Land surface downscaling using a spatially and temporally varying lapse rate.

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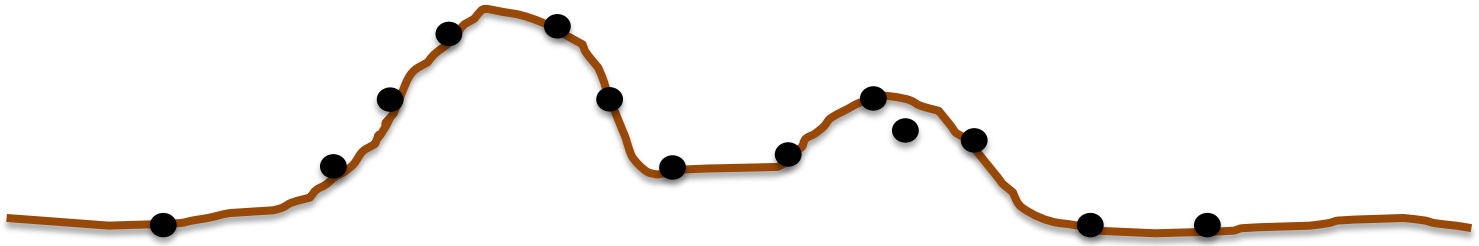
Overview

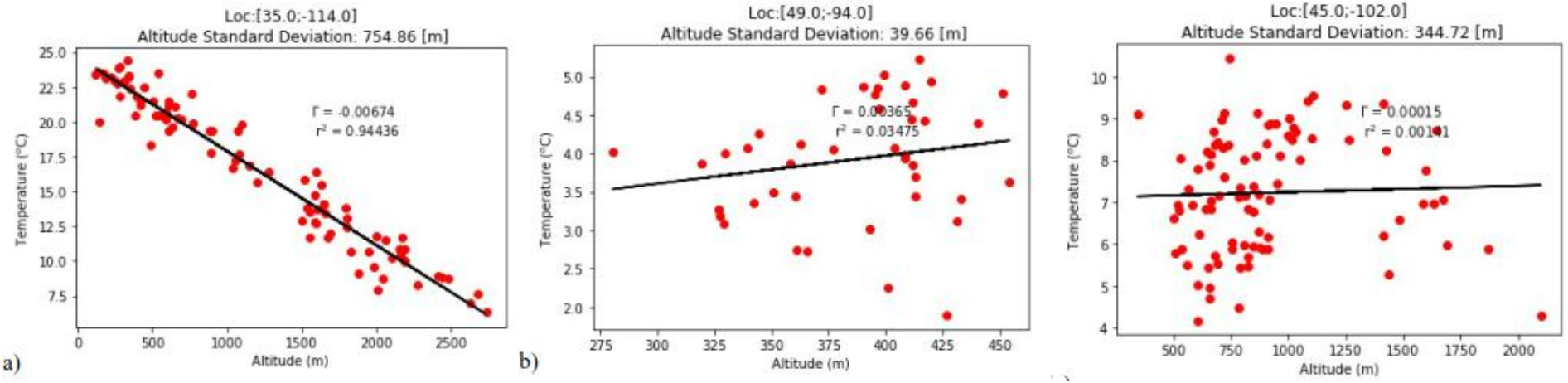
- Environmental lapse-rate (ELR):
  - Is it constant? Spatially & temporally ?
  - Estimating the ELR from reanalysis vertical profiles;
  - Observational evidence;
- Direct downscaling of ERA5 temperature to stations;
- Land surface downscaling:
  - What's the added value of correcting temperature?
  - Constant vs temporal & spatially varying ELR;
  - Impact on snow and soil temperature;
- Comparing ERA-Interim, ERA-Interim/land, ERA5, ERA5-Land
- Spatial representativity of point observations;
- Final remarks

Environmental lapse rate (ELR)

ELR is the defined as the rate of temperature change with height : $\Gamma = \frac{DT}{DZ}$

