INTEGRATION OF CLIMATE CHANGE SCENARIOS IN AIR POLLUTION MODELS

Validation and comparison of two statistical downscaling methods of climate change scenarios

PROJECT 2fun — CC-IAM Climate Change Impacts, Adaptation and Mitigation Research Group

Pedro Lopes 1, Pedro Serpa1, Ricardo Aguiar 1, Elsa Casimiro 1,2

1 Climate Change Impacts, Adaptation & Mitigation Research Group, Faculty of Sciences, University of Lisbon, Portugal

2 INFOTOX Environmental Risk Consultants, Lisbon, Portugal

pedro_garrett@netcabo.pt

ABSTRACT

Climate change impacts are very dependent on regional geographical features, local climate variability, and socio-economic conditions. Impact studies should therefore be performed at the local or at most at the regional level. However, climate scenarios are produced by Global Circulation Models (GSMs) for the entire globe with spatial resolutions of several hundred kilometres. Downscaling methods are thus needed to bridge the gap between the large scale climate scenarios and the finer climate scale required for local impact studies.

In this study we assess the capability of two statistical downscaling methods to represent local climate variability. We conduct an inter-comparison and uncertainties analysis study between the LARS-WG stochastic weather generator and SDSM which is a hybrid of stochastic weather generator with transfer function methods. Models errors and uncertainties were estimated using non-parametric statistical methods at the 95% confidence interval for precipitation, maximum temperature and minimum temperature for the mean and variance for a single site in Lisbon.

The comparison between the observed dataset and the simulations showed that both models performance are acceptable. However, the SDSM tool was able to better represent the minimum and maximum temperature while LARS-WG simulations on precipitation are slightly better. The analysis of both models uncertainties for the mean are very close to the observed data in all months, but the uncertainties for the variances showed that the LARS-WG simulation performance is slightly better for precipitation and that both model simulations for minimum and maximum temperature are very close from the observed.

These climate change scenarios will be integrated in the Air Pollution Model (TAPM version 4, Oct.2008) from CSIRO (Australia). This is a commercial 3D, Dynamic (Euler), forecast/analysis, airflow model able to calculate dispersion from multiple point line area and volume sources generating atmospheric concentrations of ozone, PM10 and PM2.5, as well as dry and wet deposition.

Average daily temperature and precipitation data from future climate change scenarios is used directly. Wind speed and direction data are from sub-scenarios which are based on predominant wind conditions (average speed and direction pairs), and critical exposure pathways derived from expected wind behavior, and the location of main emission sources and receptors.

METHODS

Two different statistical downscaling methods were tested for a single site in Lisbon. The first method is a stochastic weather generator that can be use for the simulation of weather for a single site under current and future climate conditions. This method was applied using the LARS-WG (Long Ashton Research Station Weather Generator) tool developed by Semenov and Brooks, (1999) that provides means of simulating synthetic weather time series with similar statistical characteristics of the observed statistics at a site.

