Seventh Framework Programme

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Improving the capacity of agro-meteorological crop modelling to integrate climatic variability and extreme weather events

MODelling vegetation response to EXTREMe Events

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2. Revision history

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3. Dissemination level

PU	Public	☒
PP	Restricted to other program participants (including the Commission Services)	☐
RE	Restricted to a group specified by the consortium (including the Commission Services)	☐
CO	Confidential, only for members of the consortium (excluding the Commission Services)	☐

EXECUTIVE SUMMARY

Background	Time series of weather data suitable for simulation with crop models have been developed by the JRC in the frame of AVEMAC and PESETA projects. Such time series cover four time horizons (2000, 2020, 2030, and 2050), spatially the whole Europe with a grid of 25 x 25 km, and include climate projections by the GCM ECHAM5 and HadleyCM3, downscaled using the same RCM. One of the key uncertainties in building weather series of climate projections, to be used in simulation via crop models, is the variability of weather variables. Multi-years synthetic series are derived from GCM simulations and are bias-corrected, but whether it is accepted that they represent current knowledge in estimating mean values of climate projections, the impact of possible underestimate of variability is still an open point.
Objectives	• To make available a sample datasets to be accessed for simulations by MODEXTREME partners and stakeholders from the software being developed, to be implemented in the MODEXTREME WP6 server; • To create time series of weather data to be used to explore, with respect to different levels of weather variables variability, old and new modelling solutions for crop/plant growth.
Methods	The dataset developed by the JRC, for the part covering France, Italy and Spain was made available as first instance in the MODEXTREME server for connection and use with simulation tools developed in the project. Nine sites across Europe were selected from the weather time series. The original parameter sets used in the weather generator ClimGen were altered to generate data with +15% and +30% of variability in temperatures and rainfall (keeping the same mean monthly values). A software was specifically developed to generate the time series which will have a use also for developing weather data time series in the WP4.
Results & implications	The full coverage at 25 km grid for France, Italy and Spain, 30 years for 2000, 2030, 2050 time horizons and ECHAM5 and HadleyCM3 GCM were implemented in the MODEXTREME server and are ready for use with simulation models. Perturbed (+15% and 30% of variability for temperature and rainfall) time series of 30 years of daily data were created for nine sites in Europe, for the time horizons 2000, 2030, and 2050. The datasets are available for simulations to test the impact of increased variability on the modelling solutions being built in the project.

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Introduction

The basis for assessing potential impacts of climate change is future climate projections. To obtain such projections, it is necessary to have a reliable model of the climatic system and to use it to estimate possible future outcomes. Climate change projections realized by running GCMs (Global Circulation/Climate Models) or RCMs (Regional Climate Models) under different emission scenarios are intrinsically subject to a significant amount of uncertainty.

Translating climate forecasts to estimate of impact on agriculture remains a challenge, due to the significant differences in spatial and temporal scales between GCMs and crop growth models (Hansen et al., 2006). Despite an increasing ability of GCMs to successfully model present-day climate and provide realistic quantitative predictions of climate change at continental scale (IPCC, 2007), they still have serious difficulties in reproducing accurate daily estimates at local scale. The need for bias correcting GCM-RCM projections for use by impact models is well known (e.g. Christensen et al., 2008), and the influence of such biases on hydrological and crop modelling has been extensively investigated by (e.g. Teutschbein and Seibert, 2010), who claimed that unless climate model outputs are corrected, their application to impact models may be unrealistic. Even though GCMs operate at sub-daily time scale, the spatial averaging at the coarse grid-scale distorts the temporal variability of daily weather sequences (Osborn and Hulme, 1997). This is especially true for precipitation. For instance, while a GCM may estimate monthly precipitation correctly, the daily precipitation may be spread throughout the month in a very unrealistic way (e.g. raining a small amount water every day). Such distortions of daily weather variability can seriously bias crop model simulations (Semenov and Porter, 1995; Mearns et al., 1996; Hansen and Jones, 2000; Baron et al., 2005). Time series of weather data consistent for use with crop simulators were built by Donatelli et al. (2012), covering whole Europe on a grid base and with regards to future time spans. The first objective of this work was to make available such dataset, via the software being developed in this project, for simulations within the project and by external users.

However, a substantial uncertainty remains on the variability to weather variables, both in terms of projections and actual presence of extremes in time series. To explore in a sensitivity-like approach crop models response to a possible greater variability in weather series, it might prove useful to create synthetic time series in which variability is artificially increased. This was the second objective of this work.

1. Materials and methods

1.1 Weather scenarios

A database of consolidated and coherent future daily weather data covering Europe with a 25 km grid was created, which is adequate for crop modelling in the near-future. Climate data were derived from the ENSEMBLES downscaling of the HadCM3 and ECHAM5 realizations of the IPCC A1B emission scenario, using for HadCM3 two alternative regional models for downscaling. Solar radiation, wind speed and relative air humidity where either estimated or collected from historical series, while derived variables such as reference evapotranspiration and vapour pressure deficit were estimated from other weather variables, thus ensuring consistency within daily records, as described by Donatelli et al. (2012). Synthetic time series data were finally generated using the weather generator ClimGen (Stockle et al., 2001). The data covering France, Italy and Spain were stored on the MODEXTREME server for future use with simulators.

1.2 Sites chosen for time series perturbation

Nine grid cells of the MARS database were selected to represent cold and hot climates, with different precipitation and air temperature patterns. The selection of cells by no means had the target to represent possible climates in Europe; instead it had the target of being a first sample to explore the methodology. The cells, selected from the prototype database built on the MODEXTREME server which currently covers France, Italy and Spain, are described as latitude, longitude and elevation in Table 1.

Table 1. *Country, grid code, latitude, longitude and altitude for all the locations used.*

Country	Grid Code	Latitude (deg)	Longitude (deg)	Eleva-tion (m a.s.l.)
Italy	76116	45.179	2.478	1029
Italy	76104	45.186	8.304	134
Italy	60119	41.548	12.884	19
France	94088	49.013	2.695	104
France	90079	47.881	-0.172	65
France	74075	44.192	-0.757	80
Spain	59078	40.938	0.698	139
Spain	45065	37.373	-2.478	1029
Spain	57067	40.126	-2.417	1001

