An Assessment of Long Term Temperature Variability in the Sierra de Guadarrama (Spain)

GuMNet:
Guadarrama Monitoring Network

Vegas & GuMNet Consortium

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Motivation

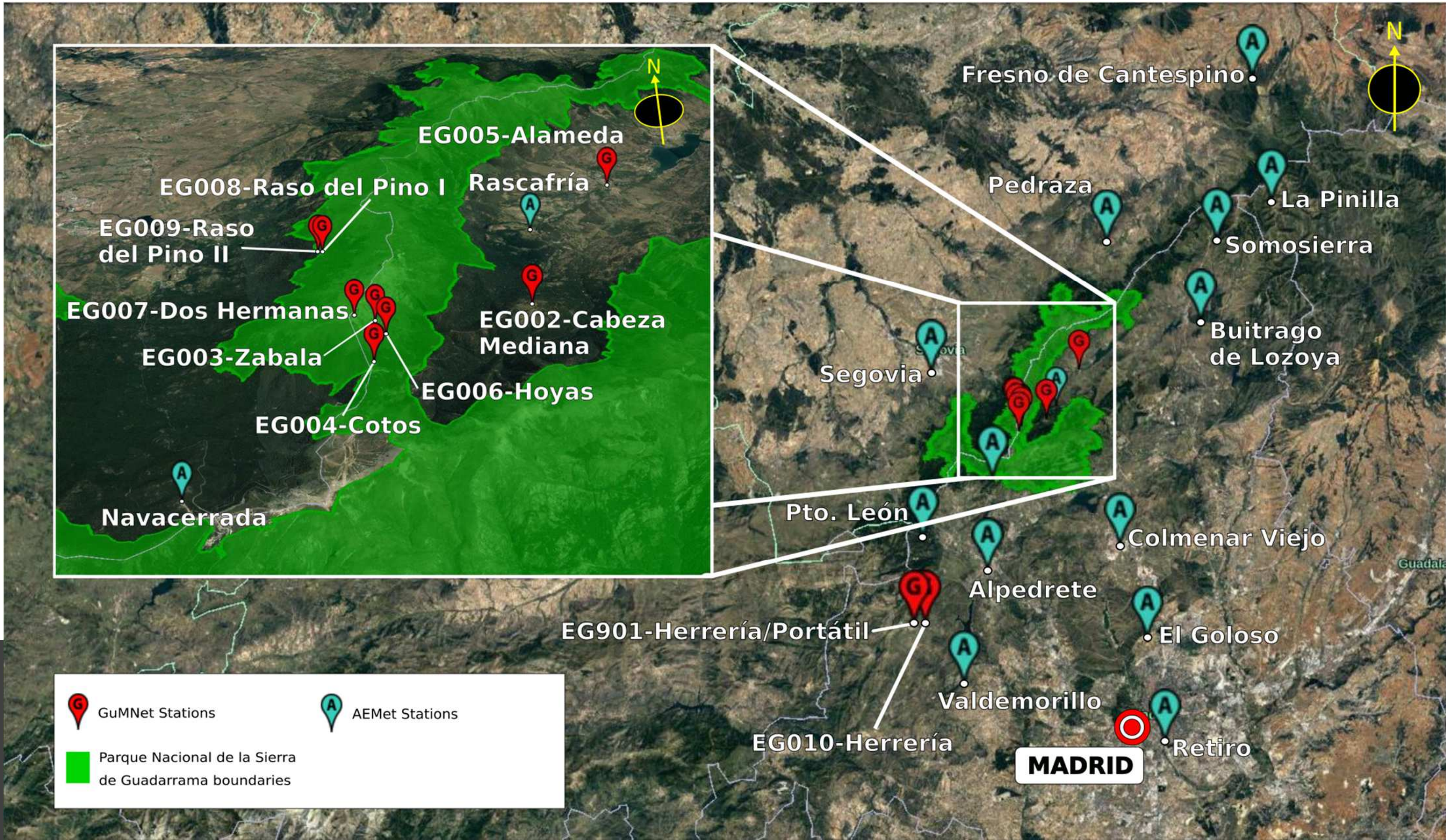
- ❑ Mountains offer many natural resources and a space for many activities.
- ❑ Mountains serve as home for many species, both animals and plants.
- ❑ Mountains have been greatly affected by climate change → extreme events → observations in the mountains are very important.
- ❑ Complex orography → Obtaining meteorological observations represents a challenge
- ❑ Complex terrains not easy to simulate → increase of the horizontal resolution → Regional Climate Models (RCMs)
- ❑ This study is focused on the Sierra de Guadarrama (Spain).
  - A High Resolution Weather Research and Forecasting (WRF) will be evaluated vs. ERA Interim reanalysis data & Observations .
  - Temperature variability will be analysed for the period 2000-2018 through daily temperature anomalies.
  - Temperature trends for the period 2000-2018 and the last decades will be analysed through monthly temperature anomalies.