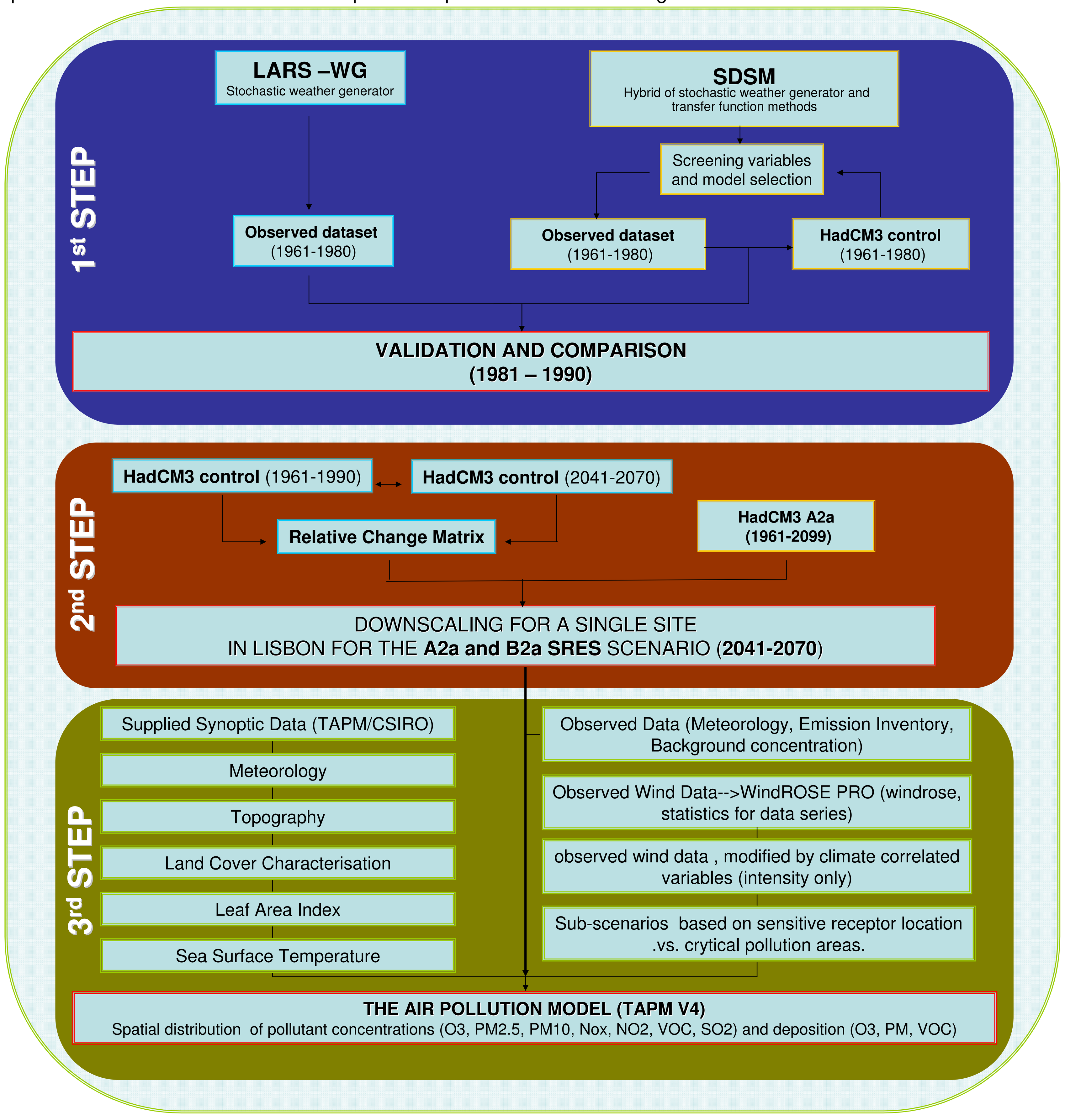
The second statistical downscaling method is a hybrid of stochastic weather generator and transfer function methods. In this case, large-scale circulation patterns and atmospheric moister variables are used to condition local scale weather parameters such as precipitation occurrence and intensity. Stochastic techniques are then used to artificially inflate the variance of the downscaled daily time series. This method was applied using the SDSM (**S**tatistical **D**own**S**caling **M**odel) tool developed by Wilby, Dowson and Barrow, 2001.

The climatic inputs for both statistical methods was daily precipitation, daily maximum temperature and daily minimum temperature for Lisbon during the 1961-1990 period, obtained from the European Climate Assessment & Dataset (ECA&D) for the following meteorological station: **Name:** 177 LISBOA GEOFISICA; **WMO:** 08535; **Latitude:** 38:43:00; **Longitude:** -09:09:00; **Height:** 77m.

The GCM chosen was the coupled atmosphere-ocean HadCM3 developed by the Hadley Centre, with a horizontal resolution of 2.5º of latitude and 3.75º of longitude producing a global grid of 96 x 73 grid cells.
For this study the GCM HadCM3 daily data were collected in two different sources. The predictors for the A2 scenario used in the SDSM tool were acquired at the Canadian Climate Change Scenarios Network (CCCSN), and the input for the LARS-WG tool were collected at the British Atmospheric Data Centre, from the Climate Impacts LINK Project.

