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Evaluating the Performance of Artificial Neural Network Model in Downscaling Daily Temperature, Precipitation and Wind Speed Parameters

Review:

1. Sailor et al., 2000使用具有一个sigmoid 传递函数的误差反向传播算法的前传神经网络，对美国三个地区（一个在德克萨斯州，两个在加利福尼亚州）风速进行了研究（他们的文献表明风速在年尺度上，在加州两个地区中减少0.4%和0.8%，在德州地区相较于其他地区增加2.7%）；
2. Mendes et al. and Hoai et al., 同样使用具有误差反向传播算法的前传神经网络对亚马逊盆地和越南中部的日降水进行研究，传递函数为双切线tangent函数（结果表明神经网络模型的表现明显优于统计和线性回归模型）；
3. 一般来说，海表面比湿，500hPa地势高度(geo-potential height)，近地面风速，850hPa地势高度和2m平均温度是绝大多数降尺度方法的重要输入参数；
4. 最重要的是，降尺度方法依靠一个非常重要的假设：大尺度变量和观测数据间的关系在过去和未来时间区间内不会改变，否则就会造成非常大的误差。

Methods:

Table 1. NCEP large-scale variables (predictors)

No.	Predictors	Description
1	ncepmslp	Mean sea level pressure
2	ncepp__f	surface Geostrophic air flow velocity
3	ncepp__u	surface Zonal velocity component
4	ncepp__v	surface Meridional velocity component
5	ncepp__z	surface Vorticity
6	ncepp_th	surface Wind direction
7	ncepp_zh	surface Divergence
8	ncepp5_f	500 hPa height Geostrophic air flow velocity
9	ncepp5_u	500 hPa height Zonal velocity component
10	ncepp5_v	500 hPa height Meridional velocity component
11	ncepp5_z	500 hPa height Vorticity
12	ncepp5th	500 hPa height Wind direction
13	ncepp5zh	500 hPa height Divergence
14	ncepp8_f	850 hPa height Geostrophic air flow velocity
15	ncepp8_u	850 hPa height Zonal velocity component
16	ncepp8_v	850 hPa height Meridional velocity component
17	ncepp8_z	850 hPa height Vorticity
18	ncepp8th	850 hPa height Wind direction
19	ncepp8zh	850 hPa height Divergence
20	ncepp500	500 hPa geopotential height
21	ncepp850	850 hPa geopotential height
22	ncepr500	Relative humidity at 500 hPa height
23	ncepr850	Relative humidity at 850 hPa height
24	nceprhum	Near surface relative humidity
25	ncepshum	Near surface specific humidity
26	nceptemp	Mean temperature at 2 m

Correlation coefficient (ρ)

$$\rho = \frac{\frac{1}{n}\sum_{m=1}^{n}(X_s-\mu_s)(X_0-\mu_0)}{\sigma_s \times \sigma_0} \quad (1)$$

Root mean square error (RMSE)

$$RMSE = \sqrt{\frac{\sum_{m=1}^{n}(X_s-X_0)^2}{n}} \quad (2)$$

Table 2. Results of the selected neural network models for the downscaling of mean temperature in all provinces of Iran