What is GuMNet? https://www.ucm.es/gumnet

a glimpse at the facility

GuMNet is a new infrastructure of atmosphere, surface and subsurface observation

It is composed of 10 sites distributed from 900 masl to 2200 masl

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Data

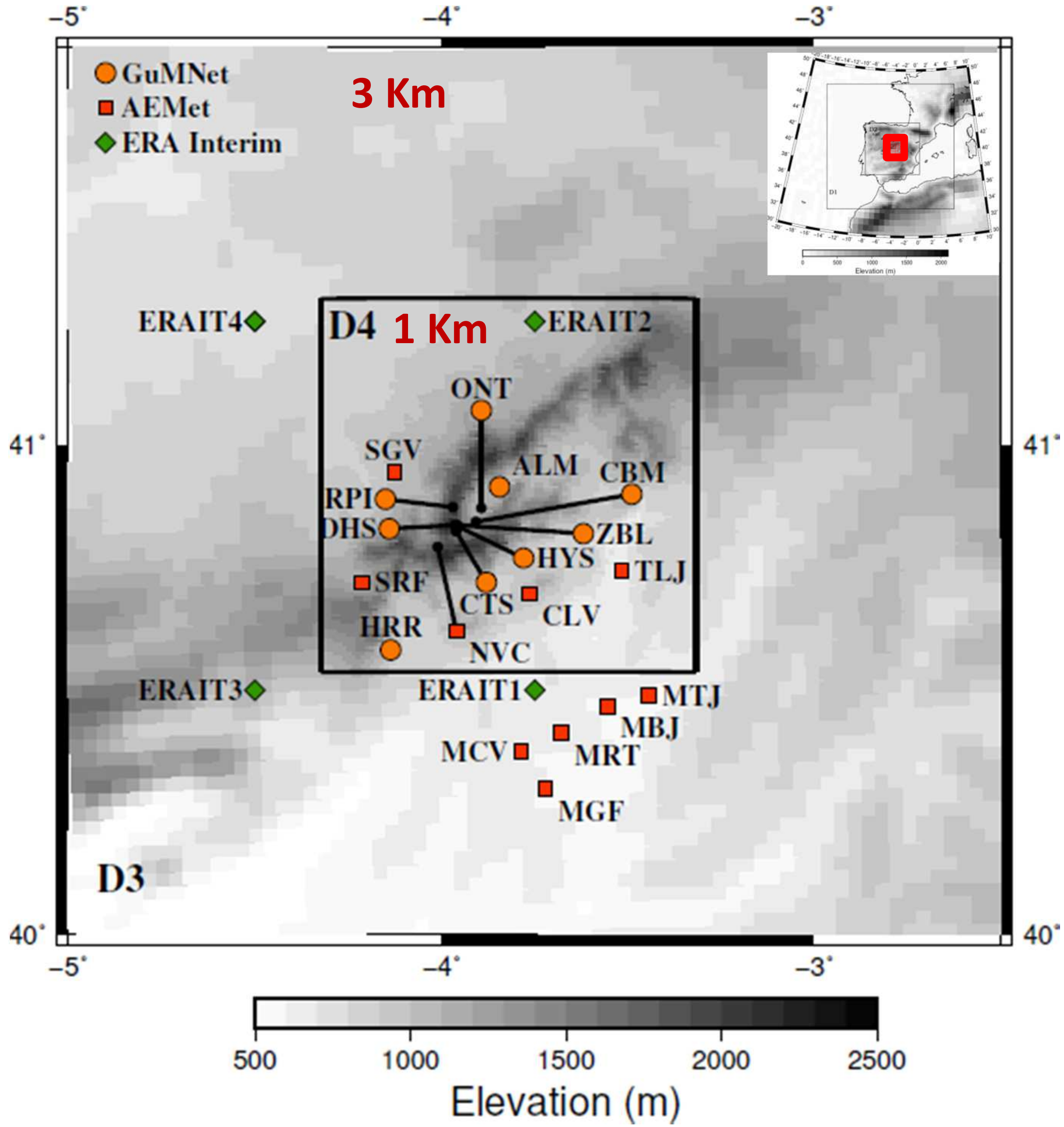

Figure 1. Configuration of the WRF domains D3 and D4, where symbols represent observational sites (see legend to identify data sources). Grey shadings depicts orographic height with the resolution of the boundary reanalysis fields (outer border) and the increasing resolution of the WRF domains.