Model validation of the downscaled daily precipitation and daily maximum and minimum temperature (Tmax and Tmin respectively) was assessed in terms of model errors in the estimates of the mean and variances for the 1981-1990 period using non-parametric statistical analysis tests at 95% confidence level. For the mean it was used the non-parametric Mann-Whitney *U* test that constructs the hypothesis test p value for the difference of the two population means (μ_1-μ_2), assessing whether two samples of observations come from the same distribution (Mann and Whitneu, 1947). Here the null hypothesis is that there is no difference between the two population means. For $p < 0.05$ the null hypothesis is rejected at 95% confidence level and the two population are different, the null hypothesis is accepted when $p > 0.05$. The chosen non-parametric test for the equality of two population variances was the Brown-Forsythe test (Brown and Forsythe, 1974).

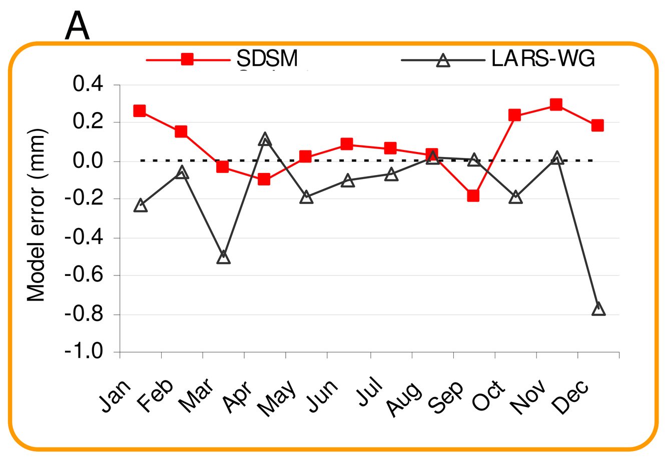
After calibration and validation of the downscaling meteorological data, these results will supply, in future work, the air pollution model TAPM to assess the impact of air pollution in climate change scenarios on human health.



RESULTS

Evaluation of the errors in the estimates of means:

A



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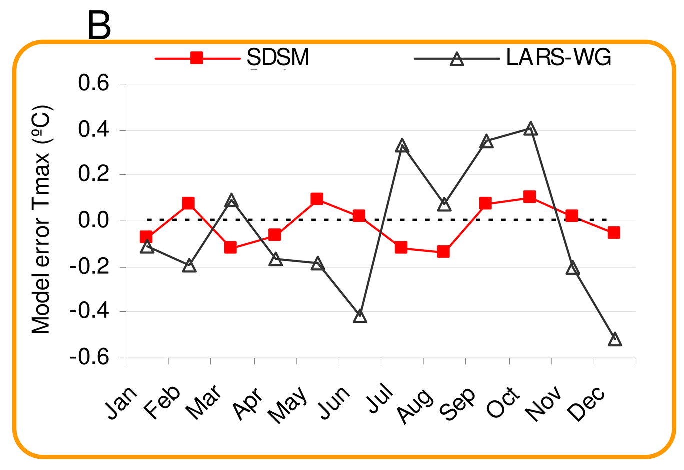

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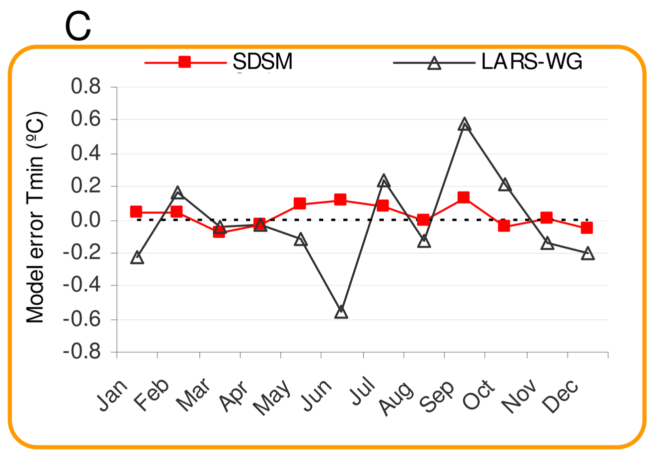


