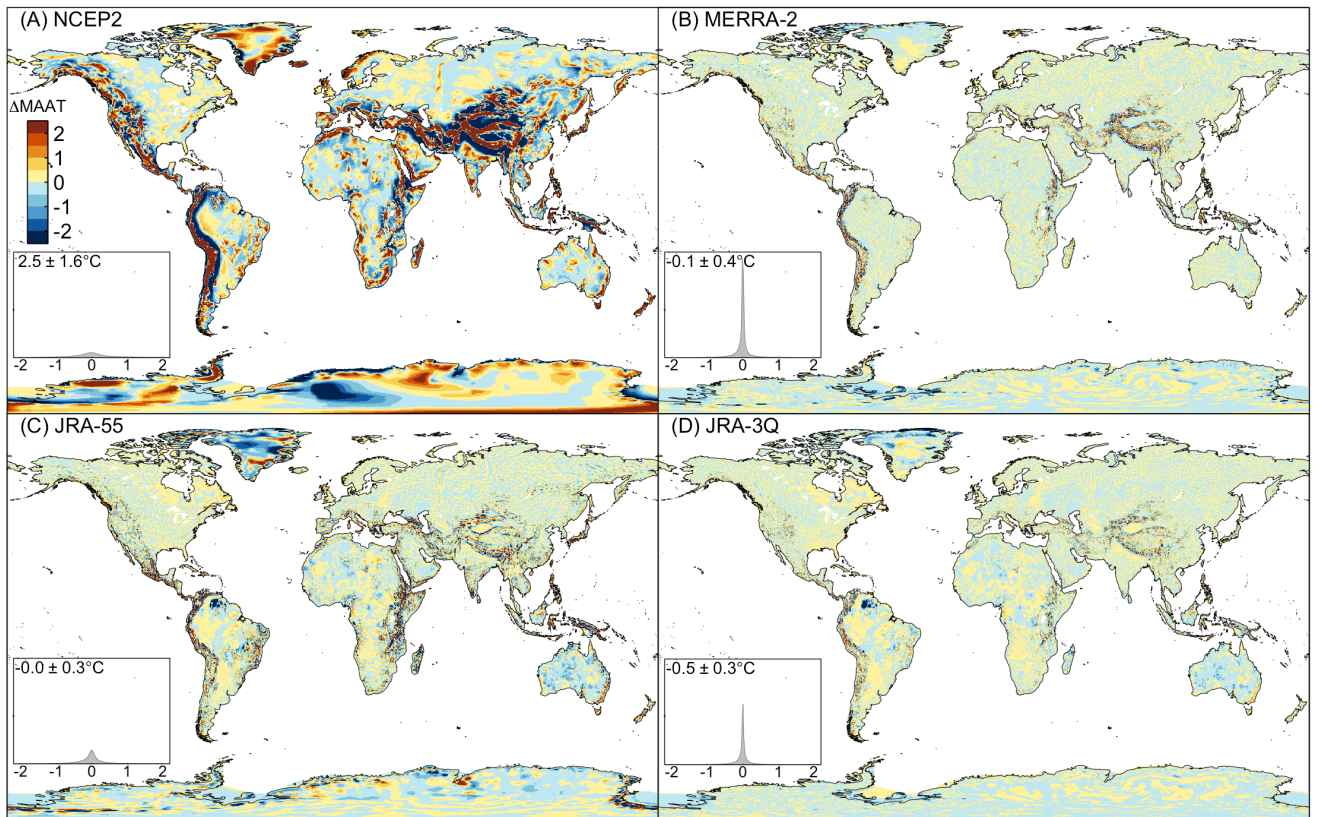


Figure S1. The MAAT difference between 3D downscaling considering variable lapse rate (see Methods) and 2D linear interpolation. As an example, the MAAT in 2000 is shown. Insets show the distribution of differences with mean and standard deviation.