Can be estimated from observations as: $T_i = \Gamma_O \times Z_i + T_0$

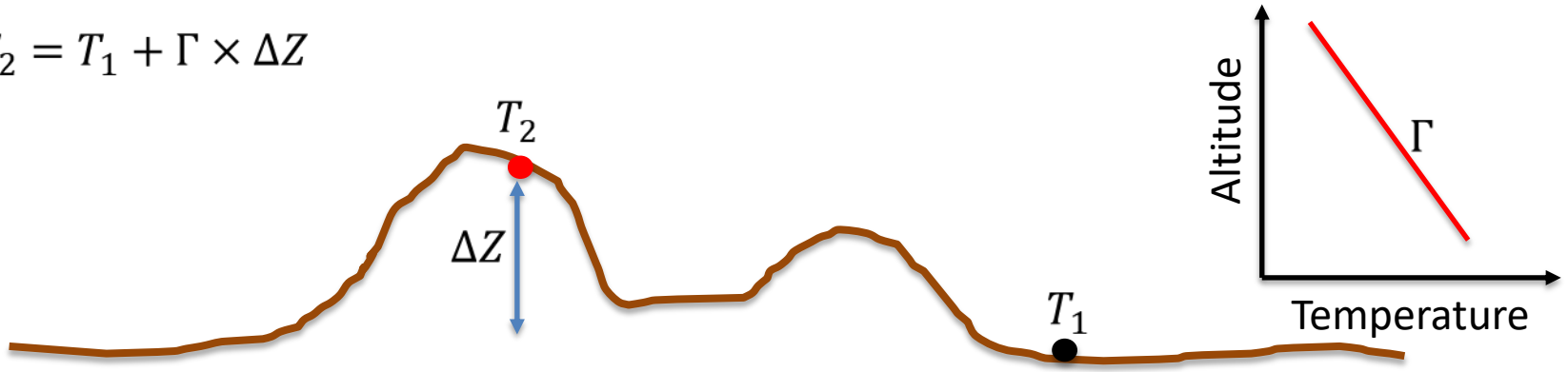




ELR: Estimated from reanalysis vertical profiles

Can we estimate the ELR from the lower troposphere vertical profiles?

$$T_2 = T_1 + \Gamma \times \Delta Z$$



$$\Gamma = \frac{DT}{DZ}$$

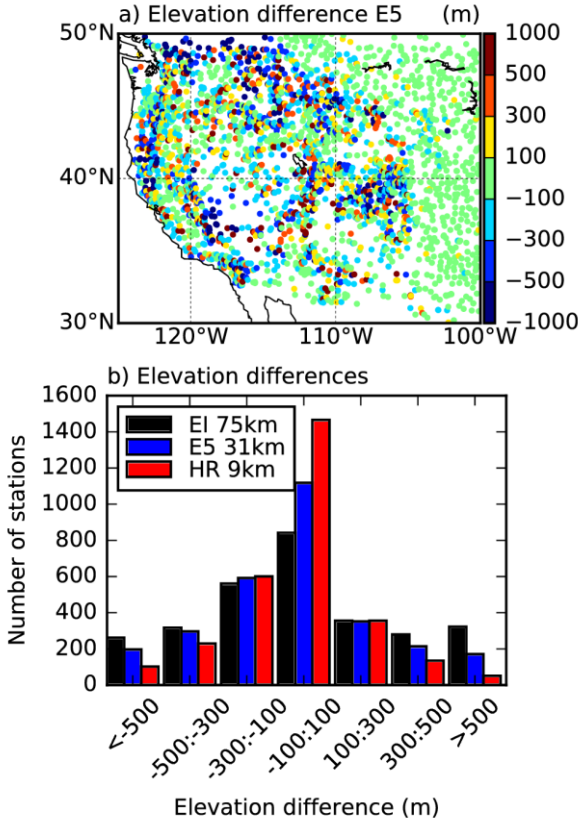
Between ERA5 16 combinations of model levels centered between: model level 124 (**500** m above the surface) and model level 116 (**1200** meters above the surface).

