A temporally and spatially varying environmental lapse-rate for temperature downscaling

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Motivation

Temperature near the surface varies with altitude accordingly to the environmental lapse-rate (ELR). The ELR depends on the overlying air masses, large-scale situation and local effects. In this study we propose the derivation of the ELR from the reanalysis lower troposphere vertical profiles of temperature. This creates a temporally and spatially varying ELR, that can be used to downscale near-surface air temperature from the reanalysis resolution to higher resolutions.

Methods

The ELR estimates based on ERA5 are compared with observationally based ELR over the U.S using the GHCN daily temperature data for the 2009-2014 period (see fig.1). The method is used to downscale ERA5 directly to the stations elevation and to perform global 9 km land only simulations (see table 1). In addition to GHCN, observations of snow depth and soil temperature from the SCAN network are used for the evaluation. Three temperature adjustments are tested: (i) daily maps of ELR, (ii) a monthly climatology and (iii) a globally constant ELR of -6.5 K km^{-1}.

Table 1.

Acronym	Details
E5	ERA5 reanalysis (35 km)
CLR	Direct downscaling to station elevation using a constant ELR of -6.5 K km^{-1}
MLR	Direct downscaling to station elevation using a climatological ELR
DLR	Direct downscaling to station elevation using a daily ELR
bil5	Surface only at 9 km driven by E5 with bilinear interpolation
clr5	As bil5 but with a constant ELR of -6.5 K km^{-1} temperature adjustment
ml5	As bil5 but with a climatological ELR temperature adjustment
dlr5	As bil5 but with a daily ELR temperature adjustment
E5L	Surface only at E5 resolution
EI	ERA-Interim reanalysis (75 km)
EIL	Surface only at EI resolution driven by EI forcing

