Generalized drought index: A novel multi-scale daily approach for drought assessment

João António Martins Careto[1], Rita Margarida Cardoso[1], Ana Russo[1], Daniela Catarina André Lima[1], Pedro Miguel Matos Soares[1]

[1] Universidade de Lisboa,Faculdade de Ciências,Instituto Dom Luiz, 1749-016 Lisbon, Portugal.

Correspondence to: João Careto (jacareto@ciencias.ulisboa.pt)

Table 1. Regional models forced by the ERA-Interim reanalysis from the European Centre for Medium-Range Weather Forecasts, for the 1989-2008 period.

RCM	Reference	acronym
CLMcom-CCLM4-8-17	Keuler et al. (2016)	CCLM
ETH-COSMO-crCLIM-v1-1	Pothapakula et al. (2020), Vautard et al. (2020)	ETH
CNRM-ALADIN53	Colin et al. (2010), Herrmann et al. (2011)	CNRM53
CNRM-ALADIN63	Daniel et al. (2019), Nabat et al. (2020)	CNRM63
DHMZ-RegCM4-2	Giorgi et al. (2012)	DHMZ
DMI-HIRHAM5	Christensen et al. (2007)	DMI
GERICS-REMO2015	Remedio et al. (2019)	GERICS
ICTP-RegCM4-6	Giorgi et al. (2012)	ICTP
IPSL-INERIS-WRF381P	Vautard et al. (2013)	IPSL
KNMI-RACMO22E	van Meijgaard et al. (2008)	KNMI
MPI-CSC-REMOO2009	Jacob et al. (2012)	MPI
SMHI-RCA4	Samuelsson et al. (2011)	SMHI

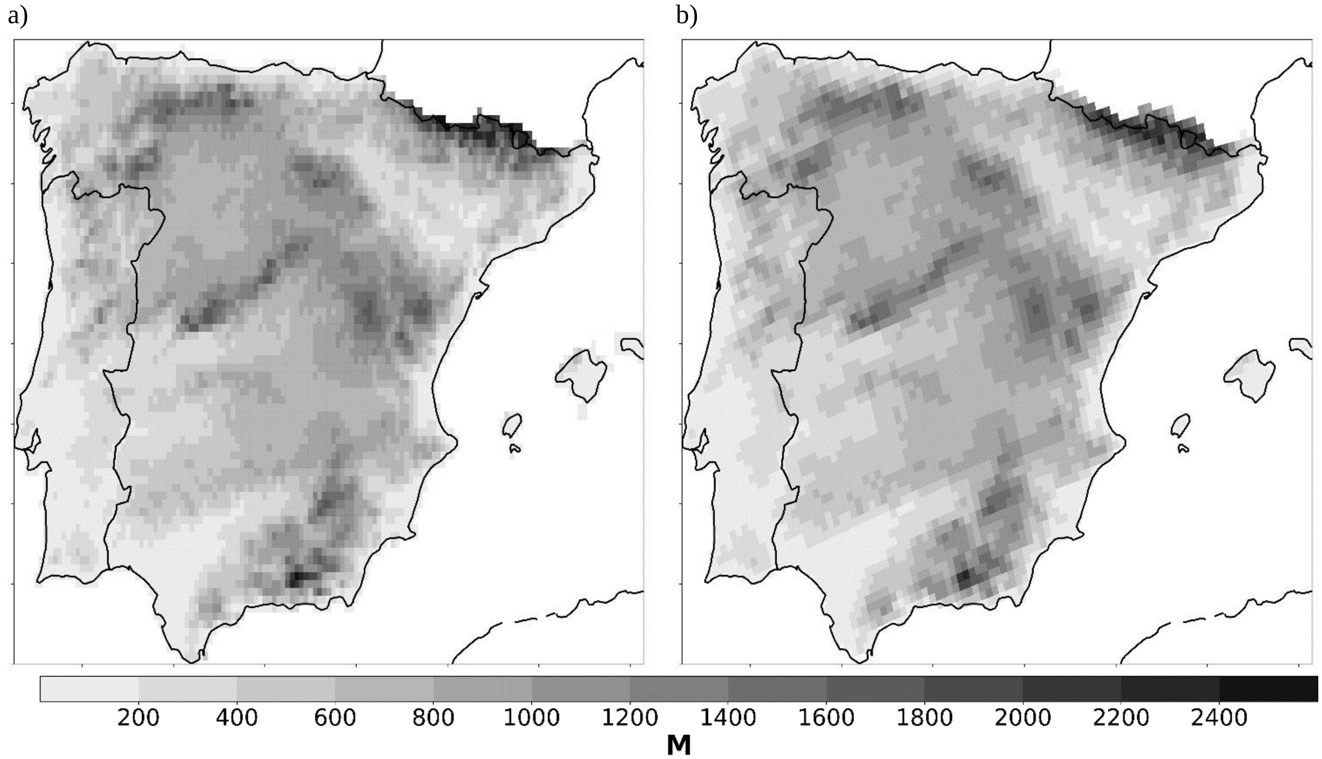


Figure S1. Orography for (a) IB01 dataset at 0.1° resolution and (b) the EURO-CORDEX orography at 0.11°.