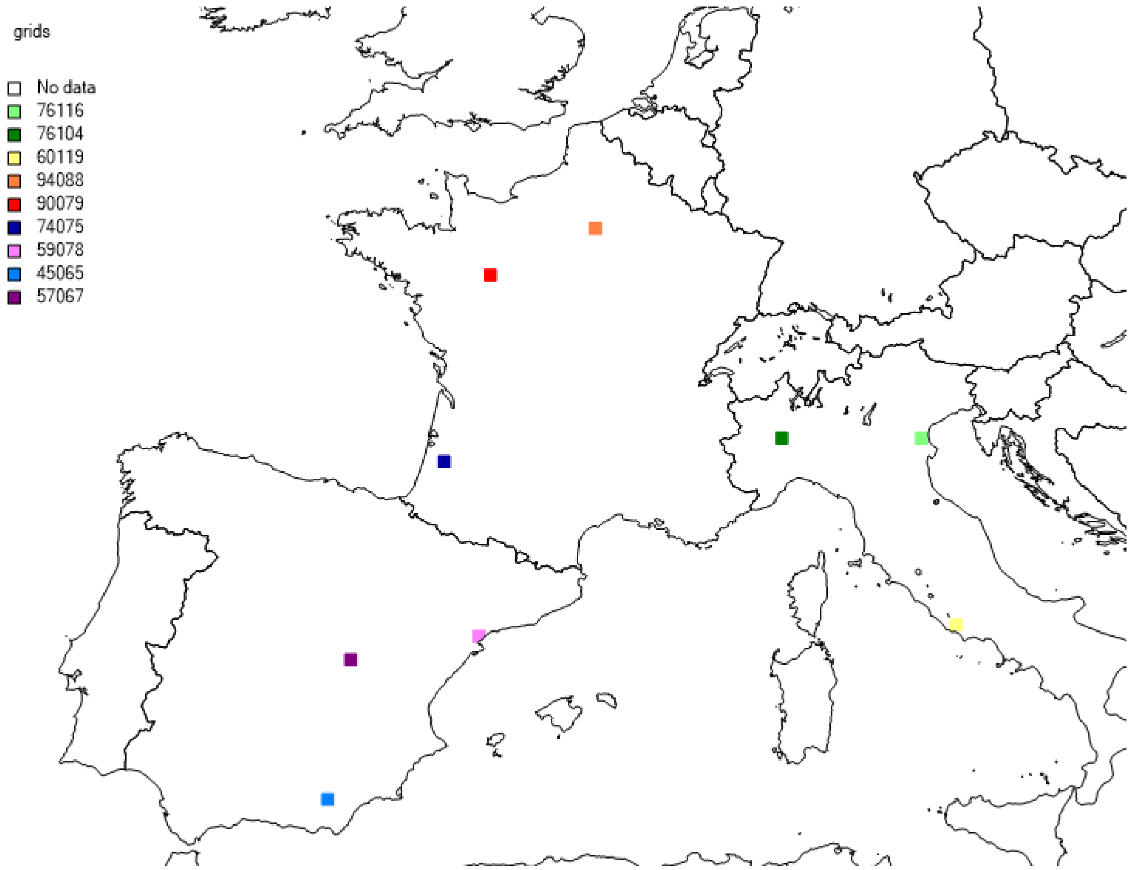


Figure 1. *Map of the study locations.*

1.2.1 Methodology

Each of the original time series was characterized by an associated set of ClimGen parameters, which were used to generate the time series of weather variables. The time series were perturbed by changing parameter values and then re-generating the time series. The description of ClimGen models for weather generation is at:
http://www.biomamodelling.org/backend/documents/climgen_help.rar.

1.2.2 Parameters modification

The rationale behind the modification of ClimGen parameters was to keep the same monthly values both for rainfall and air temperature (maximum and minimum), but to increase variability.

In the case of rainfall, to target was to keep the amount on monthly rainfall while increasing the possibility of high intensity events. This was done changing values of three ClimGen parameters (and keeping average monthly rainfall unchanged):

- Probability of rainy day: decrease of 15 and 30%;
- Probability wet/wet days: decrease of 15 and 30%;
- Probability of wet/dry days: increase of 15 and 30%.

In the case of air temperature, maximum and minimum standard deviations were increased of 15 and 30%, while the average monthly values were kept unchanged.

1.2.3 Diagrams presented

Each time series (unchanged, changed by 15% and 30% in parameter values as in 1.2.2) was sorted independently for each variable, then the 15% and 30% data were paired to the unchanged values.

This regarded 30 years times 365 values for air temperature, and only days with rainfall >0 for rainfall. Data are presented as 1:1 graphs, where the original values are in the X axes, and the +15% and +30% are the pairing Y values. The expectation for temperature data was to observe a slope of data >1, meaning that the perturbed series would show lower and higher values generated with respect to the unperturbed series. In case of rainfall, given that the perturbation of parameters had to lead to a smaller number of rainy days, only data with non-zero values were considered. Again, the expectation was to see data above the 1:1 line for higher precipitation values.

1.3 Software

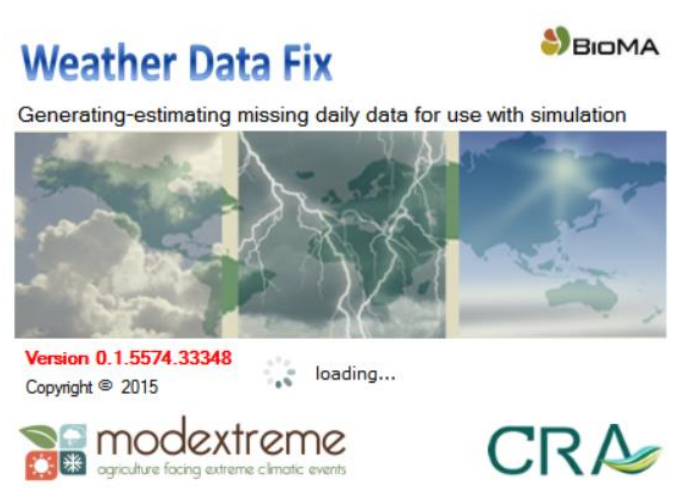
The software developed, WDF – Weather Data Fix (and ClimGen generation) was developed (development still on going for some functionalities) with two targets:

1 Develop a tool to be used as weather generator as a complementary tool to the suite developed in the project for crop/plant simulations;
2 Create utilities to build time series ready to use in the applications being developed by the project, having conversion of units problems.

The help file (still under development) is at:

http://components.biomamodelling.org/components/wdfix/help.

The program is currently capable to generate time series from parameter sets, as the ones developed and made available for the whole Europe for the climate scenarios described in section 1.1. It also allows importing time series and adding missing variables/records based on the generation capabilities of the ClimGen reimplementation.



2. Results

The changes in the parameters of air temperature yielded the expected results, whereas for rainfall in a few cases the results were probably affected by the number of daily records generated – likely too small.