- **WRF:** 1 km finest resolution within the innermost domain, D4.
- **WRF:** the closest grid points to the observational stations & masked with observations → *cmWRF*
- **ERA Interim (ERAIT):** initial & boundary conditions for WRF.
- **ERAIT:** 80km horizontal resolution → 4 grid points associated to the stations & masked with observations → *cmERAIT*.
- **Observations:** 19 stations from GuMNet & AEMet (Spanish National Meteorological Service) located in the Sierra de Guadarrama.

Evaluation of WRF. Mean temperature & vertical gradient

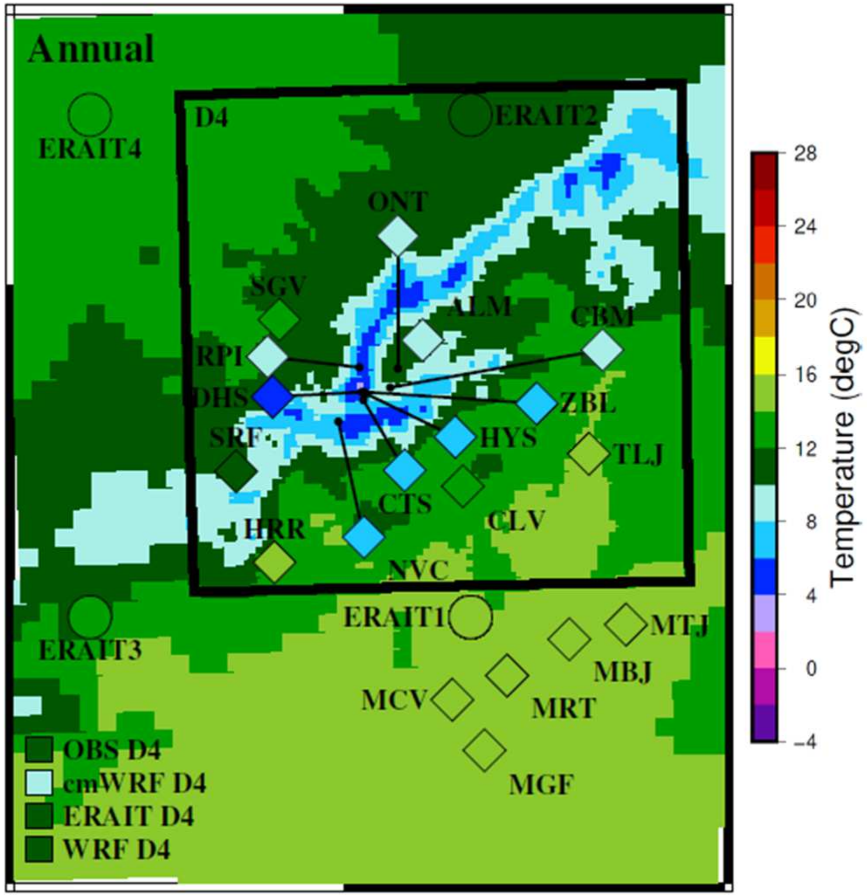

Figure 2. Mean temperature in the period 2000 – 2018 the annual season for the simulated and observed data: the shading represents the WFR simulation, diamonds indicate the values of the observational stations and the circles are for ERAIT. Squares at the bottom left represent the regional averages for the mOBS, the cmWRF inside domain D4, the ERAIT inside domain D4 and the complete WRF domain D4 field.

- Basic climatological description.
- Dominant orography.
- Local values in agreement with WRF.
- Regional averages → cold bias in WRF in the annual case.