Simulations overview

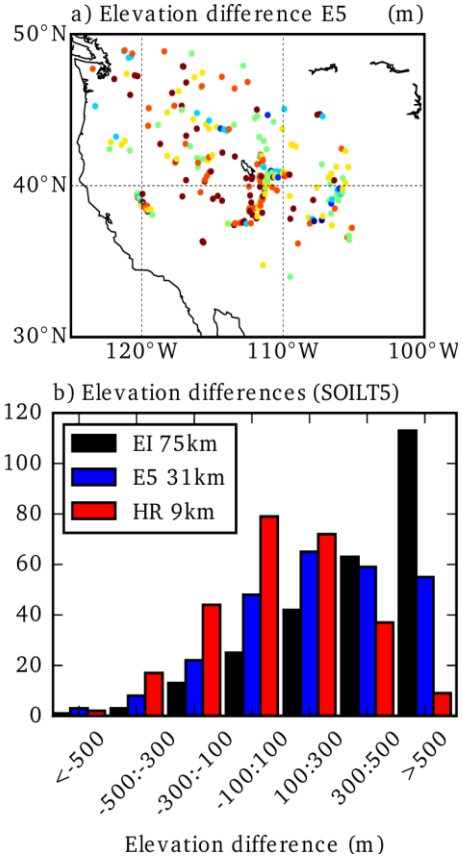
Simulation	Forcing downscaling	Resolution
bil5	ERA5 Bilinear interpolation for all variables	9 km
clr5	As bil5 but adjusting temperature, humidity and pressure using a constant ELR of -6.5 K km^{-1}	9 km
mlr5	As clr5 but using a mean monthly climatology of ELR maps.	9 km
dlr5	As clr5 but using daily ELR maps.	9 km
E5L	ERA5	31 km
EIL	ERAI	75 km

June 2009 to May 2014 (5 year)
Observations: GHCN 2-meters daily min (dtmin), max (dtmax) mean (dtmean)
Observations: SNOTEL: daily snow depth & soil temperature