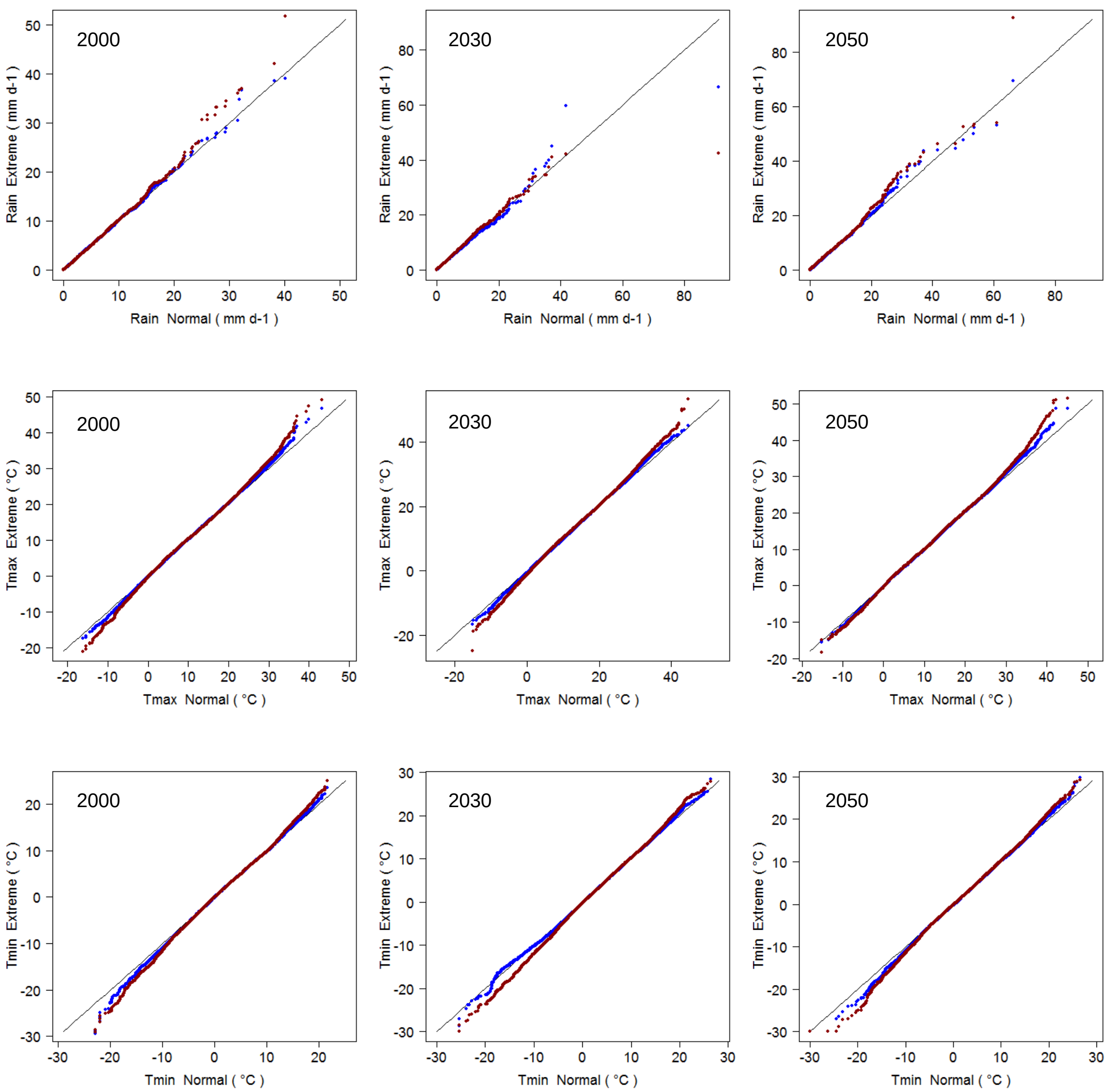


Figure 2. *Diagrams comparing the time-series generated from simple GCM projections against time-series with altered parameters, causing high presence of extreme events. The first line represents precipitation while the second and third lines represent maximum and minimum daily air temperatures, respectively. These results refer to the grid point n. 76116 (Table 1). Blue and red symbols represent increases of variability of 15% and 30%, respectively.*