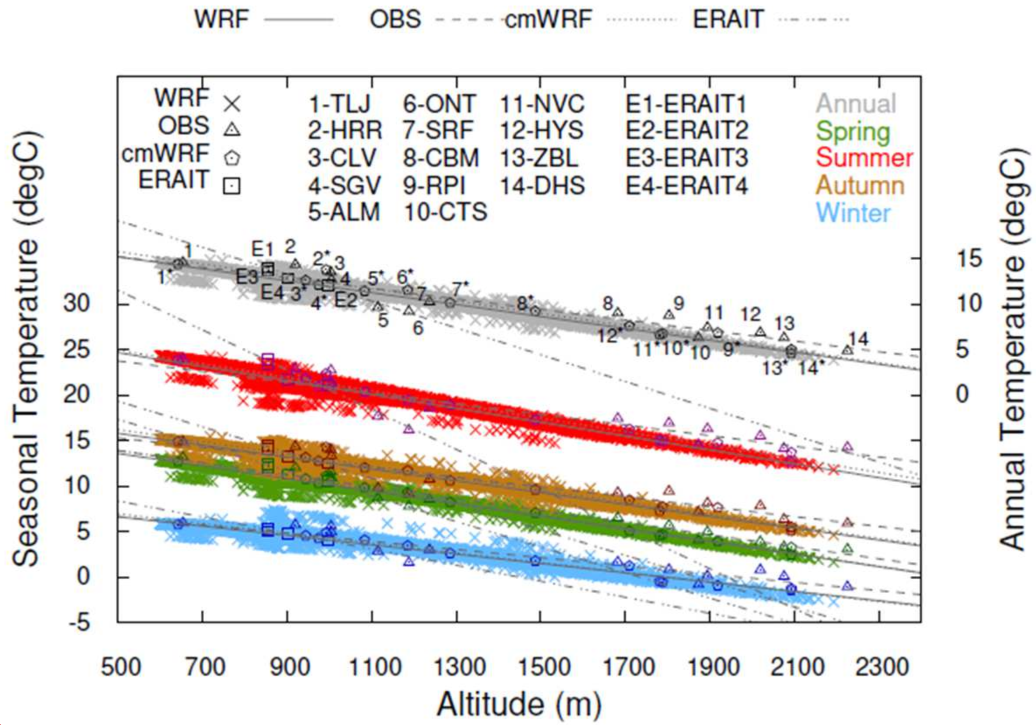

Figure 3. Distribution of vertical temperature gradients of OBS (WRF, cmWRF and ERAIT),represented by triangles (crosses, pentagons and squares) for the annual (black/grey), Spring (green), Summer (red), Autumn (brown) and Winter (blue) cases. A linear fit is shown for every dataset in a dashed line for the OBS, a continuous line for WRF, a dotted line for cmWRF and a dotdashed line for ERAIT.

- WRF gradient: -6.56°C/km
- OBS gradient: -5.81 °C/km
- OBS at high altitudes underestimated by WRF & overestimated in the valley.