Observations



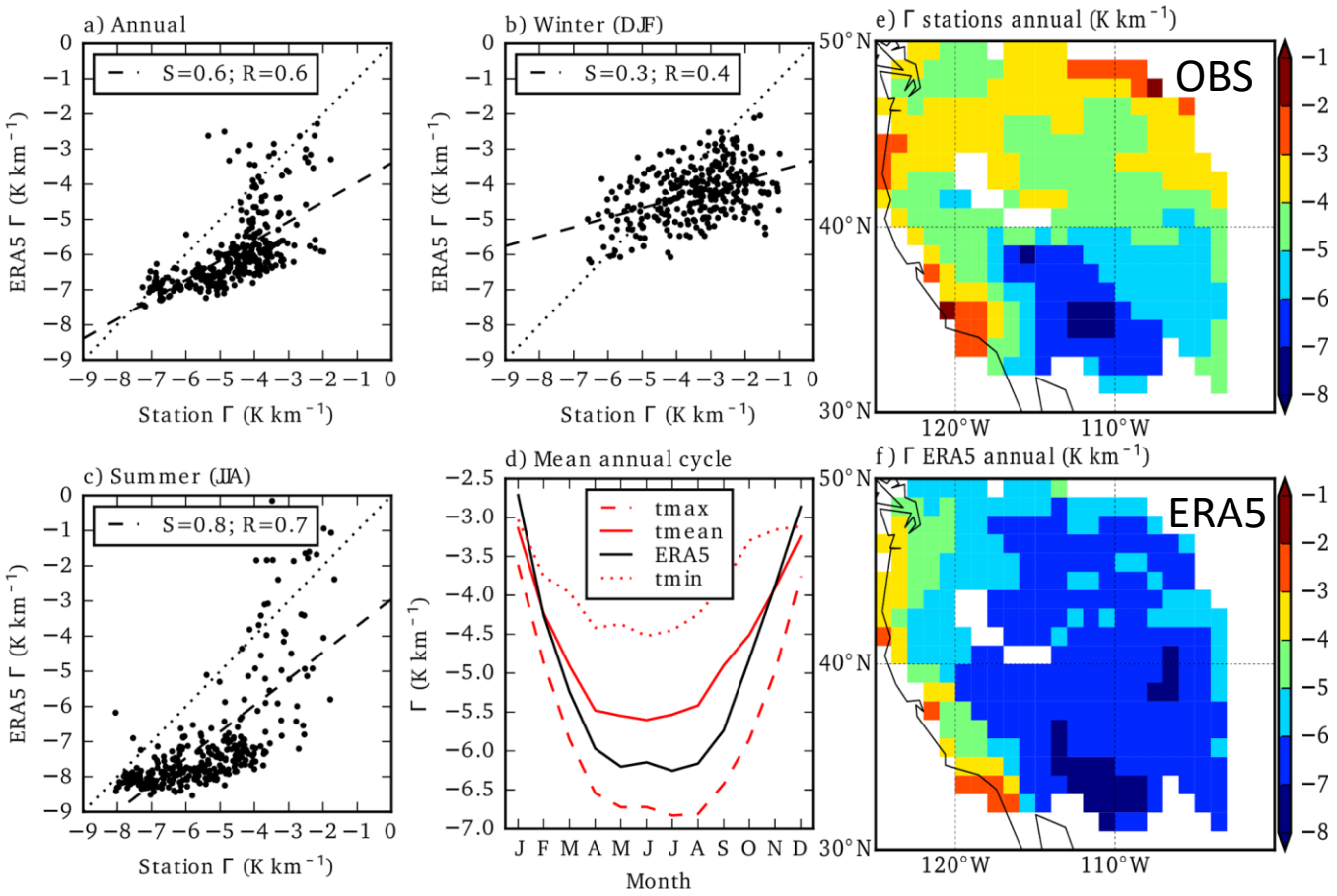
GHCN
Temperature
2941 stations



SNOWTEL
313 snow depth
260 Soil temperature

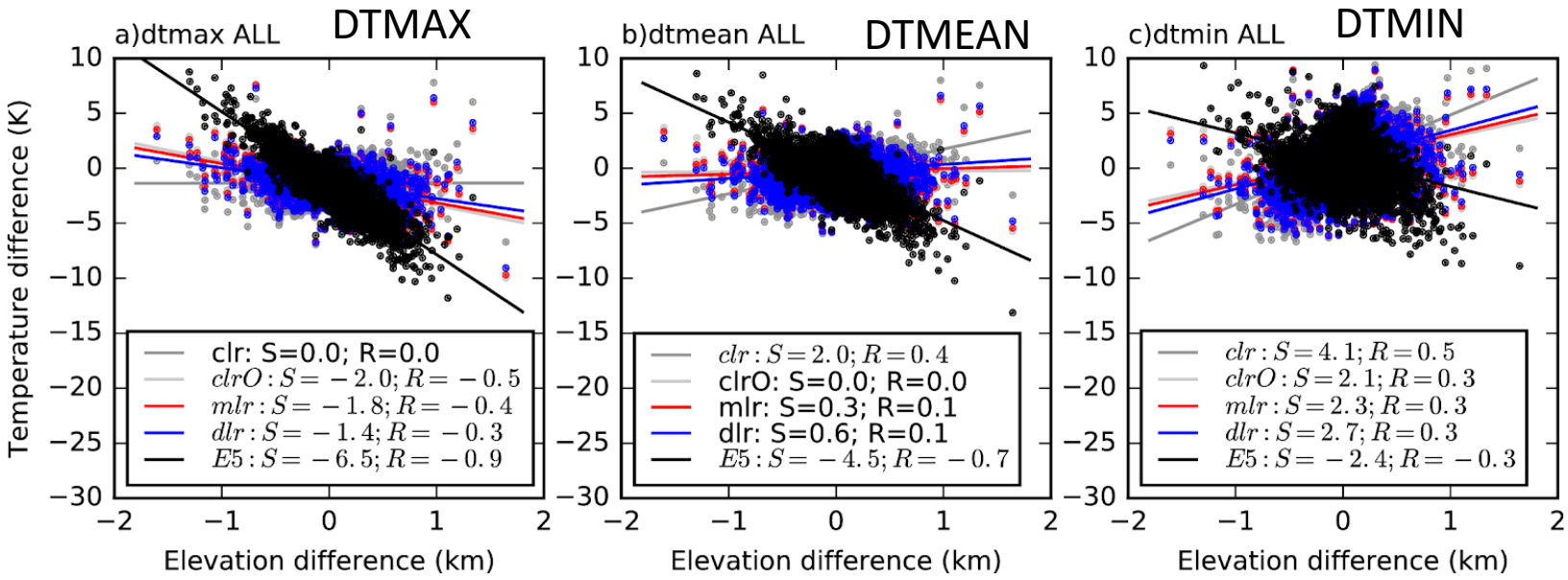
GHCN: “Bias” sampling of valleys (also common on synop)
SNOWTEL: “Bias” sampling of mountain peaks – design of the network;

