

## Supplementary materials for "Projection of future meteorological droughts in Lake Urmia Basin, Iran"

Babak Ghazi <sup>1\*</sup>, Sanjana Dutt <sup>2</sup> Ali Torabi Haghighi <sup>3</sup>

<sup>1</sup> Department of Meteorology and Climatology, Faculty of Earth Sciences and Spatial Management, Nicolaus Copernicus University in Toruń, Poland, Jurija Gagarina 11, 87-100 Toruń, babak.ghazi@doktorant.umk.pl

<sup>2</sup> Department of Geomatics and Cartography, Faculty of Earth Sciences and Spatial Management, Nicolaus Copernicus University in Toruń, Jurija Gagarina 11, 87-100 Toruń, Poland, Sanjana.dutt@doktorant.umk.pl

<sup>3</sup> Water, Energy, and Environmental Engineering Research Unit, University of Oulu, Pentti Kaiteran katu 1, P.O.Box 8000, , Oulu, 90014, Finland: Ali.TorabiHaghighi@oulu.fi

\* Corresponding author: Babak Ghazi, babak.ghazi@doktorant.umk.pl

Equation S1:

Calculation SPI values:

Using precipitation data over a long-term period, the SPI is calculated in a specific location using a probability distribution and a normal distribution. A gamma probability density function is used to describe the frequency distribution of precipitation when estimating the SPI.

$$P(x) = \frac{1}{\beta^\alpha \Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta} \text{ where } x > 0$$

where  $x$  is precipitation values,  $\alpha$  is a shape parameter,  $\beta$  is a scale parameter, and the gamma function is expressed as:

$$\Gamma(\alpha) = \int_0^\infty x^{\alpha-1} e^{-x} dx$$

To estimate  $\alpha$  and  $\beta$  with optimal values maximum likelihood methods as follow is used:

$$\hat{\alpha} = \frac{1}{4A} \left( 1 + \sqrt{1 + \frac{4A}{3}} \right)$$

$$\hat{\beta} = \frac{\bar{x}}{\hat{\alpha}}$$

$$A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n}$$

where  $n$  denotes the number of precipitation, and  $\bar{x}$  is the average precipitation. The cumulative probability for a specific month then can be calculated from:

$$G = \int_0^x g(x) dx = \frac{1}{\beta^\alpha \Gamma(\alpha)} \int_0^x x^{\alpha-1} e^{-x/\beta} dx$$

Setting  $t = \frac{x}{\beta}$  the incomplete gamma function can be calculated from:

$$G(x) = \frac{1}{\Gamma(\alpha)} \int_0^{\frac{x}{\beta}} t^{\alpha-1} e^{-t} dt$$

It is possible to have several zero values in a sample set. In order to account for zero values, the cumulative probability function for gamma distribution is modified as:

$$H=q+(1-q)G(x)$$

where  $q$  and  $(1-q)$  are the probability of zero and non-zero precipitation, respectively. The SPI values are then obtained from the cumulative probability:

for  $0.5 < H < 1$ :

$$SPI = +\left(k - \frac{c_0 + c_1 \times k + c_2 \times k^2}{1 + d_1 \times k + d_2 \times k^2 + d_3 \times k^3}\right), \quad K = \sqrt{\ln\left(\frac{1}{(1-H)^2}\right)}$$

for  $0 < H < 0.5$ :

$$SPI = -\left(k - \frac{c_0 + c_1 \times k + c_2 \times k^2}{1 + d_1 \times k + d_2 \times k^2 + d_3 \times k^3}\right), \quad K = \sqrt{\ln\left(\frac{1}{H^2}\right)}$$

where  $c_0=2.5155$ ,  $c_1=0.8028$ ,  $c_2=0.0103$ ,  $d_1=1.4327$ ,  $d_2=0.1892$ , and  $d_3=0.0013$  [1–3].

Table S1: Comparison of SPI values frequency for Historical reference period, SSP1-2.6 and SSP5-8.5 scenarios in Lake Urmia Basin.

	Mahabad		
	Historical	SSP1-2.6	SSP5-8.5
Extremely wet	4	20	7
Very wet	48	48	62
Moderately wet	73	110	106
Near Normal	507	678	690
Moderately dry	91	109	92
Severely dry	32	42	36
Extremely dry	19	19	33

	Maragheh		
	Historical	SSP1-2.6	SSP5-8.5
Extremely wet	12	20	10
Very wet	30	52	47
Moderately wet	96	103	125
Near Normal	501	685	680
Moderately dry	84	102	94
Severely dry	27	42	41
Extremely dry	24	22	29

	Saqqez		
	Historical	SSP1-2.6	SSP5-8.5
Extremely wet	6	23	10
Very wet	39	48	51
Moderately wet	91	98	104
Near Normal	491	682	698
Moderately dry	101	114	90
Severely dry	33	44	42
Extremely dry	13	17	31

	Sarab		
	Historical	SSP1-2.6	SSP5-8.5
Extremely wet	12	25	15
Very wet	33	42	48
Moderately wet	99	91	80
Near Normal	490	701	713
Moderately dry	85	88	89
Severely dry	33	54	46
Extremely dry	22	25	35

	Tabriz		
	Historical	SSP1-2.6	SSP5-8.5
Extremely wet	8	21	15
Very wet	30	49	59
Moderately wet	98	101	93
Near Normal	525	688	688
Moderately dry	62	100	103
Severely dry	26	46	42
Extremely dry	25	21	26

	Takab		
	Historical	SSP1-2.6	SSP5-8.5
Extremely wet	11	22	8
Very wet	32	45	43
Moderately wet	60	94	113
Near Normal	518	689	699
Moderately dry	96	102	90
Severely dry	40	55	40
Extremely dry	17	19	33

	Urmia		
	Historical	SSP1-2.6	SSP5-8.5
Extremely wet	6	17	14
Very wet	38	66	56
sModerately wet	82	91	111
Near Normal	516	689	694
Moderately dry	80	101	91
Severely dry	30	45	36
Extremely dry	22	17	24

