Regression-based downscaling of extreme temperatures for Spanish meteorological stations

P. Ramos Calzado

Instituto Nacional de Meteorología, Centro Meteorológico Territorial en Andalucía Occidental y Ceuta, Sevilla, Spain (*petri@inm.es*/Phone: +34 954 460884)

1 Introduction

Climate change projections supplied by coupled atmosphere-ocean general circulation models (AOGCMs) do not have the spatial resolution required by different impact models. Therefore, downscaling techniques are needed to increase the spatial resolution of AOGCM outputs. Within the frame of the Spanish National Plan of Adaptation to Climate Change (PNACC), the Instituto Nacional de Meteorología (INM) has generated and compiled regional projections for Spain based on different emission scenarios, different AOGCMs and different downscaling techniques [1].

This contribution presents the application of the SDSM multiple linear regression technique [7] to downscale extreme temperatures in 373 Spanish climatological stations. This technique links large-scale atmospheric variables (predictors) and local variables (predictands).

2 Data

Observed daily extreme temperatures from the INM in climatological database (corresponding to the period 1961-2000) have been used as predictands. NCEP reanalysis data [4] (prepared by the Canadian Institute for Climate Studies [2]), for the same period 1961-2000, have been used as predictors both for the model calibration and verification. Climate change AOCGM projections from the HadCM3[3] were applied for the period 2011-2100. The list of potential predictors includes: 2m mean temperature, mean sea level pressure, geopotential height(500 hPa, 850 hPa), relative humidity (near surface, 500 hPa, 850 hPa), specific humidity (near surface), geostrophic air flow velocity, vorticity, zonal velocity component, meridional velocity component, divergence and wind direction (surface, 850 hPa and 500 hPa).

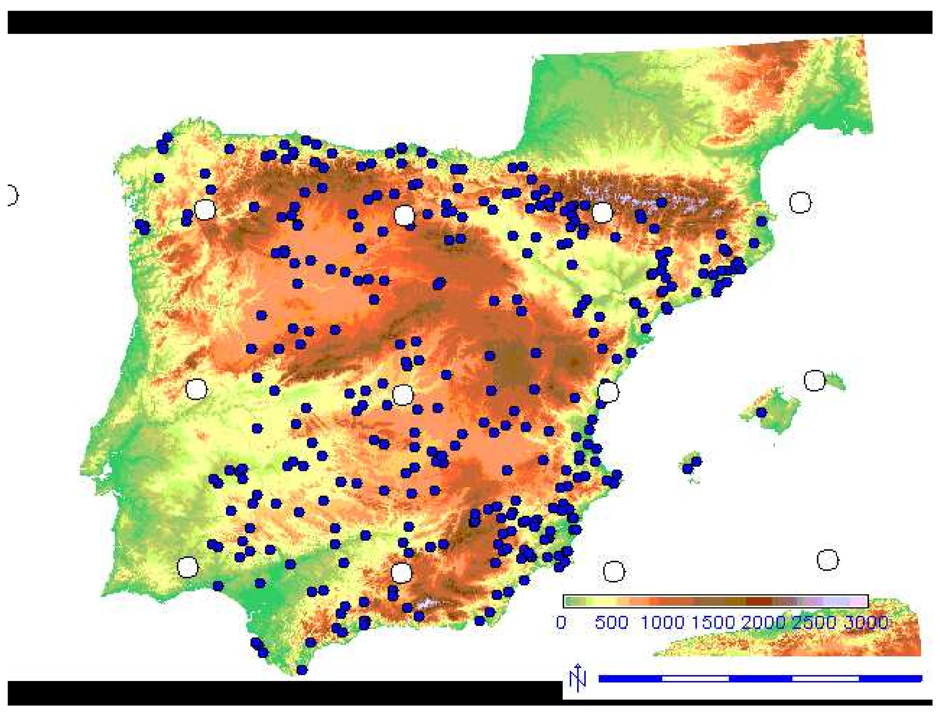

Figure 1: Spatial distribution of selected climatological stations (blue points) and HadCM3 grid points (white points) over the Iberian Peninsula and Balearic Islands

Only homogeneous (Mann test) and enough long (up 19 years) climate stations for annual mean temperature series have been selected [1].Their distribution over the Spanish territory allows a reasonable representation of different climatic areas (e.g., coasts, inland, islands, Mediterranean, Atlantic, plain, mountains, etc.). Stations are distributed among the Iberian Peninsula (359 stations), Balearic Islands (3 stations) and Canary Islands (10 stations). Station height ranges between 2 and 1800 m (see figure 1), being only 25 stations above 1000 m.