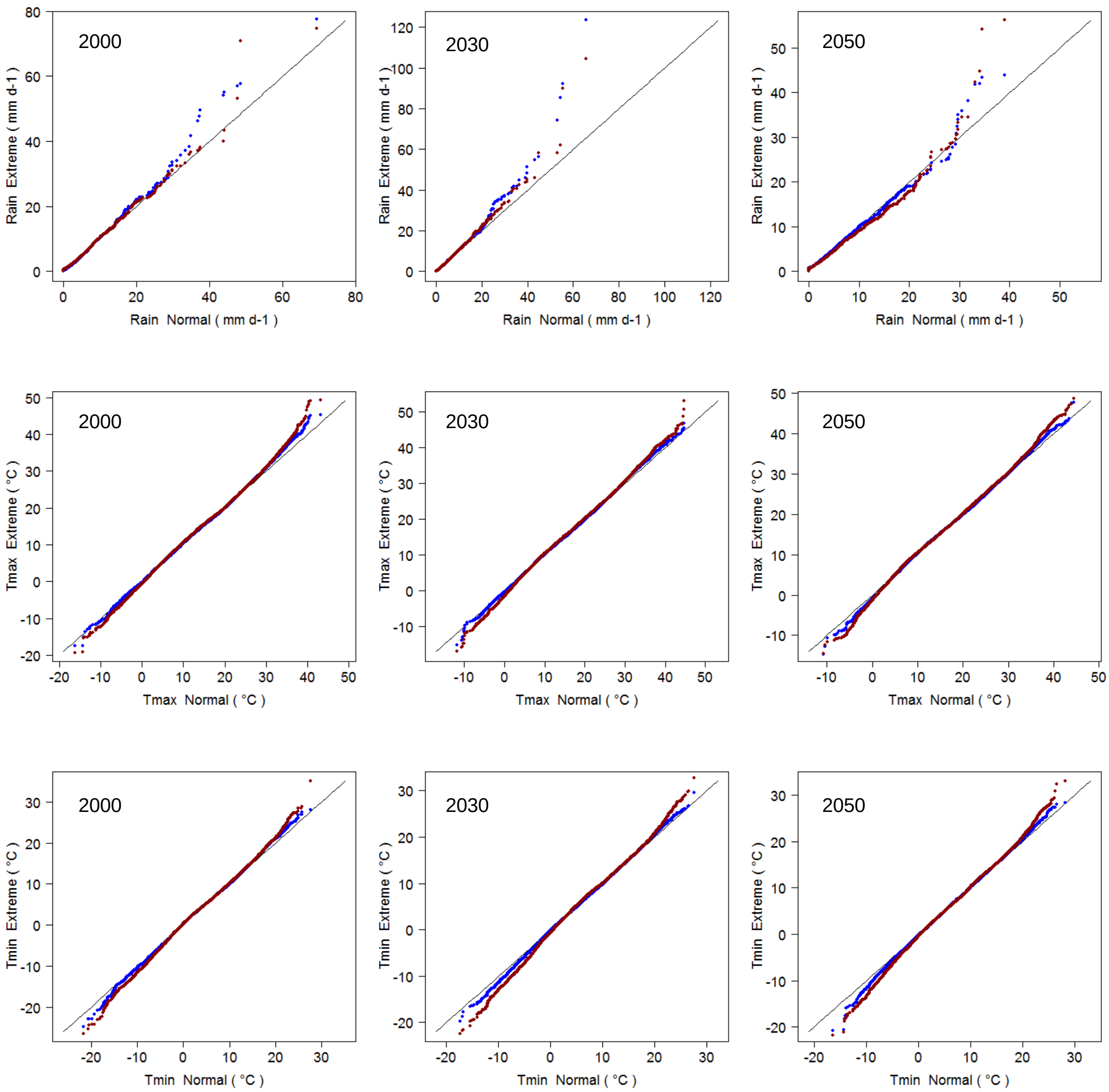


Figure 3. *Diagrams comparing the time-series generated from simple GCM projections against time-series with altered parameters, causing high presence of extreme events. The first line represents precipitation while the second and third lines represent maximum and minimum daily air temperatures, respectively. These results refer to the grid point n. 76104 (Table 1). Blue and red symbols represent increases of variability of 15% and 30%, respectively.*

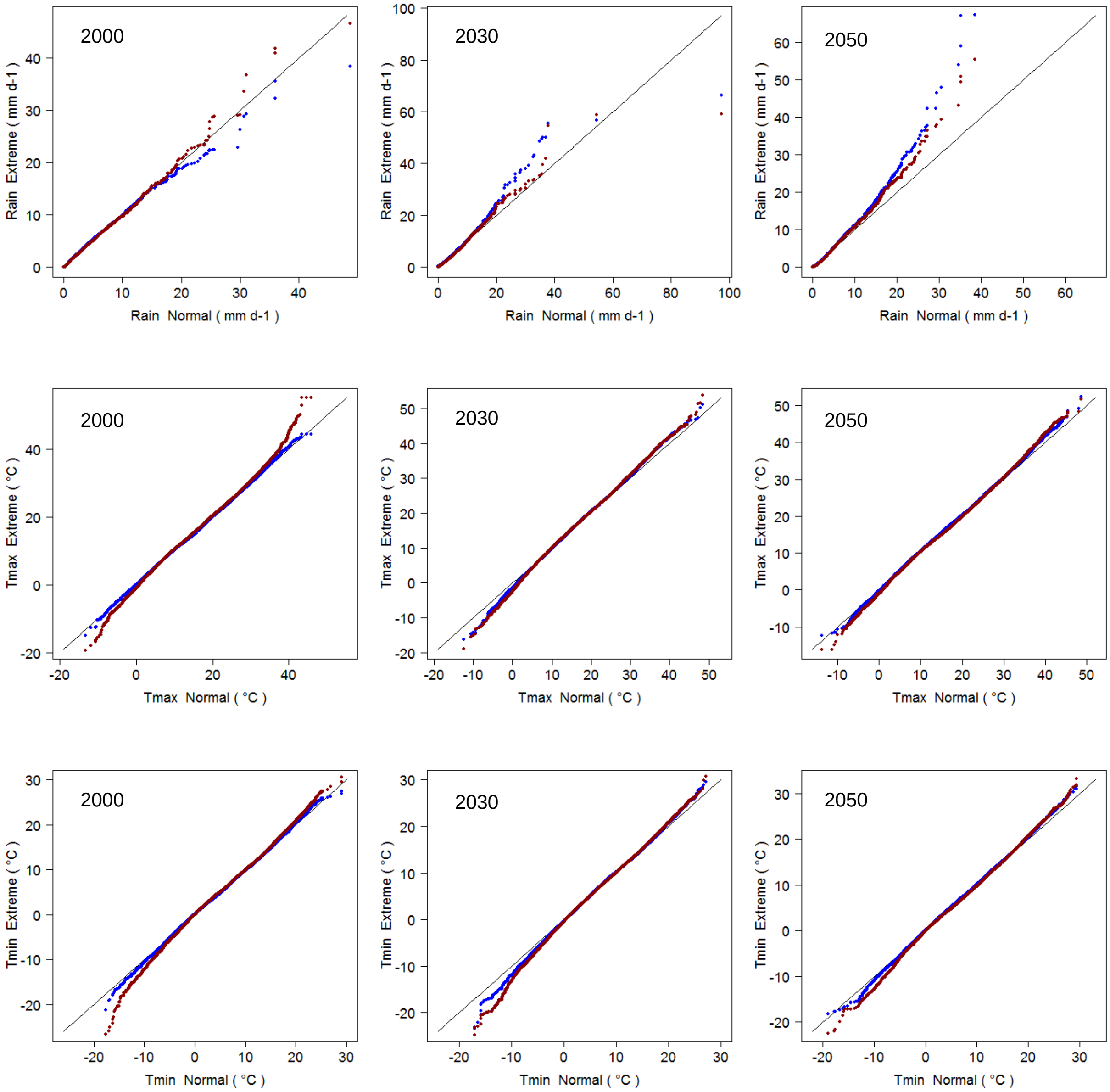


Figure 4. *Diagrams comparing the time-series generated from simple GCM projections against time-series with altered parameters, causing high presence of extreme events. The first line represents precipitation while the second and third lines represent maximum and minimum daily air temperatures, respectively. These results refer to the grid point n. 60119 (Table 1). Blue and red symbols represent increases of variability of 15% and 30%, respectively.*