ELR: Observations vs. reanalysis



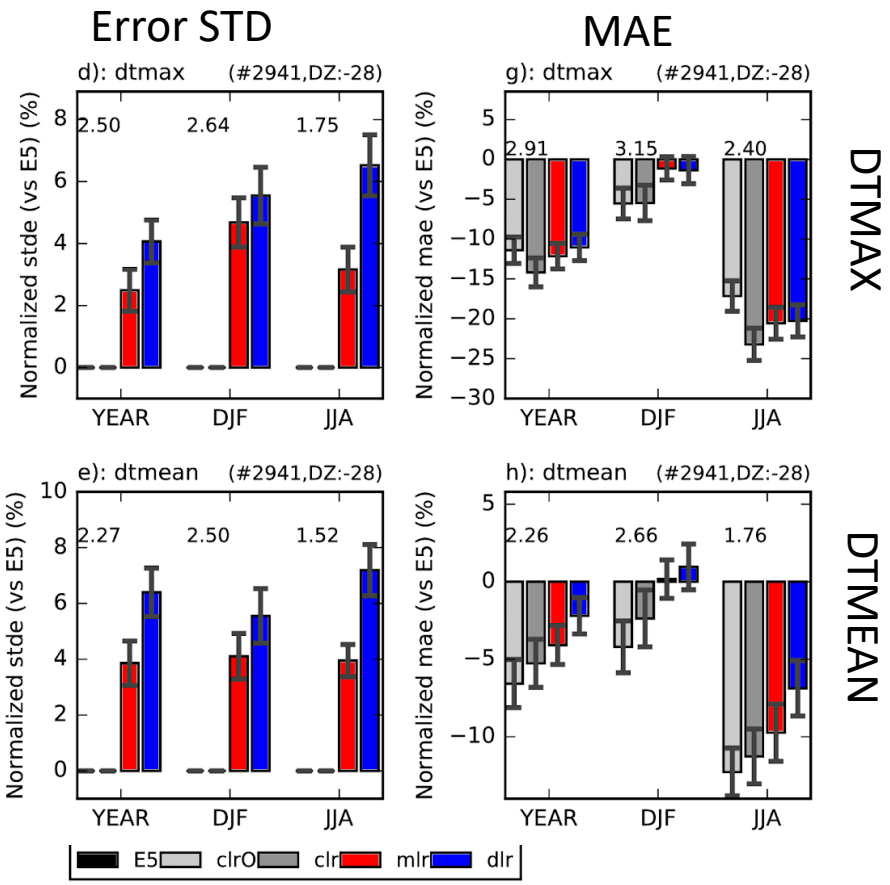
- Clear spatial & temporal variability of ELR in the observations;
- Reasonable agreement with ERA5 estimates (some overestimation) ;
- **Do you expect an impact of using a variable ELR vs constant ?**

Downscaling ERA5 temperature directly to stations (1)



- Temperature error vs Elevation differences: denote the 1st order errors induced by altitude differences;
- Clear dependence for DTMAX and DTMEAN. For DTMEAN MLR/DLR are the best in reducing the error dependence;
- For DTMIN: Nothing works – corrections overestimate the observed ELR : local effects dominate over ELR;
- clrO : -4.5 : Best estimate based on the observations.

Downscaling ERA5 temperature directly to stations (3)

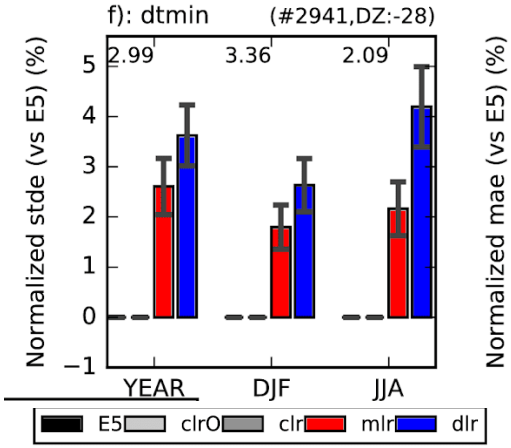


Normalized against E5 scores.
Median over all stations (+95 confidence intervals)