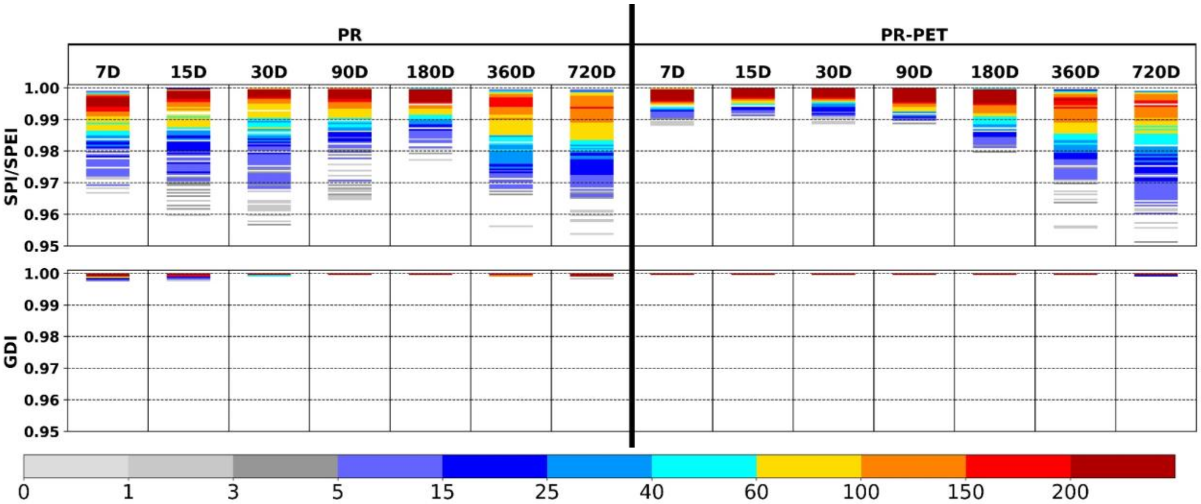


Figure S2. Coefficient of determination between the empirical cumulative distribution and the probabilities given by the log-logistic distribution used for both SPI and SPEI indices (top row). On the bottom row is the coefficient of determination between the empirical cumulative distribution and the probabilities given by the smoothing of the histogram as computed in section 4.3.3. The closer the coefficient is to 1, the better the fit of the observed and modelled probabilities. Each column denotes the accumulation periods, where PR stands for accumulated precipitation (left) and PR-PET stands for accumulated precipitation minus potential evapotranspiration (right). The lines represent each land point for the IB01 observations. The different colours are a measure of density given by counting the number of occurrences within each horizontal strip with a thickness of 0.001.

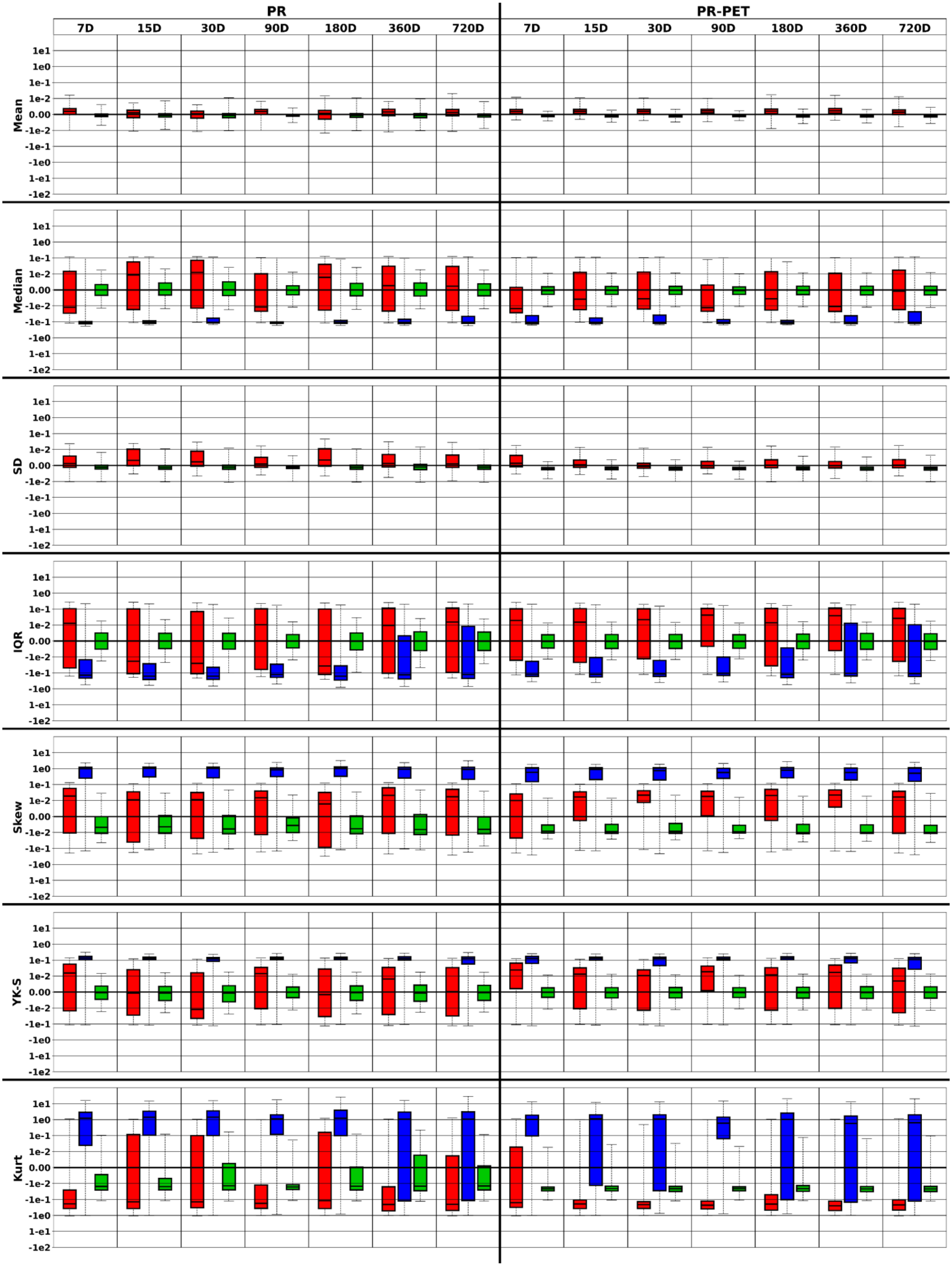

PR
PR-PET
7D
15D
30D
90D
180D
360D
720D
Mean
Median
SD
IQR
Skew
YK-S
Kurt
1e1
1e0
1e-1
1e-2
0.00
-1e-2
-1e-1
-1e0
-1e1
-1e2