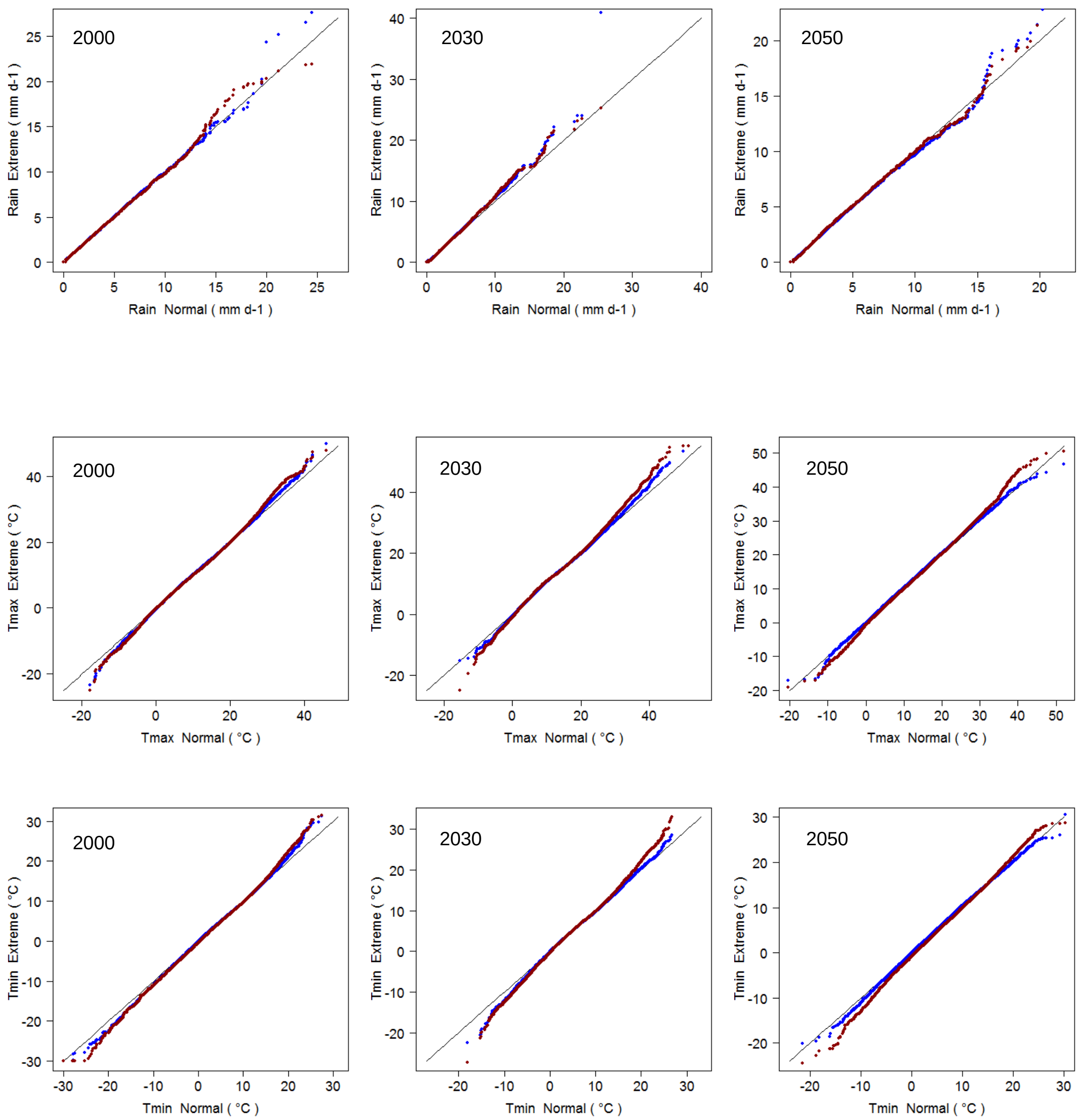


Figure 5. *Diagrams comparing the time-series generated from simple GCM projections against time-series with altered parameters, causing high presence of extreme events. The first line represents precipitation while the second and third lines represent maximum and minimum daily air temperatures, respectively. These results refer to the grid point n. 94088 (Table 1). Blue and red symbols represent increases of variability of 15% and 30%, respectively.*

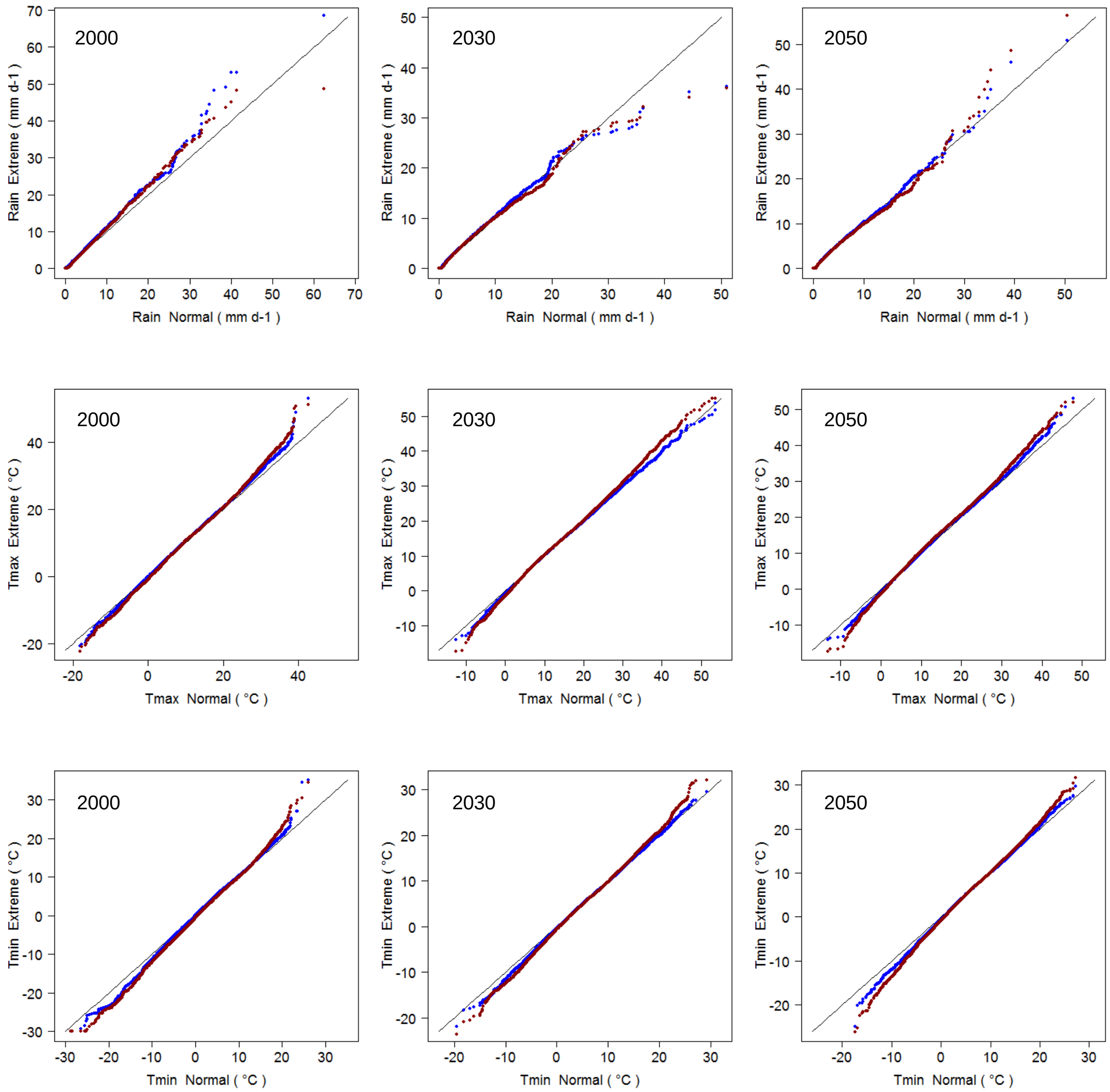


Figure 6. *Diagrams comparing the time-series generated from simple GCM projections against time-series with altered parameters, causing high presence of extreme events. The first line represents precipitation while the second and third lines represent maximum and minimum daily air temperatures, respectively. These results refer to the grid point n. 90079. Blue and red symbols represent increases of variability of 15% and 30%, respectively.*