3 Application of the downscaling technique

The model used is unconditional, i.e., the assumed links between predictand and predictors are direct. The used predictor values for each climate station correspond to the closest grid point. This feature is particularly relevant due to the high sensitivity of the regression-based downscaling technique to the selection of predictors variables. Although, 2m mean temperature (t2m) is initially a predictor variable well correlated (Corr.coeff. ~ 0.80) with the two predictands (maximum temperature and minimum temperature) here used the best subset of variables has been applied.

The improvement due to usage of the best subset of variables can be easily seen as a shift towards higher correlation from the histogram of absolute frequency versus correlation coefficient (see figure 2). This improvement is larger for maximum temperature than for mininum temperature. The difference between both distributions is larger for higher stations (mean of 8.8%) in the case of maximum temperature, and for lower stations in the case of minimum temperature (figure not shown here).

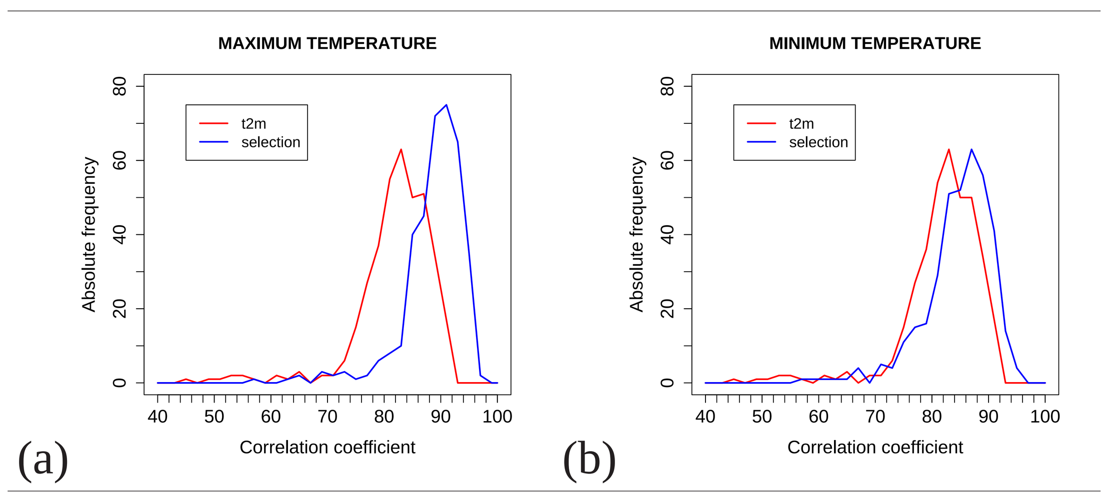

Figure 2: Histogram of correlation coefficients for (a) maximum temperature and (b) minimum temperature when have been used one predictor variable (2m mean temperature)(red) or the best subset of variables (blue) has been used.

The parameters of the linear regression have been obtained by the Narula and Wellintong algorithm [6] using data from the period 1961-1990 .

Future climate projections have been calculated adding to the determinist prediction a pseudo-random number. This number is obtained from a Gaussian distribution of mean zero and standard deviation equal to the standard deviation from the residual of the linear fit. Daily data verification for the period 1991-2000 shows small bias (-0.03 C for maximum temperature and -0.8 C for minimum temperature). Root mean square deviation is 2.7 C for maximum temperature and 2.5 C for minimum temperature.

4 Climate projections for Spanish climatological stations

The climate change daily projections for the selected Spanish climatological stations have been estimated for the period 2011-2099 under A2 and B2 IPCC-SRES scenarios [5] using HadCM3 outputs. Although these selected scenarios are not the most extreme ones, A2 corresponds to higher emissions of GHGs than B2. The increasing tendency for XXI century of both predictands is shown in figure 3, with higher rate of change under SRES A2 than B2, as expected. Daily maximum temperatures are projected to increase faster than daily minimum temperature, leading to an increase of diurnal temperature range.