Figure S3. Statistics for the SPI/SPEI (red), Z-Score standardization (blue) and DTI (green) indexes. From top to bottom, the rows are Mean, Median, Standard Deviation minus 1, Interquartile range minus the difference between the 75th and the 25th percentile from the standard normal distribution, third-moment Skewness, Yule-Kendall Skewness, fourth-moment Fisher definition of Kurtosis. Each column denotes the accumulation periods, where PR stands for accumulated precipitation indices while PR-PET stands for accumulated precipitation minus potential evapotranspiration indices.

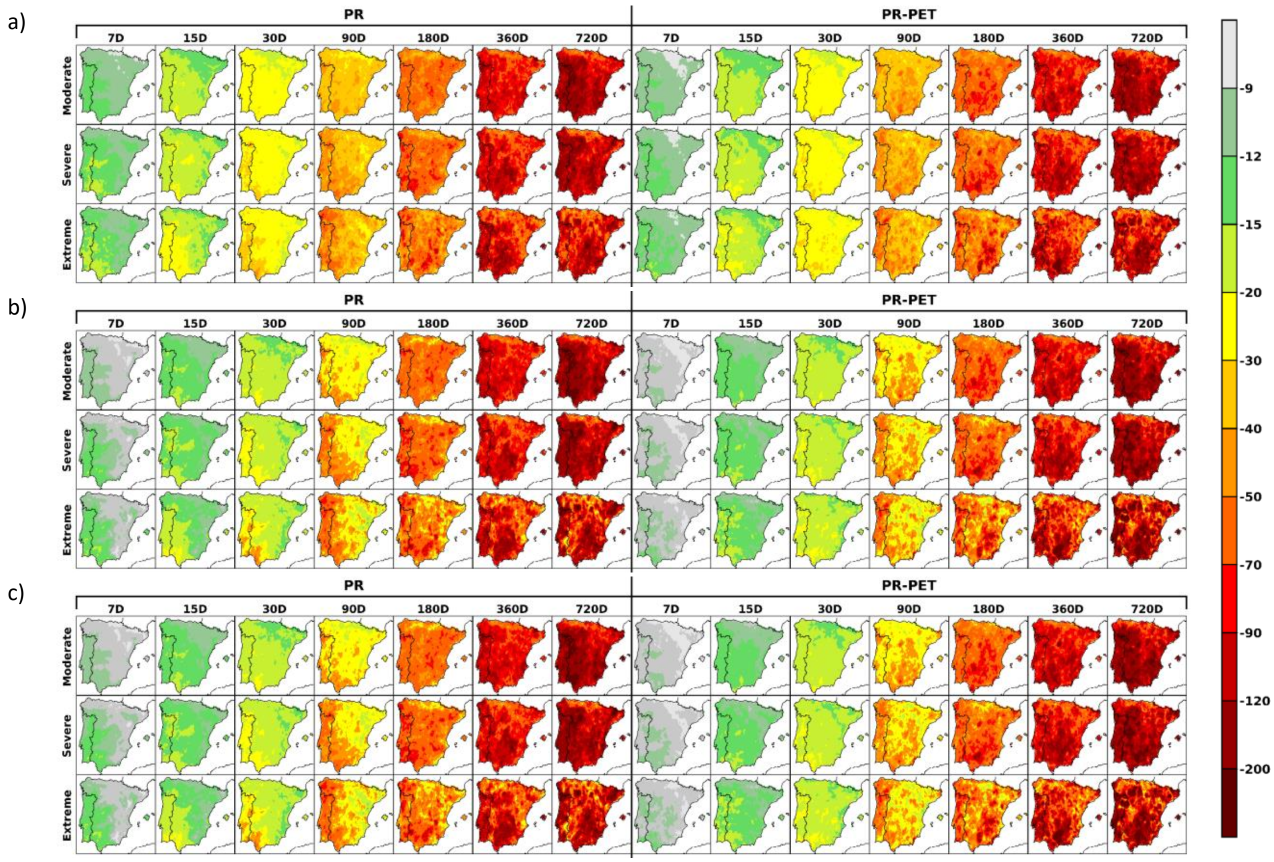


Figure S4: Mean Event Severity for (a) GDI index, (b) SPI or SPEI and (c) Z-Score index. In each panel the results for moderate, severe and extreme drought are shown. Each column denotes the accumulation periods, where PR stands for accumulated precipitation indices while PR-PET stands for accumulated precipitation minus potential evapotranspiration indices.