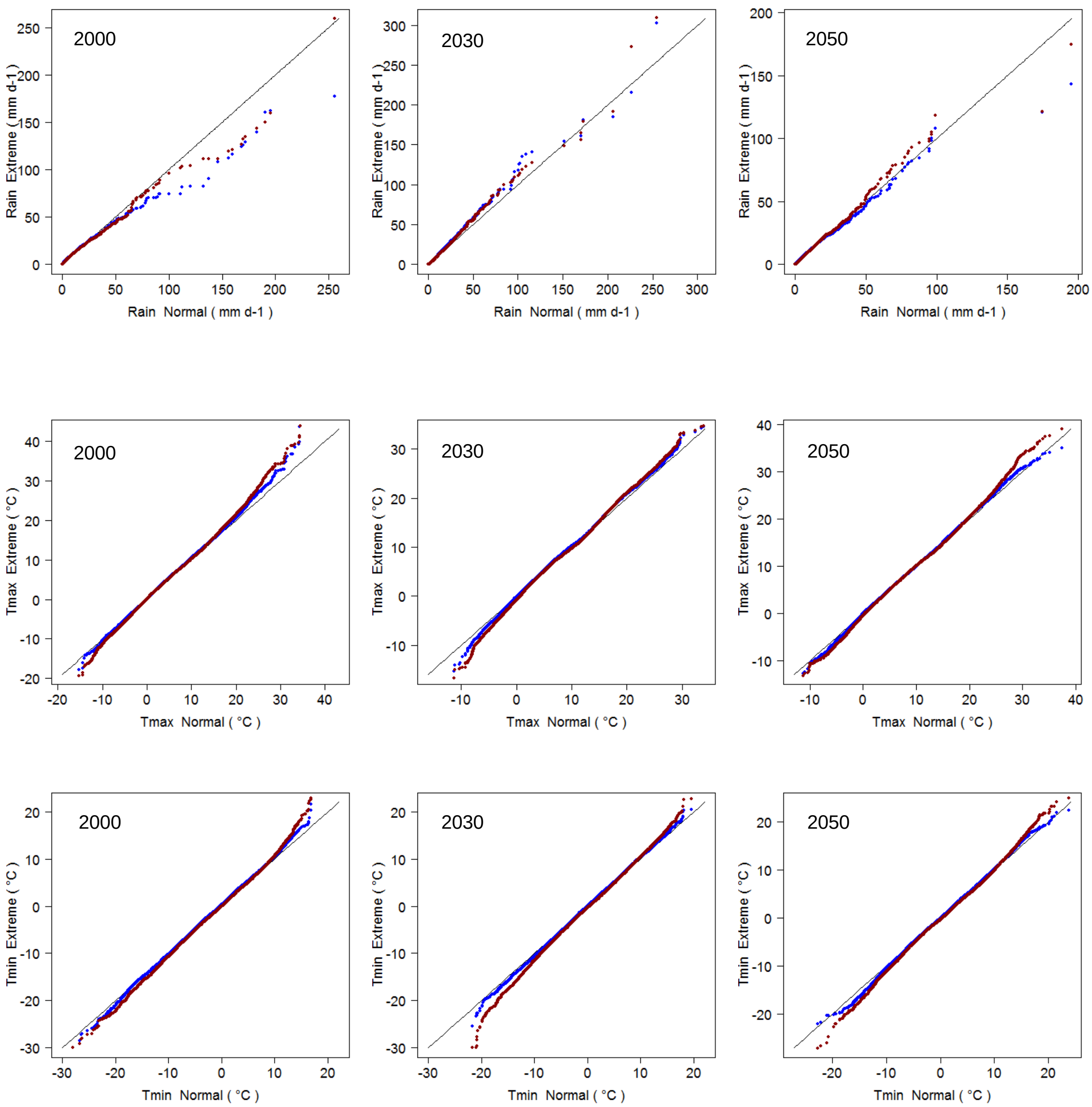


Figure 7. *Diagrams comparing the time-series generated from simple GCM projections against time-series with altered parameters, causing high presence of extreme events. The first line represents precipitation while the second and third lines represent maximum and minimum daily air temperatures, respectively. These refer to the grid point n. 74075 (Table 1). Blue and red symbols represent increases of variability of 15% and 30%, respectively.*