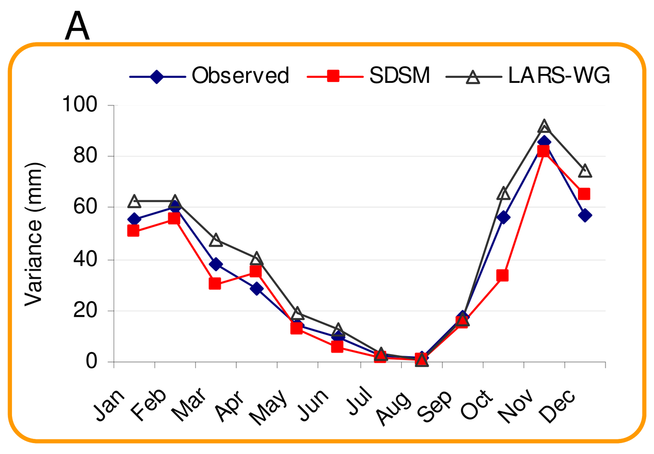
Observed minus simulated monthly means of (A) precipitation; (B) minimum temperature and (C) maximum temperature, for the 1981-1990 period.

	Tmin		Tmax		Precipitation	
	SDSM	LARS-WG	SDSM	LARS-WG	SDSM	LARS-WG
Jan	0.828	0.039	0.828	0.796	0.014	0.076
Feb	0.689	0.078	0.593	0.215	0.020	0.995
Mar	0.433	0.682	0.047	0.947	0.112	0.007
Apr	0.575	0.500	0.101	0.206	0.138	0.002
May	0.596	0.176	0.303	0.065	0.327	0.813
Jun	0.825	0.000	0.382	0.002	0.151	0.862
Jul	0.098	0.995	0.034	0.341	0.323	0.525
Aug	0.069	0.011	0.033	0.418	0.623	0.656
Sep	0.561	0.000	0.663	0.153	0.826	0.460
Oct	0.502	0.032	0.341	0.024	0.215	0.360
Nov	0.715	0.216	0.691	0.035	0.012	0.372
Dec	0.426	0.103	0.771	0.000	0.025	0.053

Test results (p values) of the **Mann-Whitney U test** for the difference of means of the observed (1981-1990) and downscaled daily Tmin, Tmax and precipitation at the **95% confidence level**

Evaluation of the errors in the estimates of variances:

A



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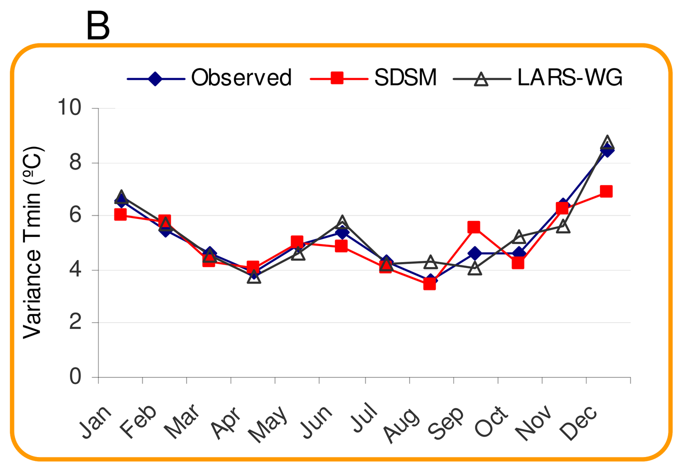