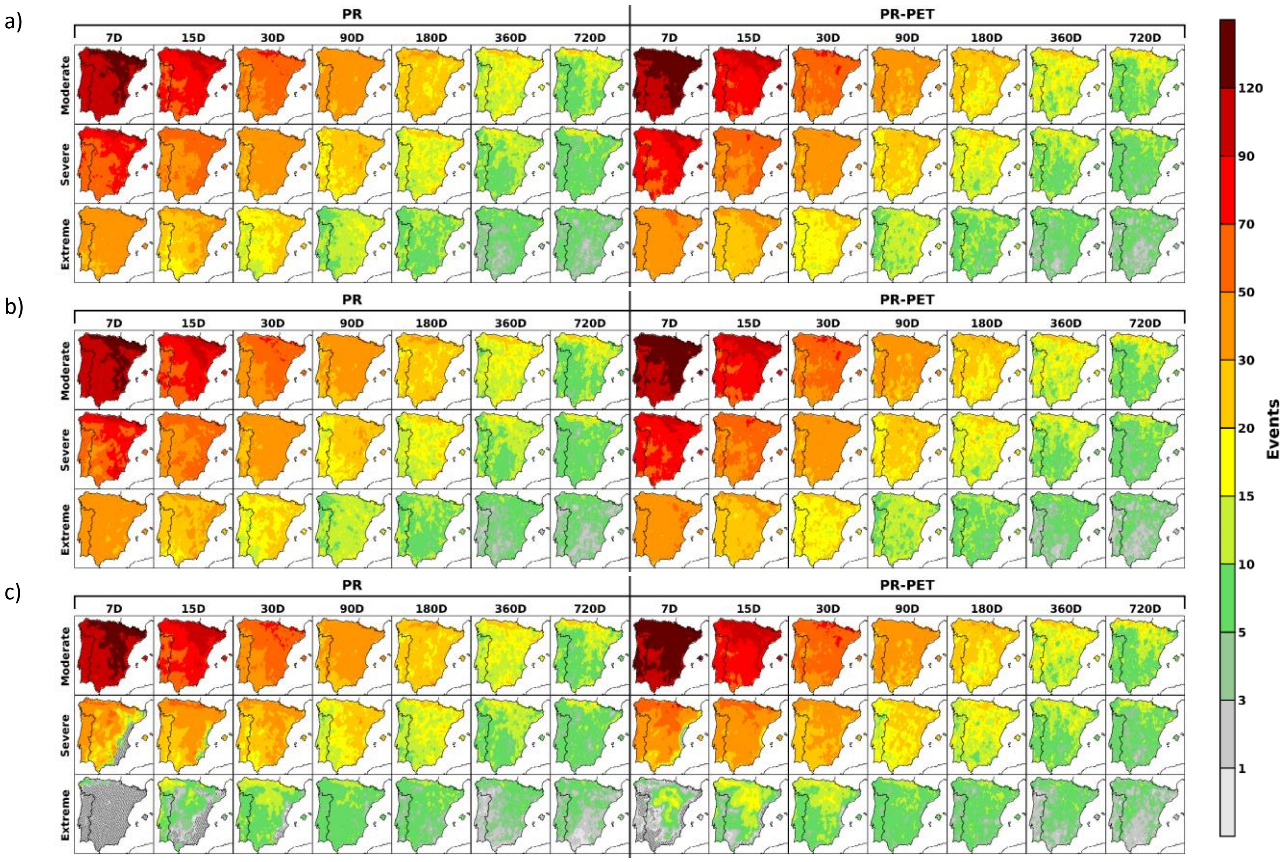


Figure S5: Decadal Event Frequency for (a) GDI index, (b) SPI or SPEI and (c) Z-Score index. In each panel the results for moderate, severe and extreme drought are shown. Each column denotes the accumulation periods, where PR stands for accumulated precipitation indices while PR-PET stands for accumulated precipitation minus potential evapotranspiration indices.