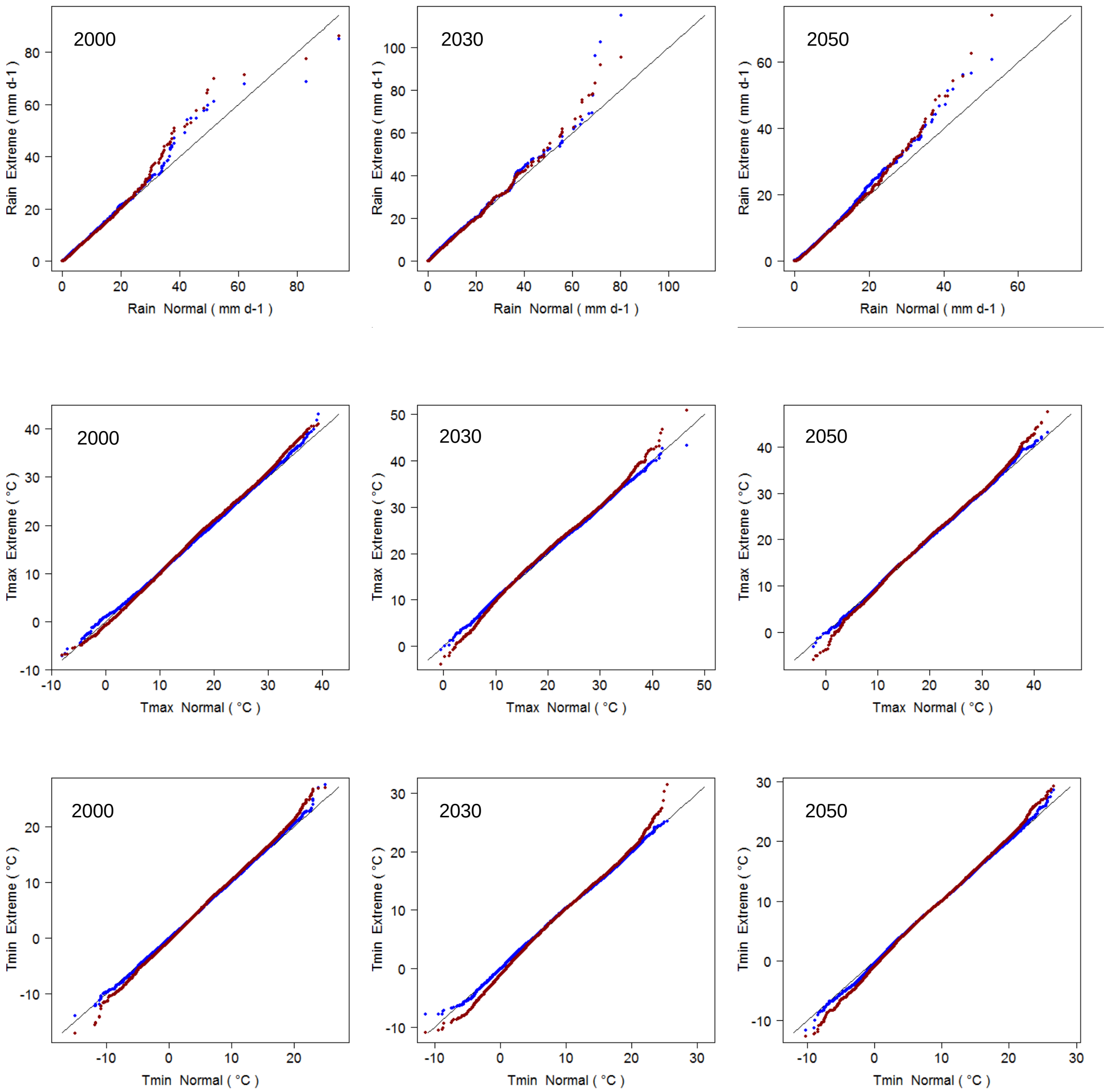


Figure 8. *Diagrams comparing the time-series generated from simple GCM projections against time-series with altered parameters, causing high presence of extreme events. The first line represents precipitation while the second and third lines represent maximum and minimum daily air temperatures, respectively. These results refer to the grid point n. 59078. Blue and red symbols represent increases of variability of 15% and 30%, respectively.*

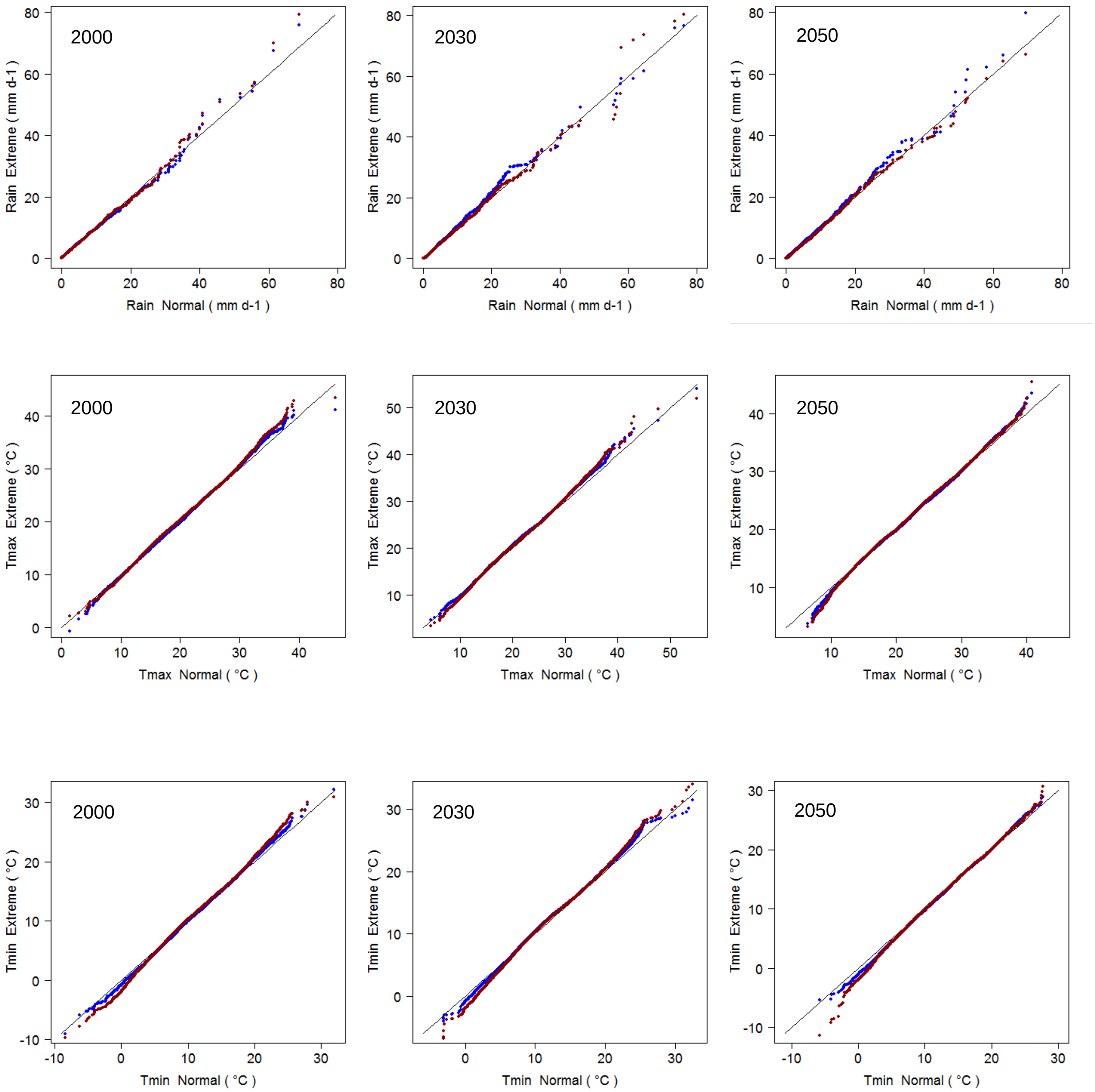


Figure 9. *Diagrams comparing the time-series generated from simple GCM projections against time-series with altered parameters, causing high presence of extreme events. The first line represents precipitation while the second and third lines represent maximum and minimum daily air temperatures, respectively. These results refer to the grid point n. 45065. Blue and red symbols represent increases of variability of 15% and 30%, respectively.*