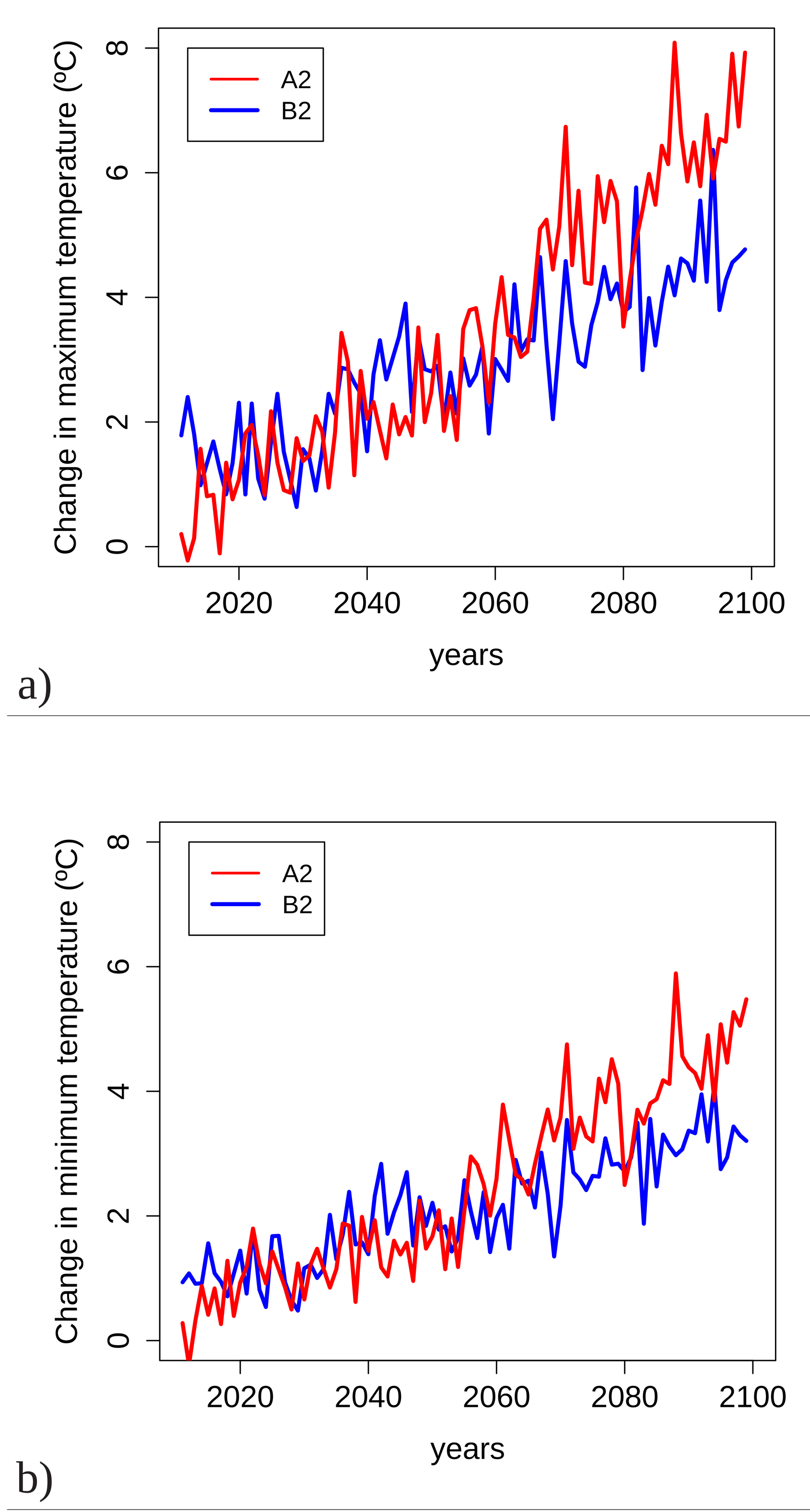

Figure 3: Downscaled mean annual maximum (a) and minimum (b) temperature changes (averaged over the selected climatological stations) for 2011 to 2099 with respect to 1961-1990, under A2 and B2 SRES scenarios for peninsular Spain and Balearic Islands.

Mean trends of 0.077±0.003 C/year (0.040±0.003 C/year) and the 0.055±0.002 C/year (0.029± 0.002 C/year) were obtained for maximum temperature and minimum temperature, respectively, under the SRES A2 (B2) scenarios. These values were calculated from averaged series over the selected climatological stations from Peninsular Spain and Balearic Islands.