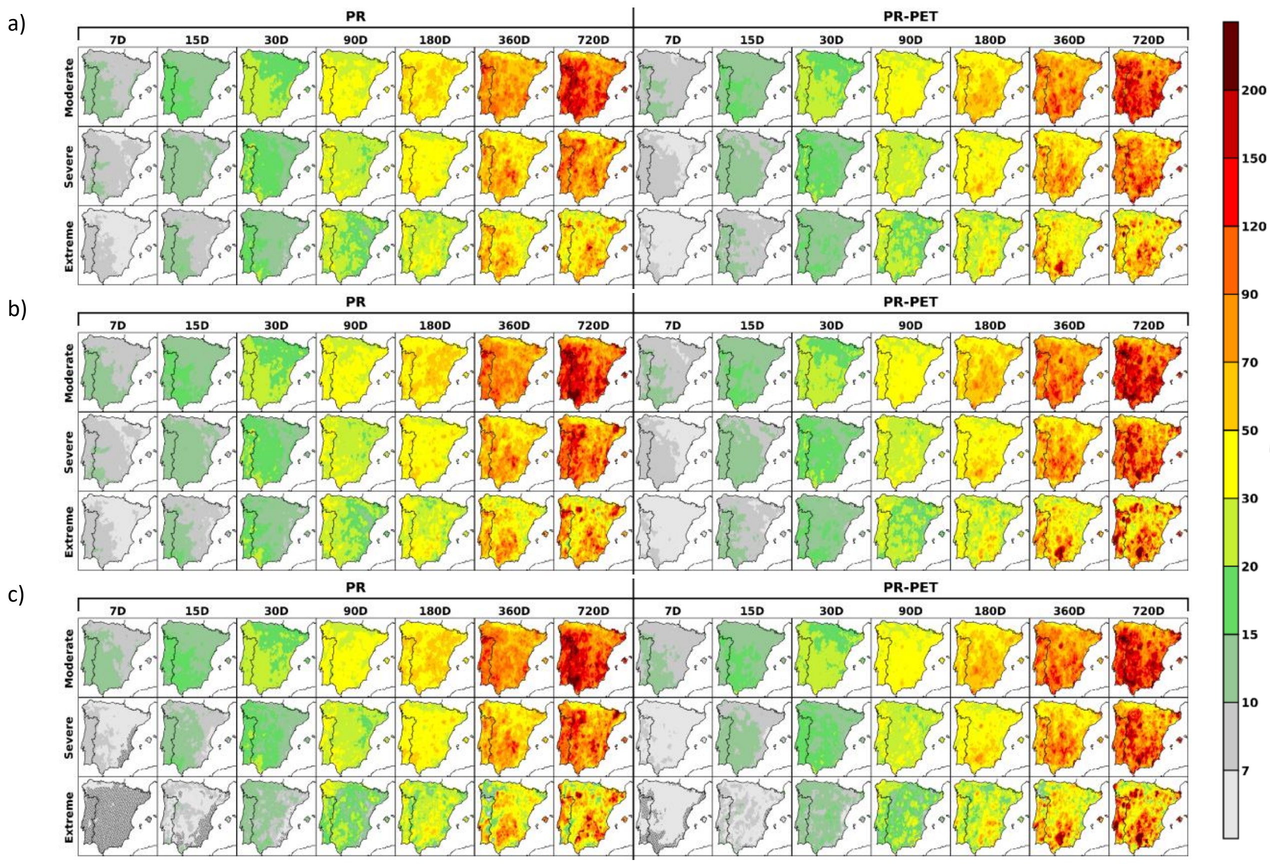


Figure S6: Mean Event Duration for (a) GDI index, (b) SPI or SPEI and (c) Z-Score index. In each panel the results for moderate, severe and extreme drought are shown. Each column denotes the accumulation periods, where PR stands for accumulated precipitation indices while PR-PET stands for accumulated precipitation minus potential evapotranspiration indices.

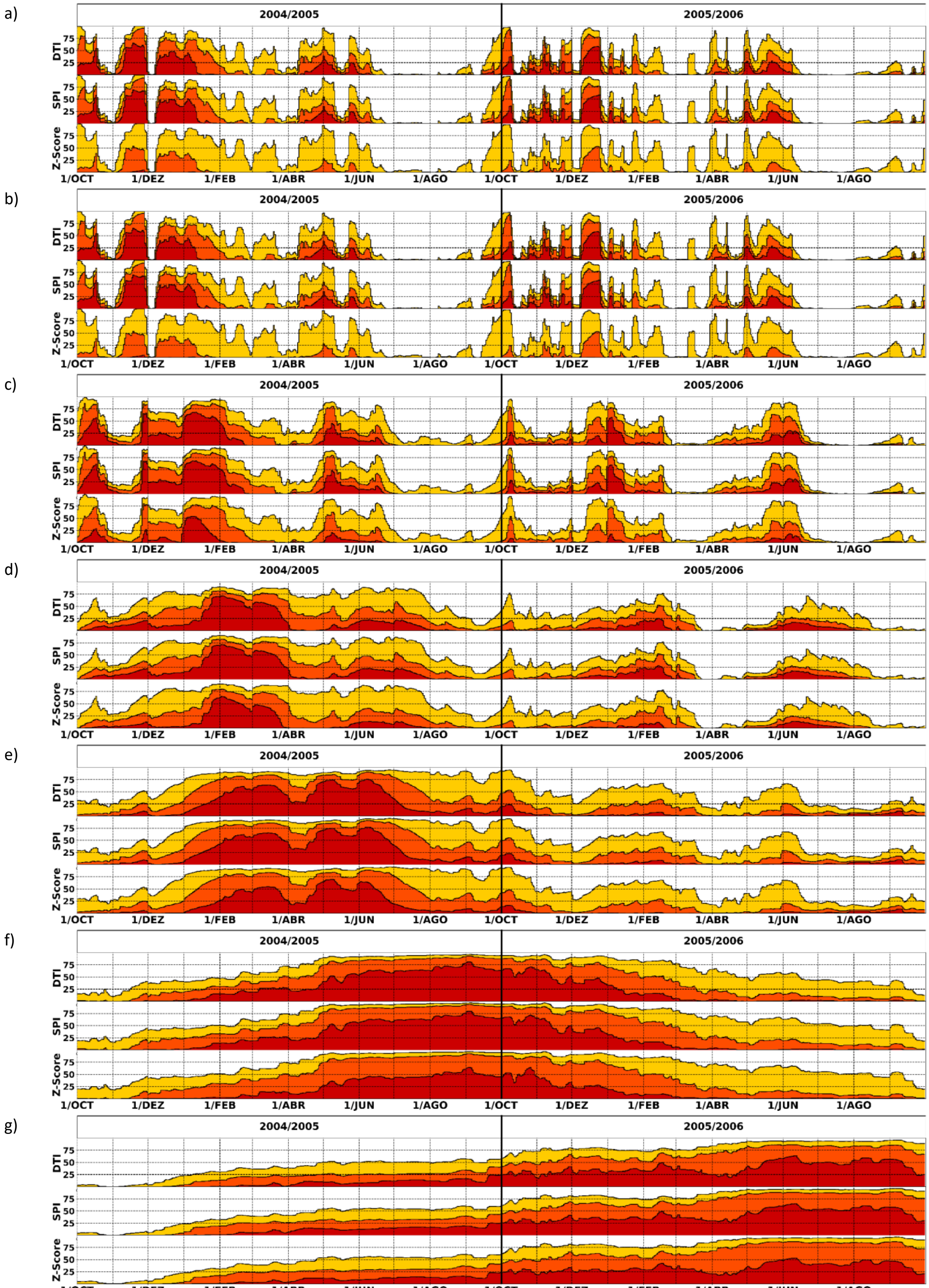

a)
2004/2005
2005/2006
DTI
SPI
Z-Score
75
50
25
1/OCT
1/DEZ
1/FEB
1/ABR
1/JUN
1/AGO
1/OCT
1/DEZ
1/FEB
1/ABR
1/JUN
1/AGO
b)
c)
d)
e)
f)
g)

Figure S7. Time series of the daily drought spatial extent of the period from 1 October 2004 until 30 September 2006 for the IB01 with aggregations of (a) 7-, (b) 15-, (c) 30-, (d) 90-, (e) 180-, (f) 360- and (g) 720-days. In each panel the top row displays the results for the GDI index, the middle row for the SPI index and the bottom row for the Z-Score standardization. All indices consider only the precipitation. The yellow colour denotes the results for moderate drought for index <-0.5, light orange for severe drought for index <-1 and dark orange for extreme drought for index <-1.5.