Evaluation of WRF. Annual Cycles

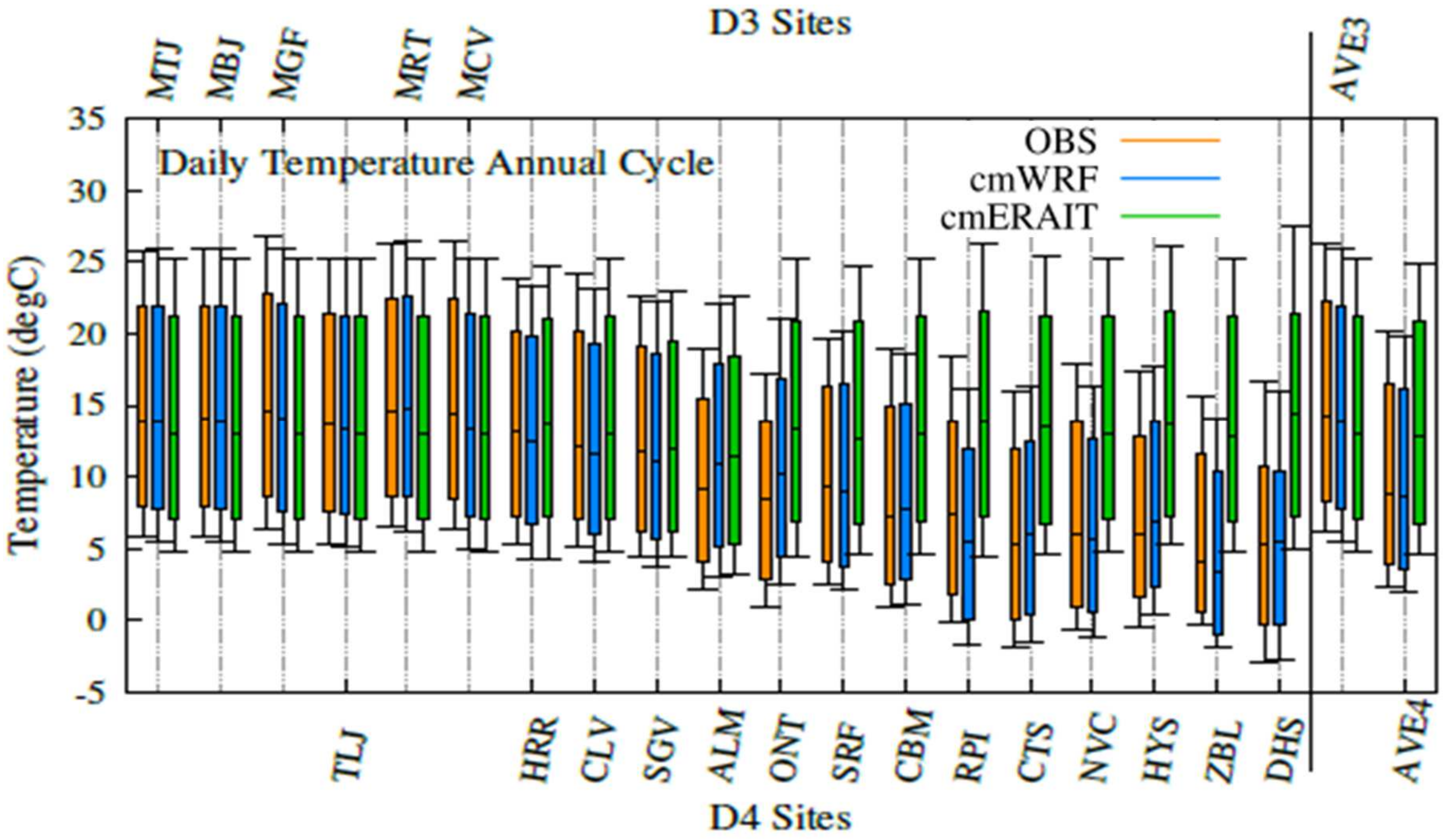

Figure 4. Statistical distribution of daily temperature annual cycles for stations in both the D3 (upper axis) and D4 (lower axis) domains. Stations are ordered by altitude. Regional averages are separated by a vertical line on the right side of the graph. Temperature from the observational stations are shown in orange, blue is for the WRF colocated grid points and green is for the ERA Interim colocated grid points.

- Annual cycle of OBS in agreement with cmWRF.
- cmWRF shows colder T than OBS at high altitude stations, but warmer T at the stations in the valley (ONT & ALM)
- cmERAIT shows a noticeable warmer bias at high altitude locations (within D4 domain)
- Regional averages are representative of local values for each domain.

Evaluation of WRF. Daily temperature anomalies

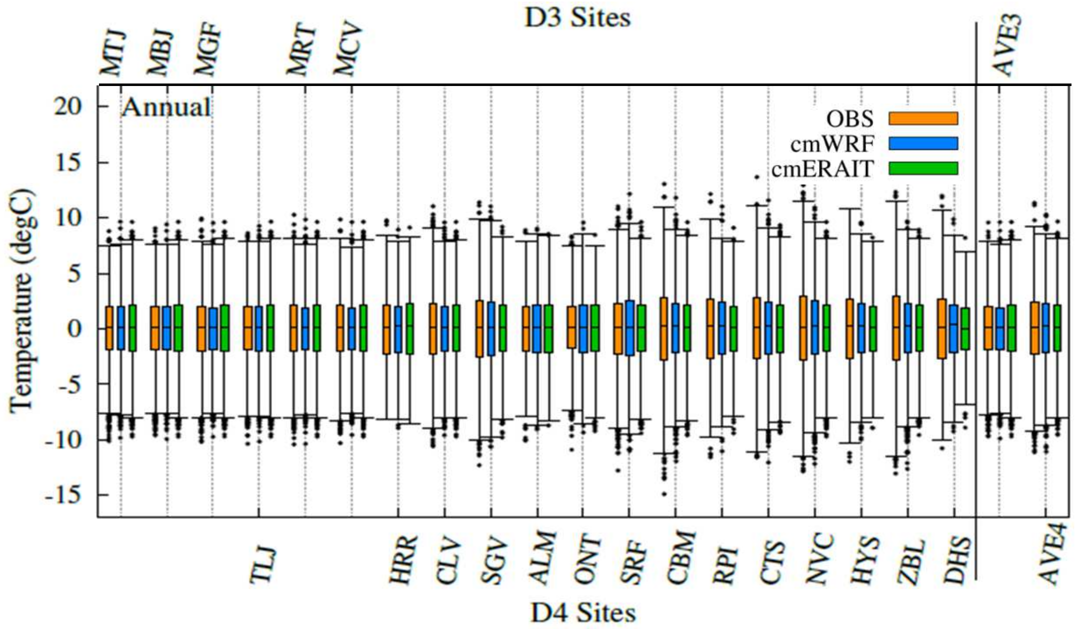

Figure 5. Frequency distribution of daily temperature anomalies for stations in both the D3 (upper axis) and D4 (lower axis) domains during the annual season. Stations are ordered by altitude. Regional averages are separated by a vertical line on the right side of the graphs. Temperature anomalies from the observational stations are shown in orange, blue is for the WRF colocated grid points and green is for the ERA Interim colocated grid points.