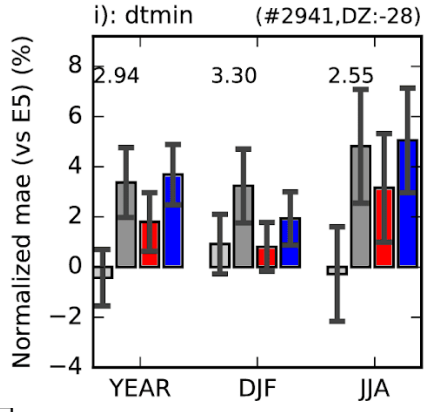
- Temporal/spatial varying ELR correction (MLR/DLR) increase the error standard deviation when compared with E5;
- About 10% reduction of MAE : no significant added value in using the MLR/DLR when compared with a constant ELR -6.5 or -4.5;
- Why?
- Hypothesis:
  - Despite the observational evidence of the ELR variability this plays a 2nd order effect on the temperature systematic /random errors;

Downscaling ERA5 temperature directly to stations (3)

Error STD DTMIN



MAE



- For DTMIN most corrections tend to deteriorate temperature (2% to 5%)
- Only a constant -4.5 ELR is neutral
- Local effects dominate DTMIN (nocturnal boundary layer, stable conditions, etc…)

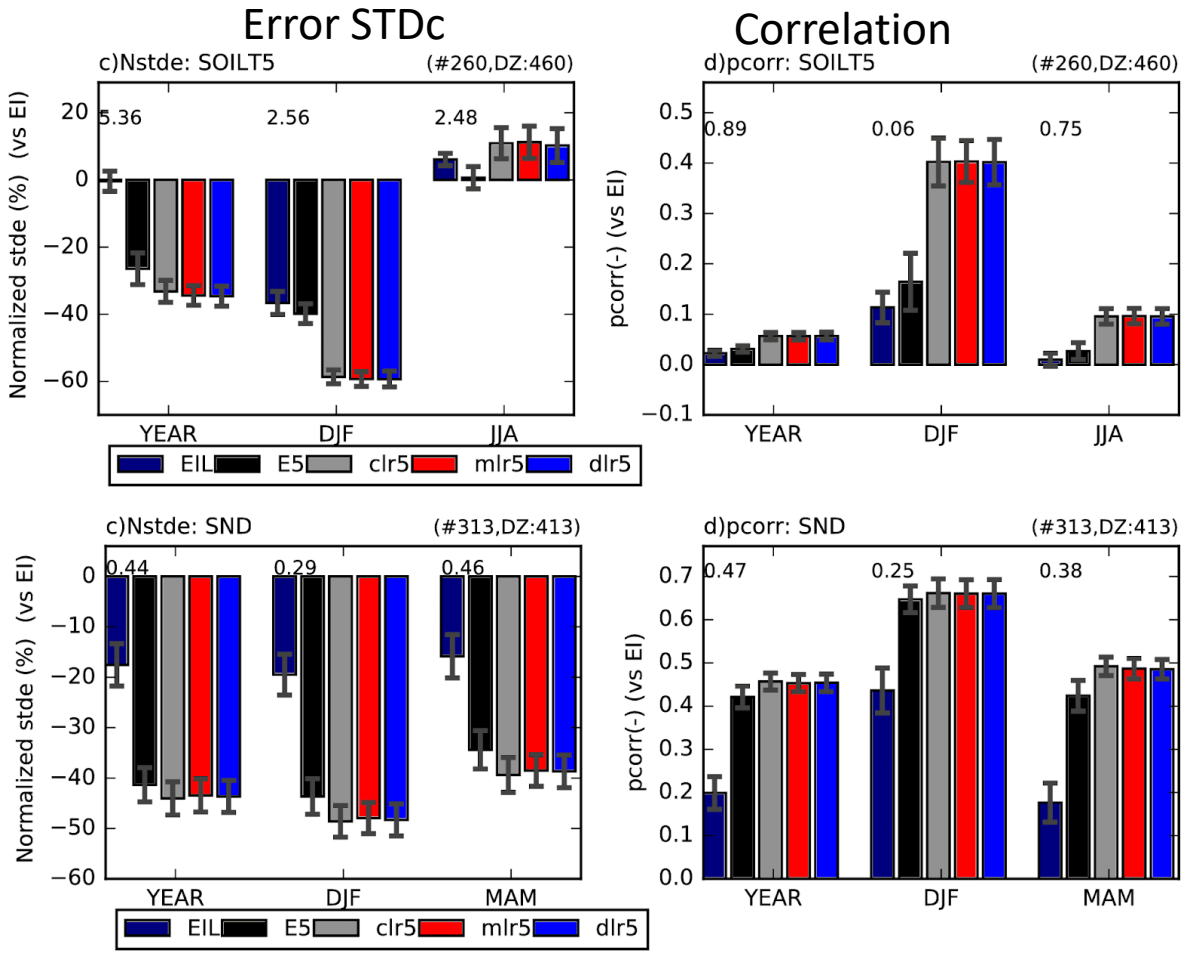
Based on these results, a constant ELR of -4.5 would be enough for this US region. Would this be true for other regions?