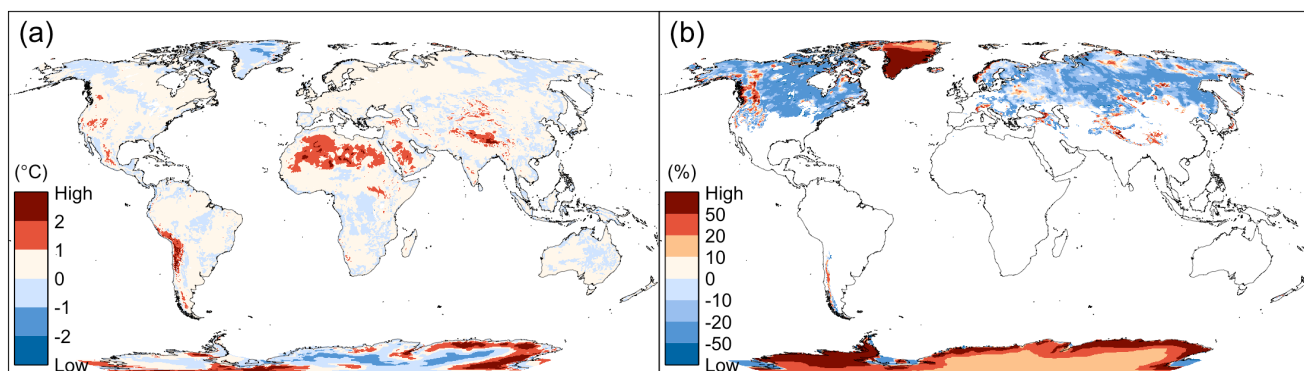


Figure S2. The difference between all five reanalyses and three 4DVar reanalyses for (a) mean annual air temperature (b) and snow water equivalent (SWE).

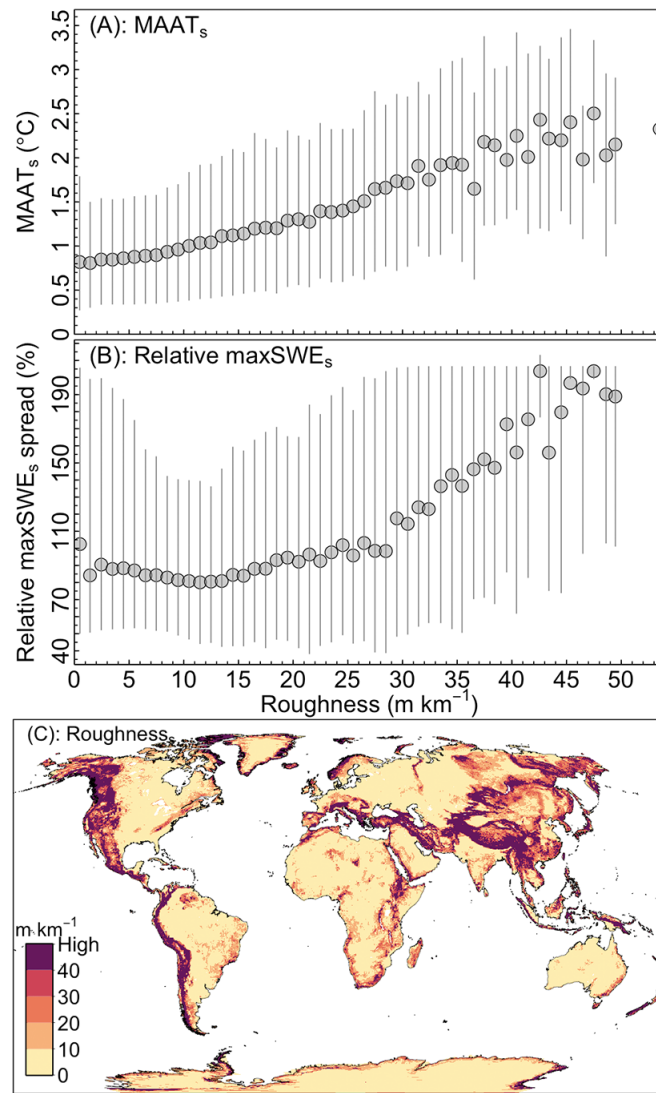


Figure S3. The changes of ensemble spread for (A) mean annual air temperature (MAAT) and (B) relative maximum snow water equivalent (maxSWE) as a function of (C) terrain ruggedness. The points represent the mean spread and lines indicate 10th to 90th percentile.

Table S1. The five state-of-the-art reanalyses used in this study.

Reanalysis	Resolution	Assimilation	References
JRA-3Q	0.375	4DVAR	Kosaka et al., (2024)
ERA5	0.25	4DVAR	Hersbach et al., (2020)
ERA5-ENS ^a	0.50	4DVAR	Hersbach et al., (2020)
MERRA-2	0.5×0.625	3DVAR	Gelaro et al., (2017)
JRA-55	0.5625	4DVAR	Kobayashi et al., (2015)
NCEP2	2.5	3DVAR	Kanamitsu et al., (2002)

^a ERA5-ENS refers to the 10-member ensemble of ERA5.

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