- cmWRF not capable of fully capturing extreme temperatures.
- cmERAIT fails in reproducing extreme variability.

- Correlations > 0.9 among regional averages of OBS, cmWRF and cmERAIT.
- Correlation extended to WRF: a few grid points are able to adequately reproduce the variability in the Sierra de Guadarrama.

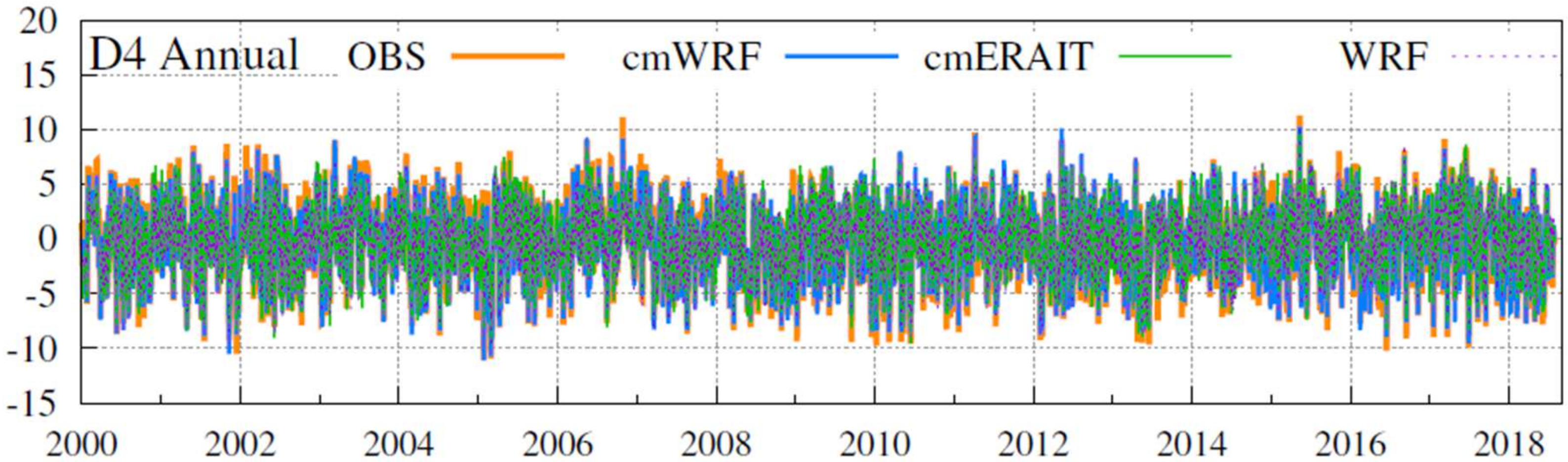

Figure 6. Regional averages of the daily temperature anomalies of the complete D4 field (dashed purple), observations (orange), cmWRF (light blue) and cmERAIT (green) for the whole year.