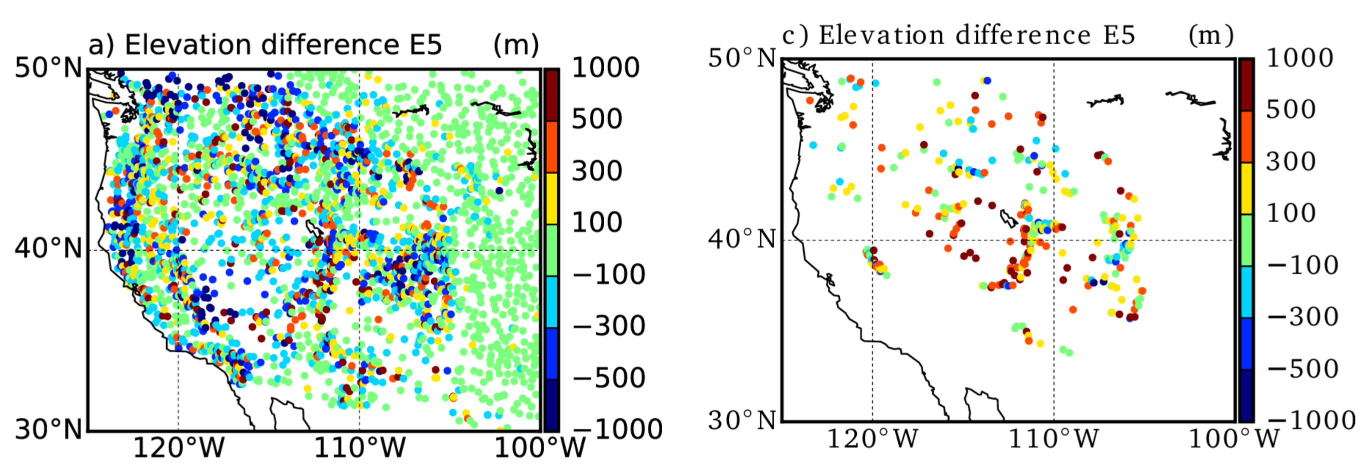


Fig. 1. GHCN (left) and SCAN (right) stations

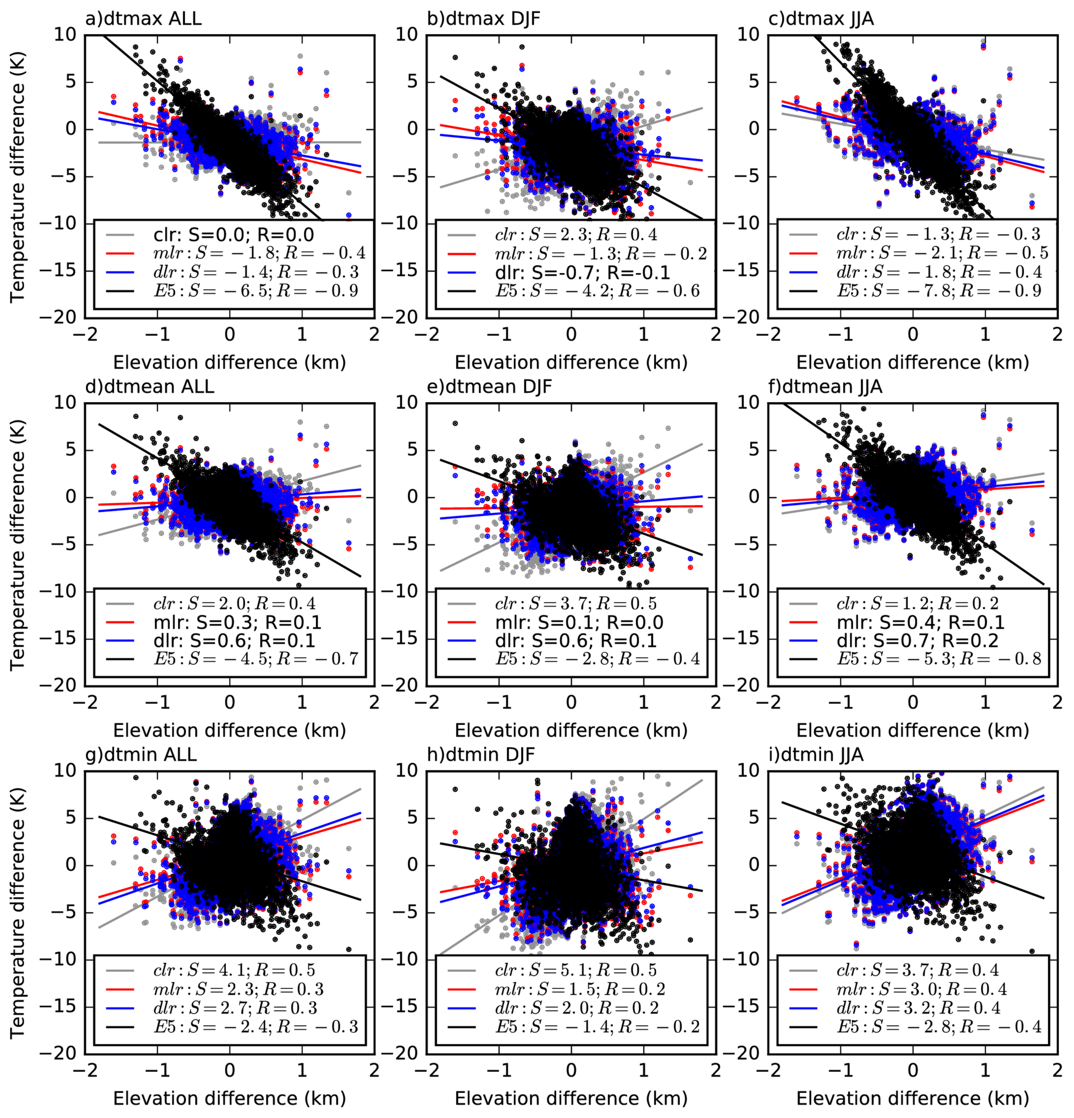


Fig. 2. Temperature differences between E5 and observations as a function of the station elevation differences for daily maximum (top), mean (middle) and minimum (bottom) temperatures.