Since the MLR/DLR are similar to the constant approach and generic, we advocate it should be used instead, even if these results do not show a clear added value.

Land-Surface downscaling – soil temperature & snow

Soil

Snow depth



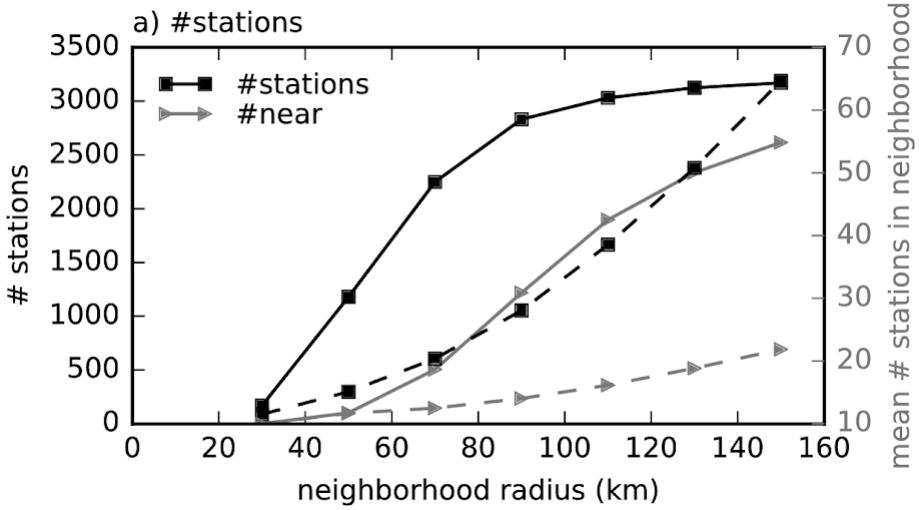
- Improvements from EI to EIL (model) and to E5 (meteorology)
- Added value of surface downscaling clear in particular during winter for soil temperatures;
- Added value of MLR/CLR : but no deterioration;

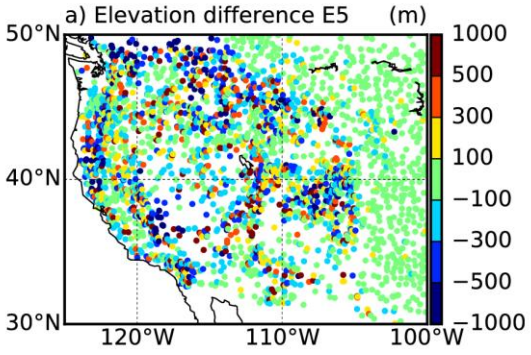
Normalized against **ERA-Interim** scores.