Evaluation of WRF. Taylor Diagrams

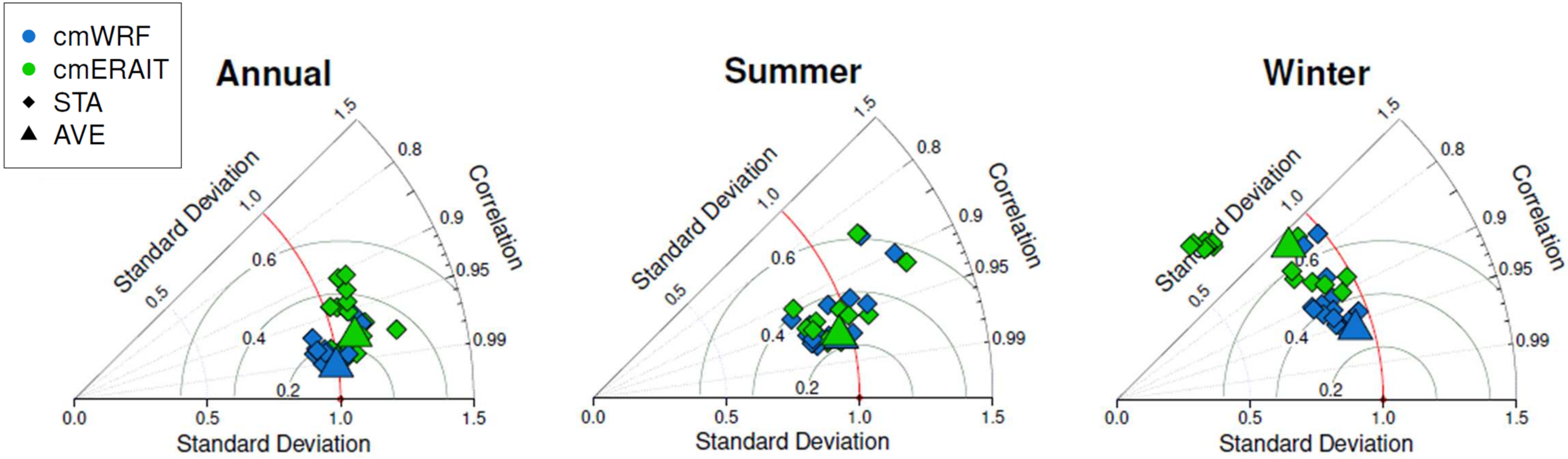

Figure 7. Taylor Diagrams of the daily temperature anomalies at each site for the annual case (left), Summer (middle), and Winter (right). Blue symbols represent the WRF outputs and the ERAIT data are in green. Triangles represent the regional average of each dataset. Spring and autumn cases not shown.

- WRF introduces and added value over ERAIT, more pronounced in winter (correlations > 0.95 for WRF & > 0.75 for ERAIT).
- Winter provides poorer performances, specially for ERAIT in higher altitude locations.
- Both WRF & ERAIT provide worse results for the valley stations, specially in summer.