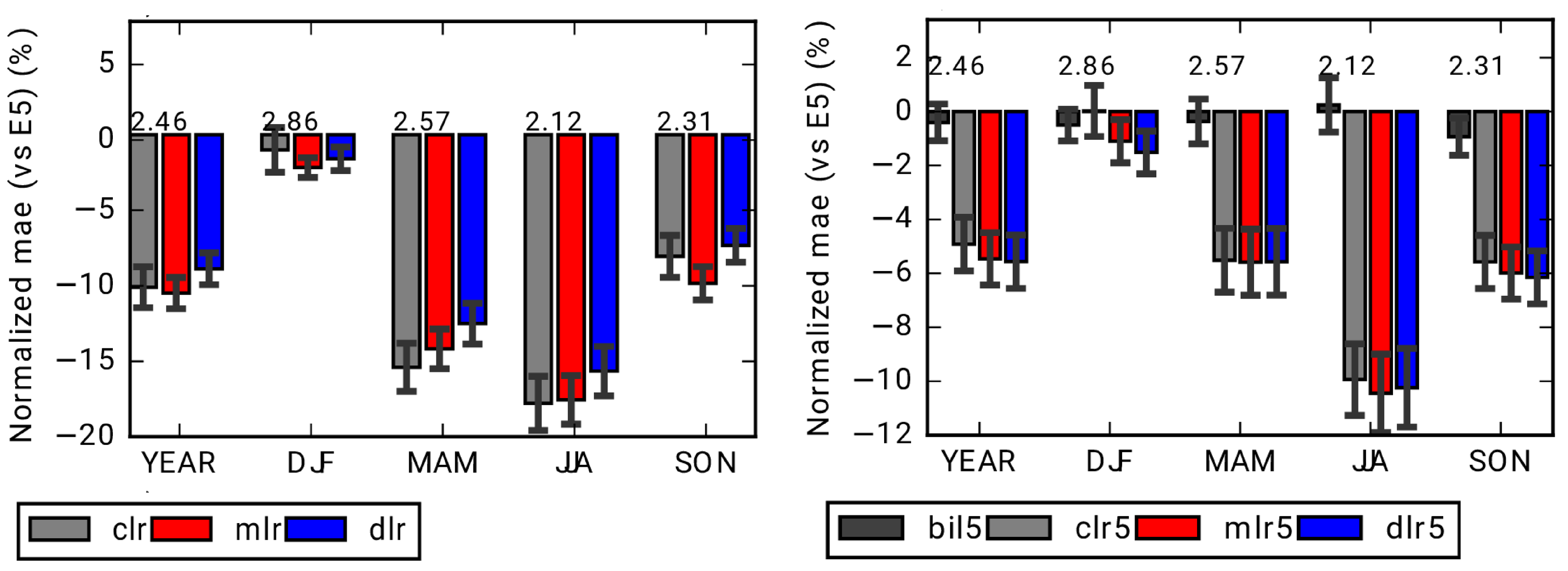


Fig. 3. Normalized mean absolute error difference in respect to E5 of daily mean temperature with direct downscaling to station elevation (left) and surface only 9 km simulations (right)

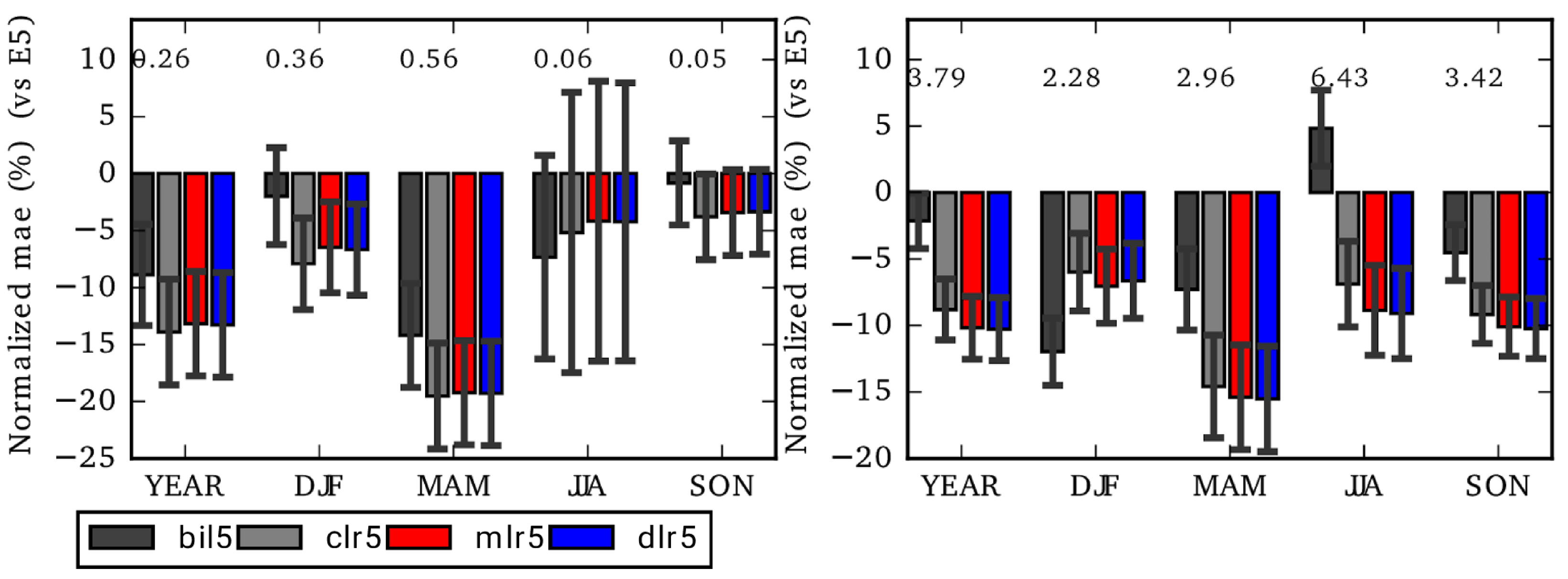
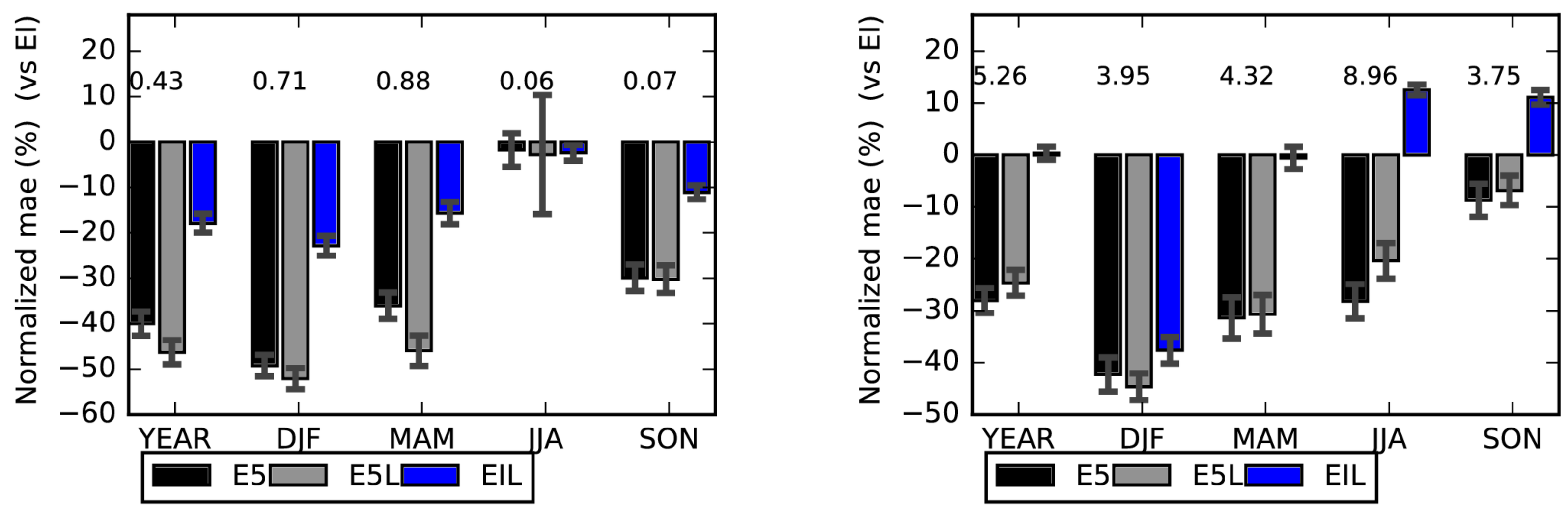