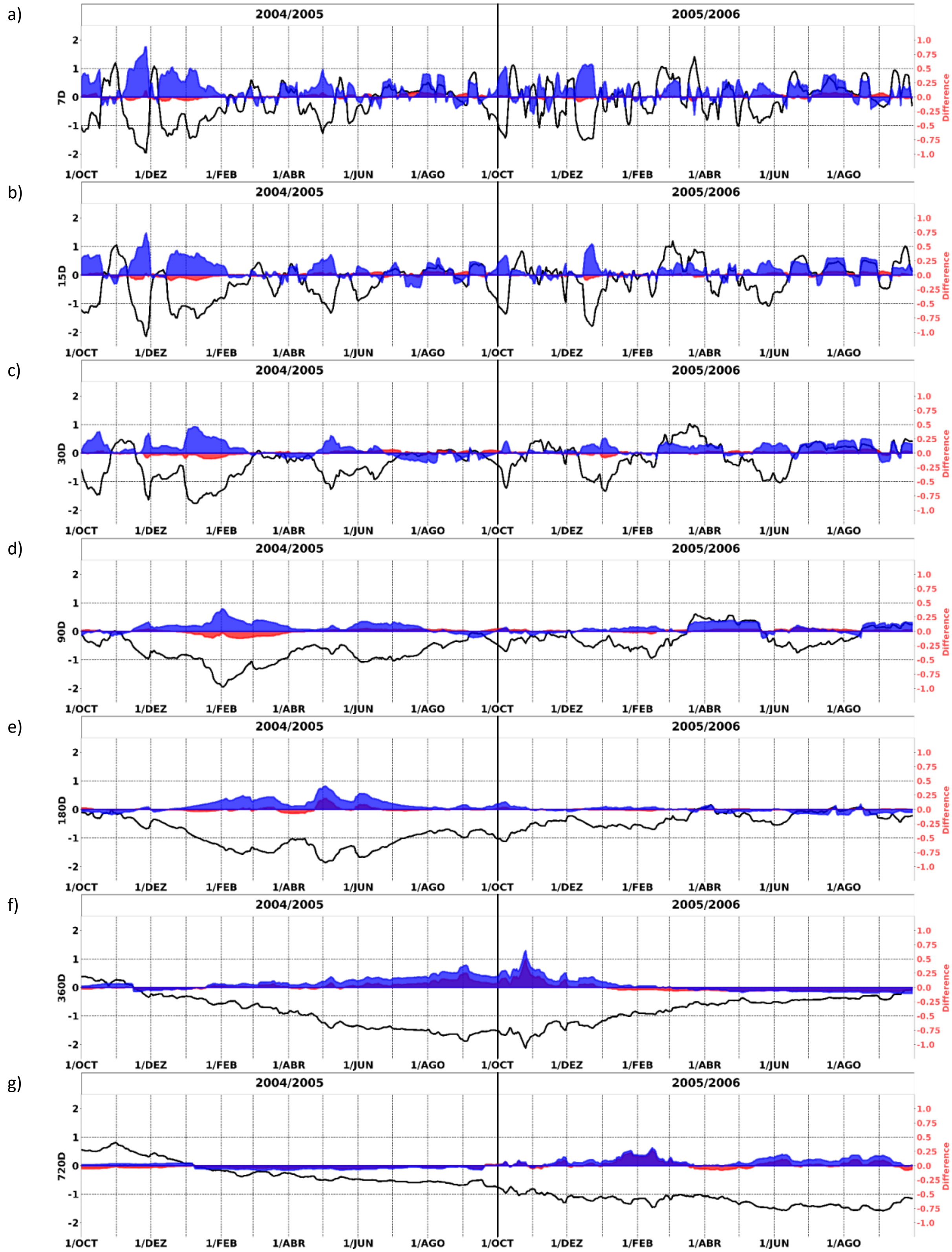
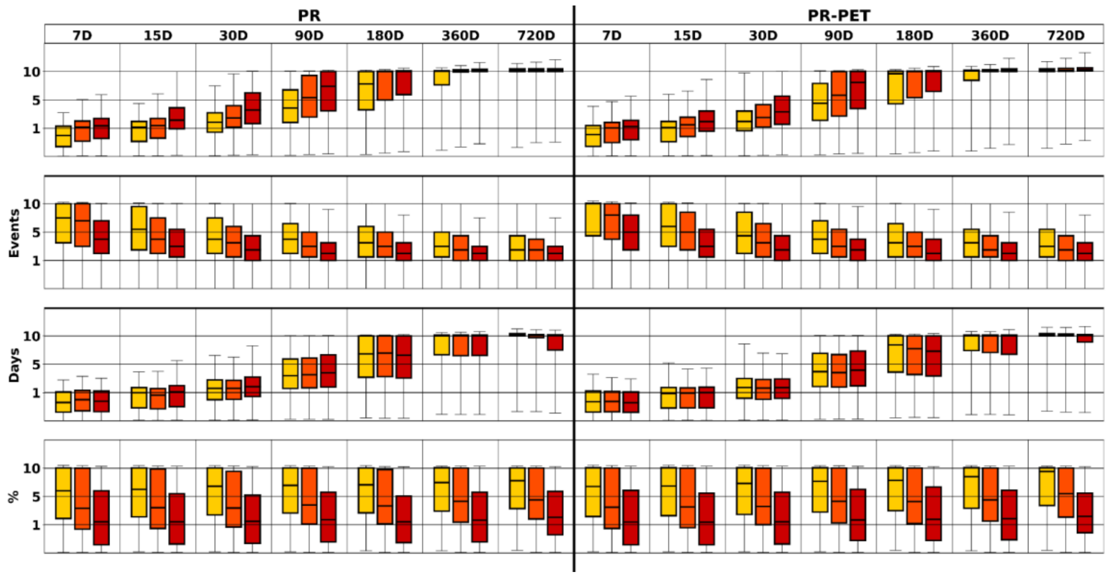
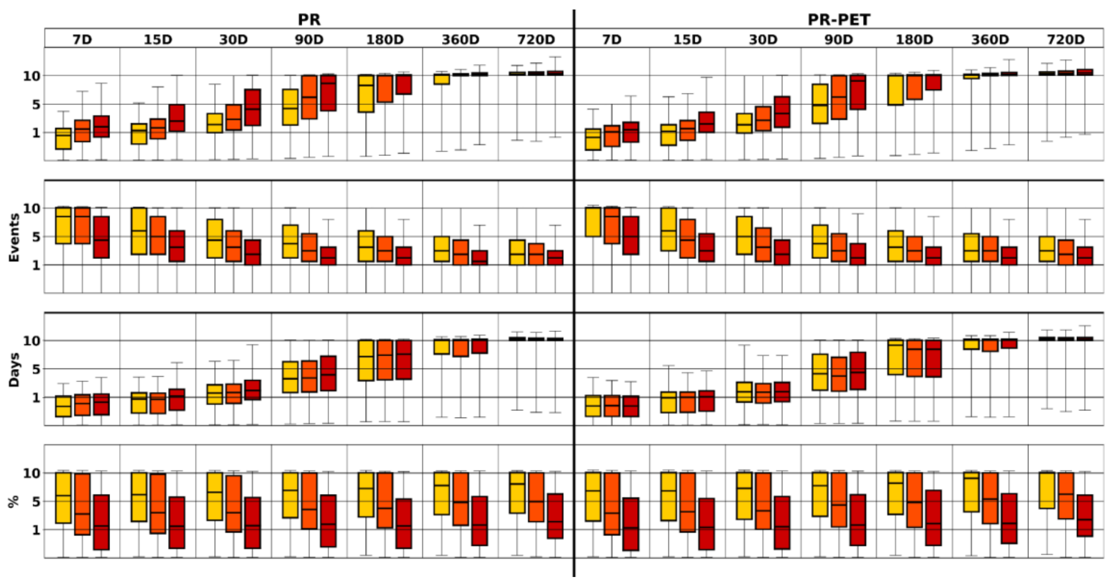