Temperature trend. 2000-2018

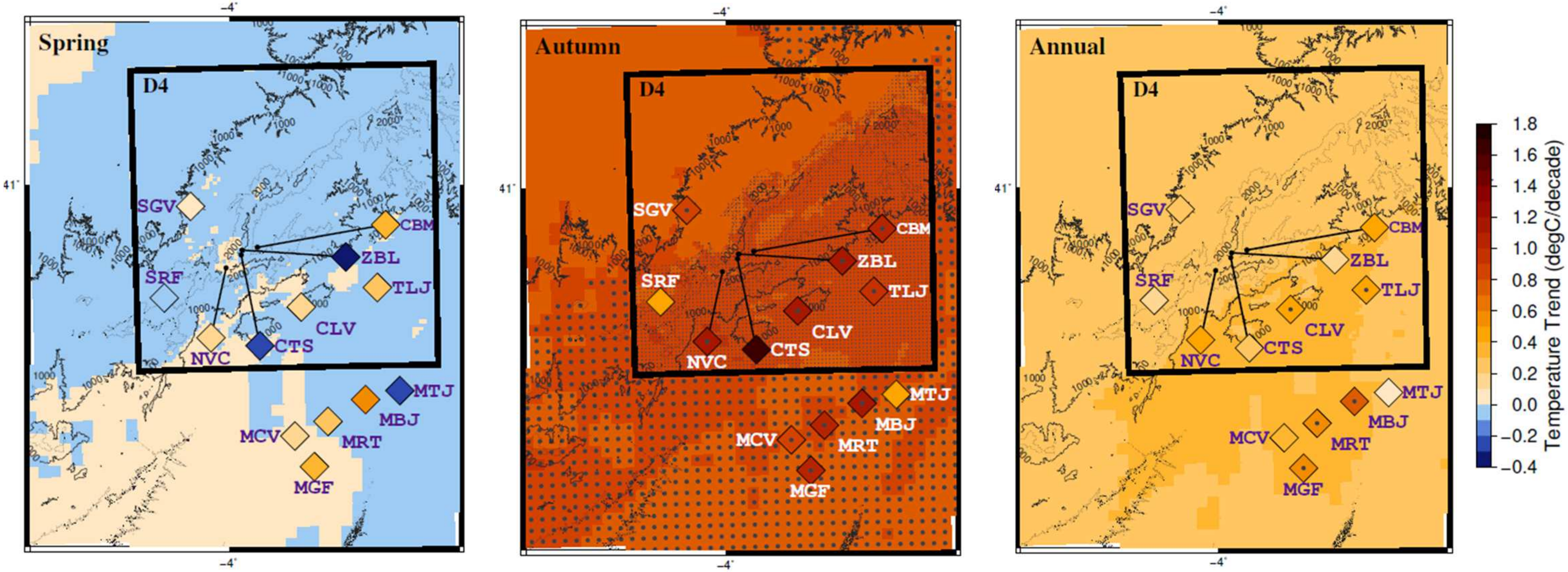

Figure 8. Monthly temperature anomalies trends for the period 2000 - 2018 for the WRF model for Spring (left), Autumn (middle) and annual case (right). Dots imply that the correlation (calculated taking into account the autocorrelation of the series) is significant ($p < 0.05$). Orography is given in meters. Summer and Winter cases not shown.

- Positive temperature trends during 2000-2018, except in Spring and the southern plateau in Winter.
- Very pronounced positive trend (~ 1°C/decade) in Autumn.
- Significant ($p < 0.05$) trends in Autumn in the southern plateau.

Temperature trend. Last decades

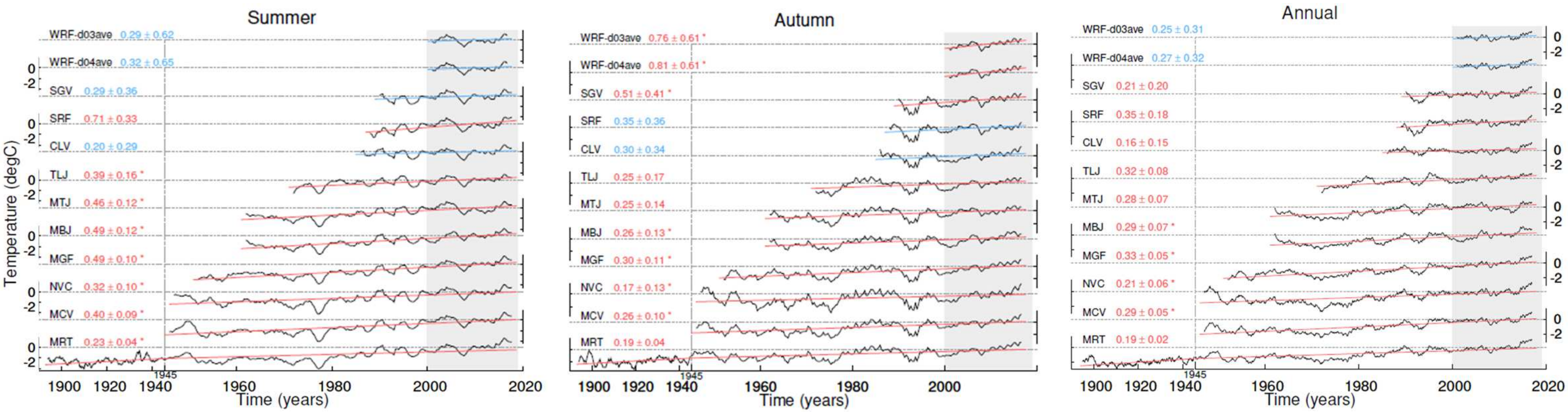

Figure 9. Monthly temperature regional anomalies for the complete record for the WRF model within domains D3 and D4 and the observational stations for the Summer (left), Autumn (middle) and annual (right) cases. Significant trends ($p < 0.05$) are highlighted in red. When a is shown, significance was calculated taking into account the autocorrelation of the series. Spring and Winter cases not shown.

- Positive temperature trends for the complete record, more pronounced in autumn (up to 0.81±0.61°C/decade).
- Higher increase in trends during periods 1970-2018 and, specially, 2000-2018 (up to 1.16 ±0.69°C/decade).
- Slowdown in increase rate of temperatures during 1990-2018.
- Most significant trends found on the southern plateau, southeast of the Sierra de Guadarrama, specially in summer and autumn.
- Very homogeneous behaviour in the entire region.

Conclusions

- Evaluation of WRF: the model improves the bias of ERAIT and shows a more realistic simulation, although it underestimates temperatures at high altitude stations
- Few sites, but representative of the temperatures over the Sierra de Guadarrama → good estimate of the variability over the region .
- Positive temperature trends during 2000-2018, more pronounced in autumn.
- Warming extends to the last decades, specially for the periods 1970-2018 and 2000-2018, although slightly slowed down during 1990-2018.
- The contents of this presentation are to be submitted to Atmosphere.