Fig. 4. Normalized mean absolute error difference in respect to E5 of snow depth (left) and soil temperature (right).



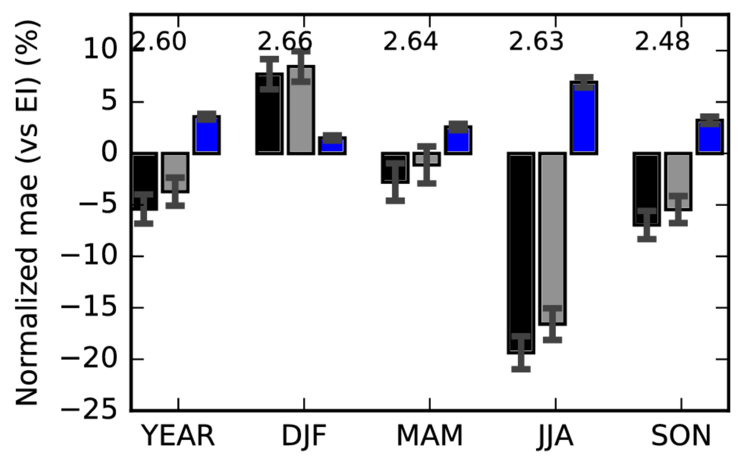


Fig. 5. Normalized mean absolute error difference in respect to EI of snow depth (top left), soil temperature (top right) and daily mean temperature (bottom).

Final Remarks

- ELR derived from observations has a clear annual cycle (fig.2) which is reasonably captured by the E5 derived ELR from vertical profiles;
- Direct downscaling of temperature to station elevation reduces mean errors by about 10% (fig.3). Surface only simulations at 9 km with temperature adjustments reduce the errors by 5%;
- The added value of the climatological or daily ELR is small when compared with a constant ELR (fig. 3) – elevation/ELR plays a secondary role on the error structure;
- Added value of temperature adjustment is clear on snow depth and soil temperature – clear benefit of downscaling E5 (fig-4);
- Snow and soil temperature much better in E5 when compared with EI, but similar errors in 2-meters temperature (fig. 5);

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