Figure S8: Area average time series of the daily drought indices for the period from 1 October 2004 until 30 September 2006 for the IB01 dataset with aggregations of (a) 7-, (b) 15-, (c) 30-, (d) 90-, (e) 180-, (f) 360- and (g) 720-days. The black line represents the GDI index, while the red and blue shadings denote, respectively, the absolute differences between the GDI and SPI and between GDI and the Z-Score index. All indices only consider the precipitation a input.

a)


PR
PR-PET
7D
15D
30D
90D
180D
360D
720D
Events
Days
%
10
5
1

b)


PR
PR-PET
7D
15D
30D
90D
180D
360D
720D
Events
Days
%
10
5
1

c)

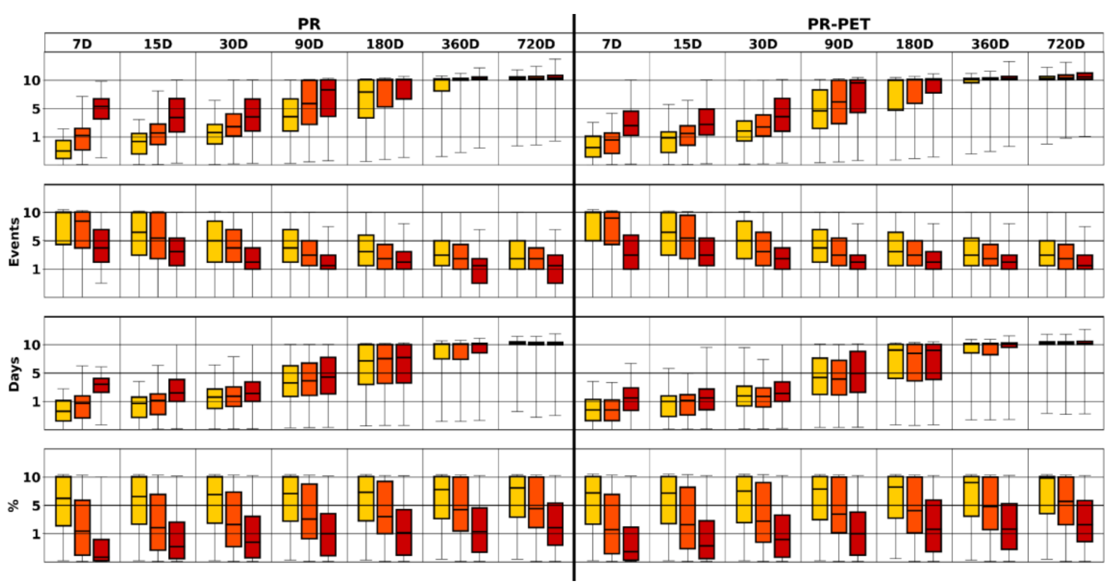

PR
PR-PET
7D
15D
30D
90D
180D
360D
720D
Events
Days
%
10
5
1

Figure S9. Boxplots for the(a) DTI bias, (b) SPI and SPEI bias and (c) Z-Score bias between the EURO-CORDEX simulations and the IIB01 observational dataset. Each boxplot features the results obtained for all the land points and EURO-CORDEX models. The results for moderate drought are shown in yellow, while the results for severe drought are shown in orange and the results for extreme drought are shown on red.