Median over all stations (+/-95 confidence intervals)

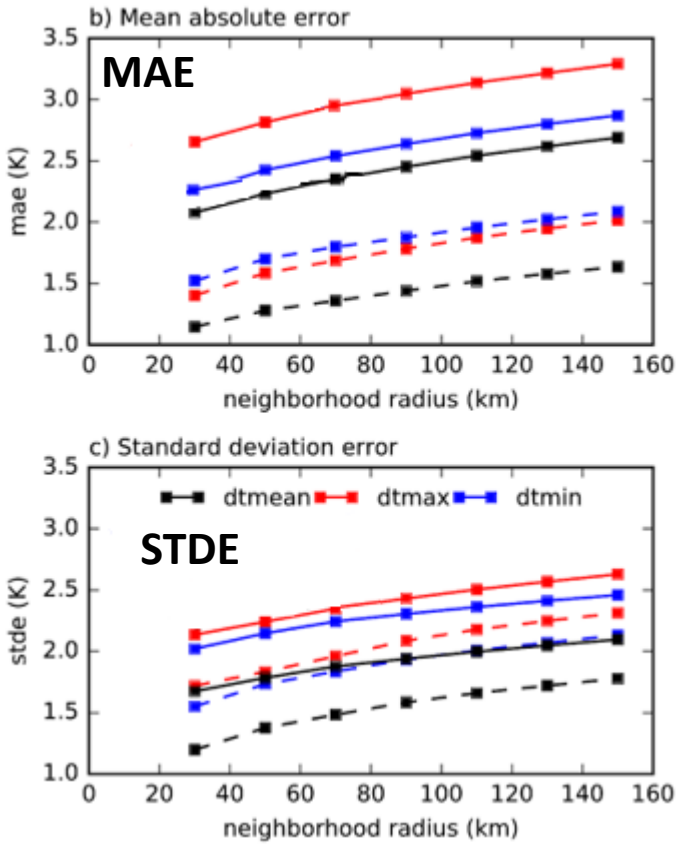
Observations representativity

- **Are the local observation representative of a region (model grid-box) ? (similar questions when dealing with EO data);**
- With a high resolution dataset we can assess the representativity :
  - For each point search for stations in a certain radius (e.g 30 km):
    - Compute the mean over all stations in that radius (as a model grid-box);
    - Compute the scores of each station against that mean:





Observations representativity



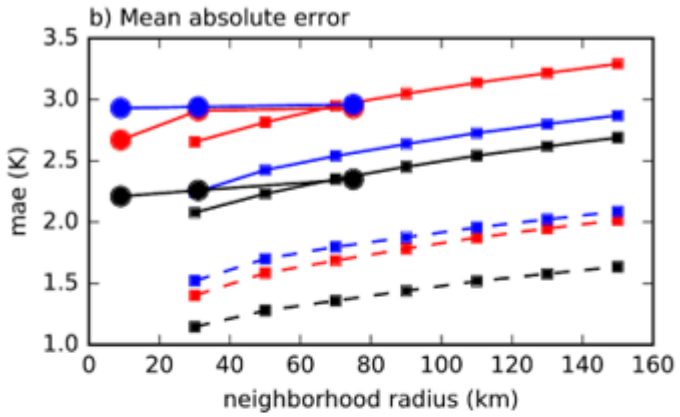
- **Higher MAE/STDE for DTMAX**
- **Reduction of about 0.25K for doubling resolution;**

- **Altitude mainly impacts the systematic errors**
- **Systematic differences are larger than random differences**

Solid : all points

Dashed: only station within 300m altitude difference

Observations representativity



Symbols indicate ERA-Interim (75km), ERA5 (30km) and DLR5 (9km)

- **No reduction of the MAE from ERAI to ERA5**
- **Surface downscaling improves mainly TMAX**
- **TMIN with higher systematic/random errors;**
- **Large reduction of STDE for TMAX from ERAI to ERA5**
- **ERAI MAE were consistent with observational uncertainty, but the scale reduction in ERA5 & downscaling did not reduced the errors;**
- **What are we missing? What are the implications when using high resolution EO data?**

Fina Remarks

- Observations clearly show a spatial and temporally variable ELR;
- ELR derived from ERA5 vertical profiles has a reasonable agreement with observations (issues in winter);
- Added value of ELR in removing the altitude dependence in the biases: dtmax (constant is ok), dtmean (variable) dtmin (none!);
- Downscaling benefits from the ELR, but the added value of the variable ELR is not clear: why? Second order effect, with main errors dominated by model errors;
- Benefits extend to other surface variables like snow and soil temperature;
- Despite the big changes from ERA-interim to ERA5, 2-meters temperature still have large systematic/random errors – cannot blame stations representativity;
- **How can we explore surface related EO data to further constrain/develop land-surface processes and increase resolution? Systematic vs random errors?**