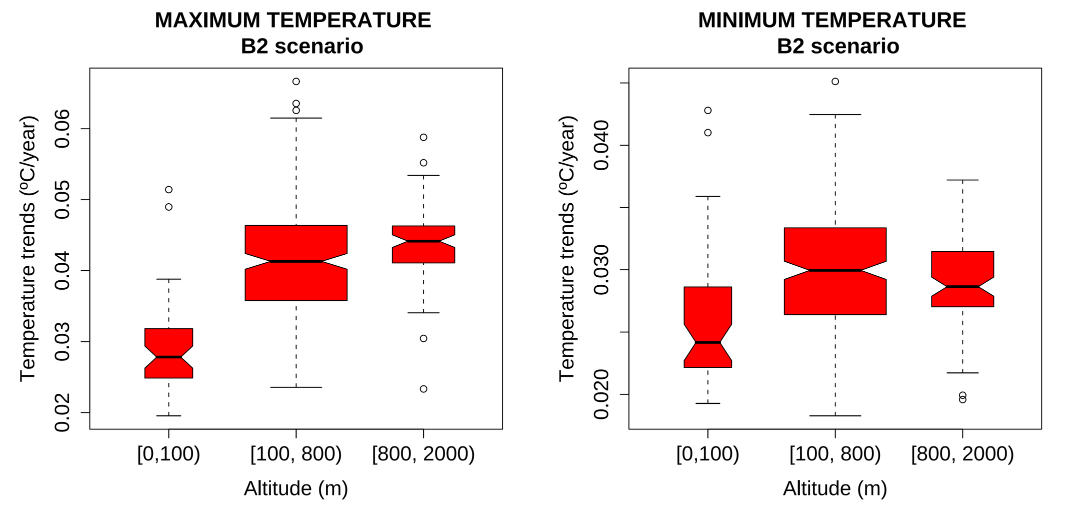

Figure 4: Boxplot of the maximum and minimum temperature trends in Spanish climatological stations (without Canarian area) for different altitude range. Box is drawn from first to third quartile and the median splits it. Its width is proportional to the squared-roots of the number of data and the whisker is 1.5 times the box length. Outliers are drawn as points.

Depending on altitude, the selected Spanish stations (without Canarian area) have been grouped on three classes for analyse the trends for the proyected daily extreme temperature in the period 2011-2099. As it can be seen in figure 4, temperature changes are slower for low altitude stations than for higher altitude stations. Low altitude stations are located, normally, close to coastal areas and, therefore, it expects the sea to regule their temperature.

5 Conclusions

- The SDSM multiple linear regression technique has been applied to the daily maximum and minimum temperature in 373 Spanish climatological stations to proyect these variable from 2011 to 2099, using HadCM3 as driving CGM.
- The predictor variable 2m mean temperature is well correlated to both predictands but the use of other variables improve the linear fit, especially for maximum temperature in high altitude stations.
- The projected daily temperature (maximum and minimum) for 2011 to 2099 increases along this period. This rise is faster for the maximum temperature than minimum temperature.
- Climatological stations at low altitude show lower temperature increase, probably due to the damping effect of oceans.
- Daily downscaled climate change projections here described are part of an ongoing project aiming to the national impacts and adaptation communities, encompassing also estimation of uncertainties based on ensembles of downscaled projections using different AOGCMs, different downscaling techniques and different IPCC-SRES scenarios.

References

[1] Ministerio de Medio Ambiente. Instituto Nacional de Meteorología. Generacion de escenarios regionalizados de cambio climático para españa. primera fase. www.inm.es/web/izq/noticias/meteonoti/pdf/Escenarios_2007040 Febrary 2007.

[2] Canadian Institute for Climate Studies. Canadian climate impacts scenarios. www.cics.uvic.sa/scenarios, 2003.

[3] C. Gordon et al. The simulation of sst, sea ice extents and ocean heat transports in a version of the hadley centre coupled model without flux adjustments. *Climate Dynamics*, 16(2/3):147–168, 2000.

[4] E. Kalnay et al. The ncep/ncar 40-year reanalysis project. *Bulletin of the American Meteorological Society*, 77(3):437–471, 1996.

[5] N. Nakicenovic et al., editor. *Special Report on Emissions Scenarios : a special report of Working Group III of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, Reino Unido y Nueva York, NY, Estados Unidos, 2000.

[6] S.C. Narula and J.F. Wellington. Multiple linear regression with minimum sum of absolute errors. *Applied Statistics*, 26(1):106–111, 1977.

[7] R.L. Wilby, C.W. Dawson, and Barrow E.M. Sdsm - a decision support tool for the assessment of regional climate change impacts. *Environmental Modelling and Software*, 17(2):145–157, 2002.