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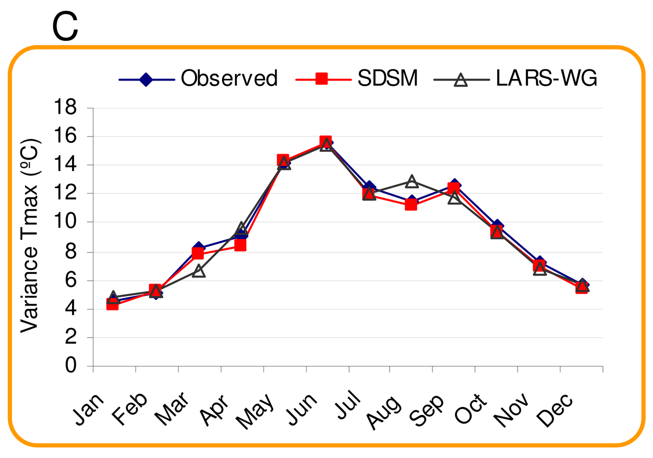
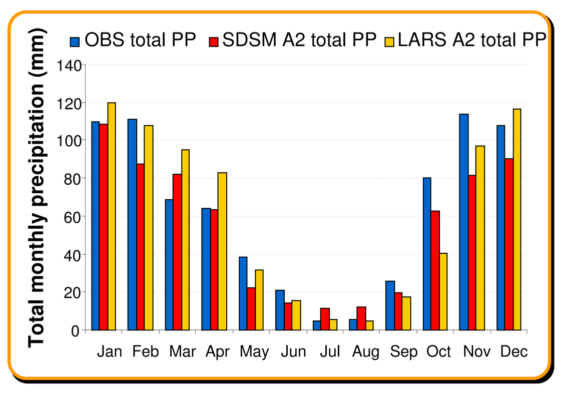


Estimation of the monthly average of daily observed and simulated variances for (A) precipitation; (B) maximum temperature and (C) minimum temperature for the 1981-1990 time period

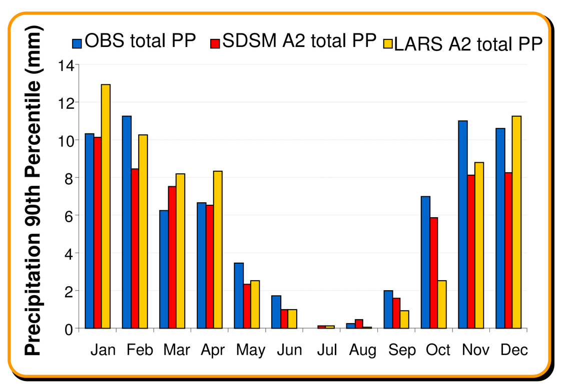
	Tmin		Tmax		Precipitation	
	SDSM	LARS-WG	SDSM	LARS-WG	SDSM	LARS-WG
Jan	0.167	0.591	0.771	0.003	0.441	0.523
Feb	0.261	0.482	0.033	0.158	0.705	0.893
Mar	0.224	0.418	0.735	0.045	0.905	0.099
Apr	0.326	0.771	0.509	0.240	0.696	0.685
May	0.265	0.792	0.695	0.363	0.917	0.318
Jun	0.844	0.065	0.674	0.764	0.523	0.513
Jul	0.164	0.125	0.530	0.505	0.310	0.383
Aug	0.244	0.000	0.687	0.114	0.563	0.771
Sep	0.003	0.110	0.853	0.397	0.336	0.967
Oct	0.133	0.147	0.495	0.728	0.449	0.614
Nov	0.701	0.028	0.470	0.832	0.500	0.965
Dec	0.002	0.979	0.483	0.565	0.613	0.042

Test results (p values) of the **Brown-Forsythe test** for the difference of variances of the observed and downscaled daily Tmin, Tmax and precipitation at the **95% confidence level**

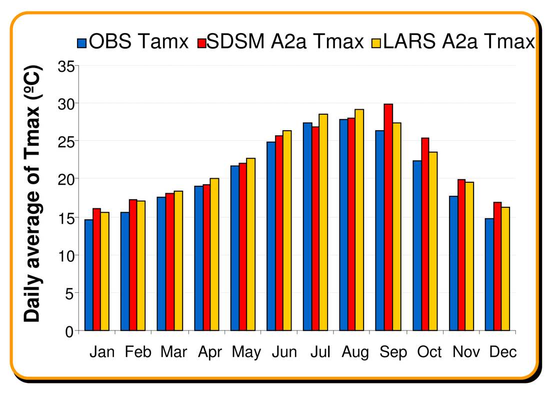
Summary statistics for Lisbon using LARS-WG and SDSM for the A2a SRES scenario:



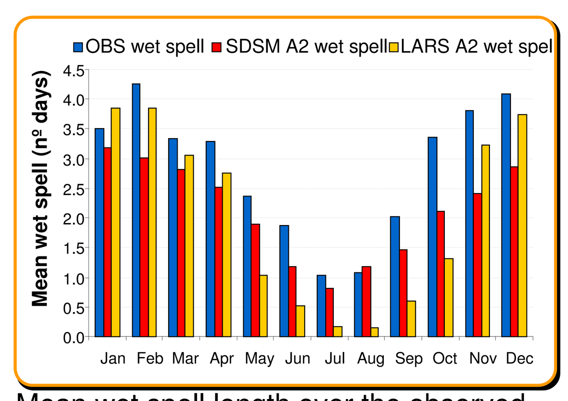
Total monthly precipitation over the observed 1961-1990 and the 2041-2070 period



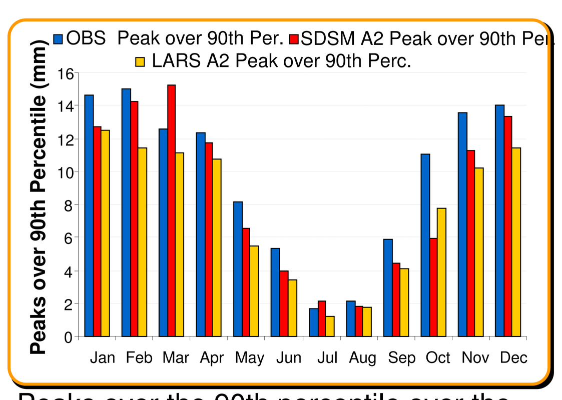
90th percentile of precipitation over the observed 1961-1990 and the 2041-2070 period



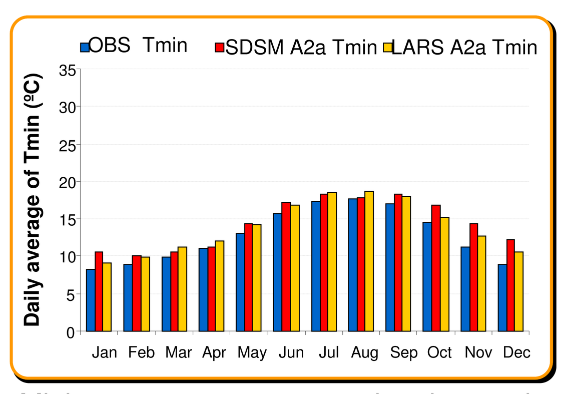
Maximum temperature over the observed 1961-1990 and the 2041-2070 period



Mean wet spell length over the observed 1961-1990 and the 2041-2070 period



Peaks over the 90th percentile over the observed 1961-1990 and the 2041-2070 period



Minimum temperature over the observed 1961-1990 and the 2041-2070 period

DISCUSSION AND CONCLUSION

The SDSM and LARS-WG validation and model comparison was done using non-parametric statics at the 95% confidence interval for daily precipitation, daily maximum temperature and daily minimum temperature for the mean and variance.
The model errors for the mean were tested using the Mann-Whitney U test and the performance of both model simulations is quite acceptable but the SDSM tool can better represent minimum and maximum temperature while LARS-WG simulations on precipitation are better. It is also important to note that the SDSM simulation for minimum temperature for the mean was well represented in all months.
The Brown-Forsythe test was used to compare the difference of variances of the downscaled dataset. Both model performances were very good in almost all months.
In conclusion model errors and variability are close from the observed dataset for precipitation, maximum temperature and minimum temperature.
The general analysis of the simulations for the A2a SRES scenario for the 2041-2070 period showed that both techniques can be an alternative to produce downscaling scenarios at a local scale but the performance of those results for each climate change scenario as to include an uncertainty analysis while some observations of the results can be slightly different. Therefore, with this analysis the air pollution model TAPM will be used to calculate point source and traffic pollution for ozone and particles in the city of Lisbon in climate change scenarios .

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