References

Christensen, O.B., Drews, M., Christensen, J.H., Dethloff, K., Ketelsen, K., Hebestadt, I. and Rinke, A., (2007) The HIRHAM regional climate model. Version 5 (beta), https://www.dmi.dk/fileadmin/Rapporter/TR/tr06-17.pdf (Last access on 1st August 2023)

Colin, J., Déqué, M., Radu, R. and Somot, S., (2010) Sensitivity study of heavy precipitation in Limited Area Model climate simulations: influence of the size of the domain and the use of the spectral nudging technique, Tellus A: Dynamic Meteorology and Oceanography, 62, 591-604, https://www.doi.org/10.1111/j.1600-0870.2010.00467.x

Daniel, M., Lemonsu, A., Déqué, M., Somot, S., Alias, A. and Masson, V., (2019) Benefits of explicit urban parameterization in regional climate modeling to study climate and city interactions, Climate Dynamics, 52, 2745-2764, https://www.doi.org/10.1007/s00382-018-4289-x

Giorgi, F., Coppola, E., Solmon, F., Mariotti, L., Sylla, M.B., Bi, X., Elguindi, N., Diro, G.T., Nair, V., Giuliani, G. and Turuncoglu, U.U., (2012) RegCM4: model description and preliminary tests over multiple CORDEX domains, Climate Research, 52, 7-29, https://www.doi.org/10.3354/cr01018

Herrmann, M., Somot, S., Calmanti, S., Dubois, C., and Sevault, F., (2011) Representation of spatial and temporal variability of daily wind speed and of intense wind events over the Mediterranean Sea using dynamical downscaling: impact of the regional climate model configuration, Nat. Hazards Earth Syst. Sci., 11, 1983–2001, https://www.doi.org/10.5194/nhess-11-1983-2011

Jacob, D., Elizalde, A., Haensler, A., Hagemann, S., Kumar, P., Podzun, R., Rechid, D., Remedio, A.R., Saeed, F., Sieck, K. and Teichmann., (2012) C. Assessing the transferability of the regional climate model REMO to different coordinated regional climate downscaling experiment (CORDEX) regions, Atmosphere, 3, 181-199, https://www.doi.org/10.3390/atmos3010181

Keuler, K., Radtke, K., Kotlarski, S., and Lüthi, D., (2016) Regional climate change over Europe in COSMO-CLM: Influence of emission scenario and driving global model, Meteorologische Zeitschrift, 25, 121–136, https://www.doi.org/10.1127/metz/2016/0662

Nabat, P., Somot, S., Cassou, C., Mallet, M., Michou, M., Bouniol, D., Decharme, B., Drugé, T., Roehrig, R., and Saint-Martin, D., (2020) Modulation of radiative aerosols effects by atmospheric circulation over the Euro-Mediterranean region, Atmos. Chem. Phys., 20, 8315–8349, https://www.doi.org/10.5194/acp-20-8315-2020

Pothapakula, P. K., Primo, C., Sørland, S., and Ahrens, B., (2020) The synergistic impact of ENSO and IOD on the Indian Summer Monsoon Rainfall in observations and climate simulations - an information theory perspective, Earth Syst, Dynam, 11, 903–923, https://www.doi.org/10.5194/esd11-903-2020

Remedio, A.R., Teichmann, C., Buntemeyer, L., Sieck, K., Weber, T., Rechid, D., Hoffmann, P., Nam, C., Kotova, L. and Jacob, D., (2019) Evaluation of new CORDEX simulations using an updated Köppen–Trewartha climate classification, Atmosphere, 10, 726, https://www.doi.org/10.3390/atmos10110726

Samuelsson, P., Jones, C.G., Will´ En, U., Ullerstig, A., Gollvik, S., Hansson, U.L.F., Jansson, E., Kjellstro¨ M, C., Nikulin, G. and Wyser, K., (2011) The Rossby Centre Regional Climate model RCA3: model description and performance. Tellus A: Dynamic Meteorology and Oceanography, 63, 4-23, https://www.doi.org/10.1111/j.1600-0870.2010.00478.x, 2011.

Vautard, R., Gobiet, A., Jacob, D., Belda, M., Colette, A., Déqué, M., Fernández, J., García-Díez, M., Goergen, K., Güttler, I. and Halenka, T., (2013) The simulation of European heat waves from an ensemble of regional climate models within the EURO-CORDEX project. Climate Dynamics, 4, 2555-2575, https://www.doi.org/10.1007/s00382-013-1714-z

Vautard, R., Kadygrov, N., Iles, C., Boberg, F., Buonomo, E., Buelow, K., Coppola, E., Corre, L., van Meijgaard, E., Nogherotto, R., Sandstad, M., Schwingshakl, C., Somot, S., Aalbers, E. E., Christensen, O., Ciarlo, J., Demory, M.-E., Giorgi, F., Jacob, D., Jones, R. G., Keuler, K., Kjellström, E., Lenderink, G., Levavasseur, G., Nikulin, G., Sillmann, J., Solidoro, C., Sørland, S., Steger, C., Teichmann, C., Warrach-Sagi, K., and Wulfmeyer, V., (2020) Evaluation of the large EURO-CORDEX regional climate model ensemble, Journal of Geophysical Research: Atmospheres, https://www.doi.org/10.1029/2019JD032344

van Meijgaard, E., Van Ulft, L.H., Van de Berg, W.J., Bosveld, F.C., Van den Hurk, B.J.J.M., Lenderink, G. and Siebesma, A.P., (2008) The KNMI regional atmospheric climate model RACMO, version 2.1 (p. 43), De Bilt, Netherlands: KNMI, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.475.9494&rep=rep1&type=pdf (Last access on 1st August 2023)