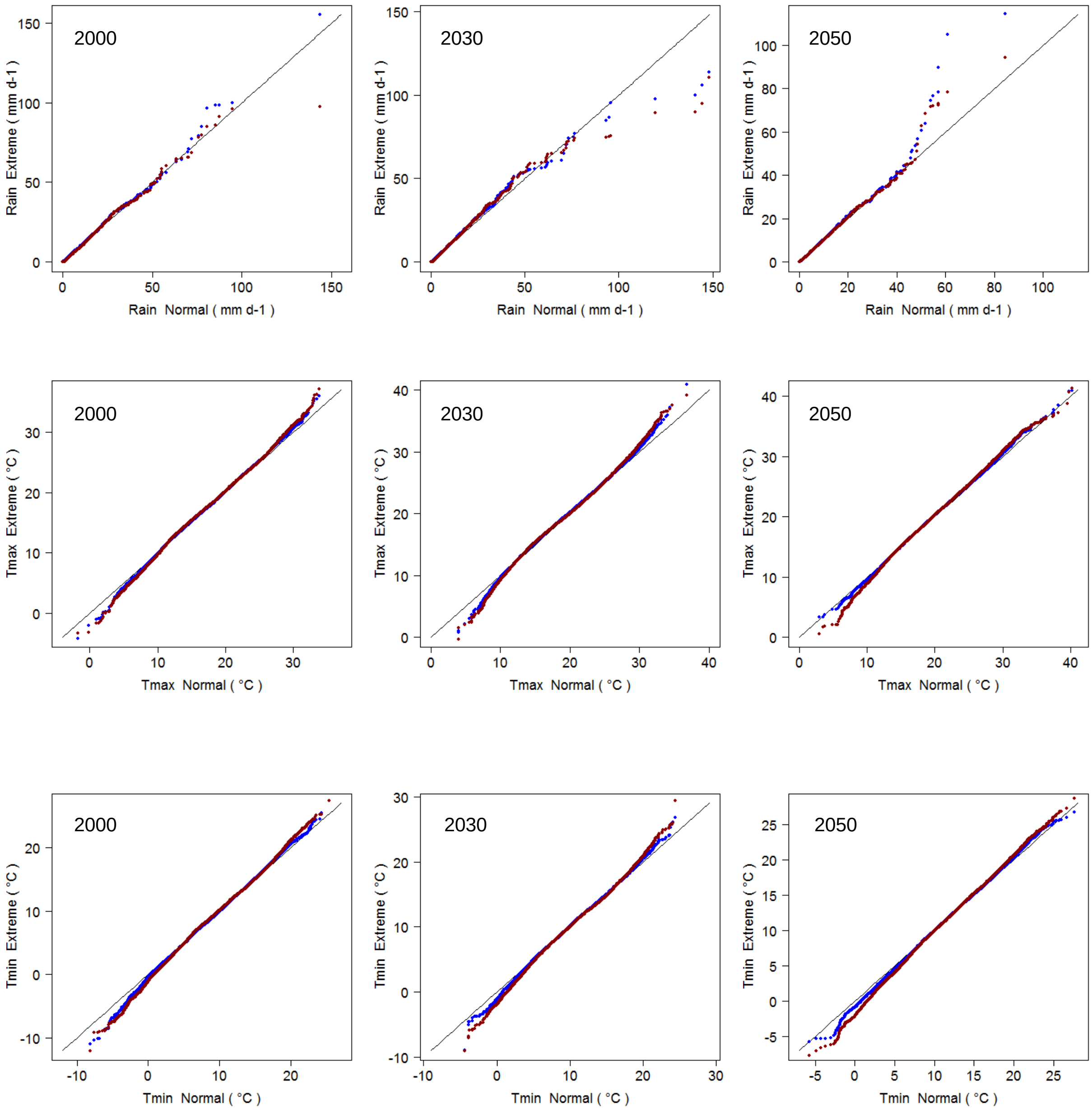


Figure 10. *Diagrams comparing the time-series generated from simple GCM projections against time-series with altered parameters, causing high presence of extreme events. The first line represents precipitation while the second and third lines represent maximum and minimum daily air temperatures, respectively. These refer to the grid point n. 57067 (Table 1). Blue and red symbols represent increases of variability of 15% and 30%, respectively.*

3. Conclusions

As for objective one, i.e. making available for crop simulations current and future scenarios, a DB including data covering at a 25 km grid France, Italy and Spain is in the MODEXTREME server and can be used by the simulation tools being developed by the project.

Perturbed time series were also made available for testing purpose, in a comparative fashion, if old and new modelling solutions will demonstrate a different sensitivity to the increase of variability synthetically generated in weather data.

References

Baron, C., Sultan, B., Balme, M., Sarr, B., Traore, S., Lebel, T., Janicot, S., Dingkuhn, M., 2005. From GCM grid cell to agricultural plot: scale issues affecting modelling of climate impact. Philosophical Transactions of the Royal Society B: Biological Sciences 360, 2095-2108.

Christensen, J.H., Boberg, F., Christensen, O.B., Lucas-Picher, P., 2008. On the need for bias correction of regional climate change projections of temperature and precipitation. Geophysical Research Letters 35, L20709.

Donatelli, M., Fumagalli, D., Zucchini, A., Duveiller, G., Nelson, R.L., Baruth, B., 2012. A EU27 Database of Daily Weather Data Derived from Climate Change Scenarios for Use with Crop Simulation Models. In: Seppelt, R., Voinov, A.A., Lange, S., Bankamp, D. (Eds.) International Environmental Modelling and Software Society (iEMSs), 2012 International Congress on Environmental Modelling and Software, Managing Resources of a Limited Planet, Sixth Biennial Meeting, July 1-5, Leipzig, Germany, pp. 868-875. http://www.iemss.org/sites/iemss2012//proceedings/C3_0815_Donatelli_et_al.pdf

Dosio, A., Paruolo, P., 2011. Bias correction of the ENSEMBLES high-resolution climate change projections for use by impact models: Evaluation on the present climate. Journal of Geophysical Research 116, D16106.

Hansen, J.W., Challinor, A., Ines, A., Wheeler, T., Moron, V., 2006. Translating climate forecasts into agricultural terms: advances and challenges. Climate Research 33, 27-41.

Hansen, J.W., Jones, J.W., 2000. Scaling-up crop models for climate variability applications. Agricultural Systems 65, 43–72.

IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg2_report_impacts_adaptation_and_vulnerability.htm

Mearns, L.O., Rosenzweig, C., Goldberg, R., 1996. The effect of changes in daily and interannual climatic variability on CERES-Wheat: A sensitivity study. Climatic Change 32, 257–292.

Osborne, T.M., Lawrence, D.M., Challinor, A.J., Slingo, J.M., Wheeler, T.R., 2007. Development and assessment of a coupled crop–climate model. Global Change Biology 13, 169–183.

Semenov, M.A., Porter, J.R., 1995. Climatic variability and the modelling of crop yields. Biospheric Aspects of the Hydrological Cycle 73, 265–283.

Stöckle, C., Nelson, R., Donatelli, M., Castellvi, F., 2001. ClimGen: a flexible weather generation program. In: 2nd International Symposium Modelling Cropping Systems, July 16-18, Florence, Italy. pp. 16-18.

Teutschbein, C., Seibert, J., 2010. Regional Climate Models for Hydrological Impact Studies at the Catchment Scale: A Review of Recent Modeling Strategies. Geography Compass 4, 834-860.