No.	Province	Model structure	Inputs' No.	Period		Training		Testing	
				Training	Testing	R	RMSE	R	RMSE
1	East Azerbaijan	9-8-1	1,3,5,9,19,20,21,25,26	1982-1988	1989-1991	0.98	1.9	0.98	1.7
2	West Azerbaijan	9-5-1	1,3,5,9,19,20,21,25,26	1992-1998	1999-2001	0.98	1.9	0.98	2
3	Ardabil	9-4-1	1,3,5,9,19,20,21,25,26	1987-1993	1994-1996	0.97	2.08	0.97	1.9
4	Gilan	9-9-1	1,3,5,9,19,20,21,25,26	1982-1988	1989-1991	0.97	1.7	0.97	1.6
5	Zanjan	9-4-1	1,3,5,9,19,20,21,25,26	1992-1998	1999-2001	0.98	1.8	0.98	1.7
6	Qazvin	9-6-1	1,3,5,9,19,20,21,25,26	1992-1998	1999-2001	0.98	1.6	0.98	1.4
7	Kermanshah	9-8-1	1,3,5,9,19,20,21,25,26	1992-1998	1999-2001	0.98	1.43	0.98	1.45
8	Markazi	9-5-1	1,3,5,9,19,20,21,25,26	1995-May 1999	Jan. 1999-2001	0.98	1.7	0.98	1.7
9	Hamadan	7-6-1	1,3,5,20,21,25,26	1992-1998	1999-2001	0.97	2.05	0.98	1.7
10	Tehran	9-8-1	1,3,5,9,19,20,21,25,26	1982-1988	1989-1991	0.98	1.6	0.98	1.6
11	Qom	9-8-1	1,3,5,9,19,20,21,25,26	1992-1998	1999-2001	0.98	1.8	0.98	1.7
12	Mazandaran	9-9-1	1,3,5,9,19,20,21,25,26	1986-1992	1993-1995	0.97	1.7	0.97	1.8
13	Isfahan	9-6-1	1,3,5,9,19,20,21,25,26	1982-1988	1989-1991	0.99	1.5	0.99	1.4
14	Chahar Mahaal and Bakhtiari	7-9-1	1,3,5,20,21,25,26	1982-1988	1989-1991	0.97	2.01	0.98	1.7
15	Yazd	9-7-1	1,3,5,9,19,20,21,25,26	1992-1998	1999-2001	0.98	1.6	0.98	1.65
16	Fars	9-7-1	1,3,5,9,19,20,21,25,26	1986-1992	1993-1995	0.99	1.2	0.99	1.3
17	Kohgiluyeh and Boyer-Ahmad	9-10-1	1,3,5,9,19,20,21,25,26	1992-1998	1999-2001	0.99	1.18	0.99	1.22
18	Ilam	9-10-1	1,3,5,9,19,20,21,25,26	1992-1998	1999-2001	0.99	1.14	0.99	1.13
19	Bushehr	9-8-1	1,3,5,9,19,20,21,25,26	1992-1998	1999-2001	0.98	1.2	0.98	1.27
20	South Khorasan	9-10-1	1,3,5,9,19,20,21,25,26	1992-1998	1999-2001	0.98	1.38	0.98	1.35
21	Razavi Khorasan	9-5-1	1,3,5,9,19,20,21,25,26	1982-1988	1989-1991	0.98	1.53	0.99	1.32
22	North Khorasan	9-8-1	1,3,5,9,19,20,21,25,26	1982-1988	1989-1991	0.98	1.54	0.98	1.67
23	Khuzestan	9-5-1	1,3,5,9,19,20,21,25,26	1982-1988	1989-1991	0.99	1.22	0.99	1.28
24	Semnan	9-9-1	1,3,5,9,19,20,21,25,26	1982-1988	1989-1991	0.99	1.35	0.99	1.36
25	Sistan and Baluchestan	9-10-1	1,3,5,9,19,20,21,25,26	1982-1988	1989-1991	0.98	1.5	0.98	1.5
26	Kurdistan	9-8-1	1,3,5,9,19,20,21,25,26	1982-1988	1989-1991	0.96	2.6	0.97	2.7
27	Kerman	9-7-1	1,3,5,9,19,20,21,25,26	1992-1998	1999-2001	0.97	1.7	0.98	1.54
28	Golestan	7-5-1	1,3,5,20,21,25,26	1992-1998	1999-2001	0.98	1.56	0.98	1.71
29	Lorestan	9-7-1	1,3,5,9,19,20,21,25,26	1986-1992	1993-1995	0.98	1.55	0.98	1.57
30	Hormozgan	7-7-1	1,3,5,20,21,25,26	1992-1998	1999-2001	0.98	1.232	0.98	1.27

Table 3. Results of the selected neural network models for the downscaling of mean precipitation in all provinces of Iran

No.	Province	Model structure	Inputs' No.	Period		Training		Testing	
				Testing	Training	R	RMSE	R	RMSE
1	East Azerbaijan								
2	West Azerbaijan	22-5-2-1	Lag (1, 5, 7, 20, 21, 22, 25, 26), (lag 24, 25)	1995-1999	2000-2001	0.68	1.58	0.77	11.4
3	Ardabil	15-7-1-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1987-1993	1994-1996	0.6	2.7	0.66	2.23
4	Gilan	15-19-2-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1992-1998	1999-2001	0.81	6.3	0.71	9.5
5	Zanjan	15-10-2-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1994-1998	1999-2000	0.71	1.92	0.76	2.26
6	Qazvin	15-7-1-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1982-1988	1989-1991	0.74	2.5	0.72	2.6
7	Kermanshah	15-8-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1992-1998	1999-2001	0.7	3.2	0.7	2.6
8	Markazi	15-5-4-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1995- Mar. 1999	Apr.1999-2000	0.77	1.5	0.71	3.2
9	Hamadan	15-13-1-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1982-1988	1989-1991	0.67	2.4	0.68	18.5
10	Tehran	15-11-1-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1982-1995	1996-2001	0.71	1.95	0.7	1.58
11	Qom	15-2-1-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1992-1998	1999-2001	0.67	1.43	0.71	1.8
12	Mazandaran	30-8-1-1	2 lag (1,5,7,20,21,22,23,24,25,26)	1984-Feb.1988	Mar.1988-1989	0.85	3.47	0.65	5.65
13	Isfahan	15-13-2-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1996- Feb. 2000	Mar. 2000-2001	0.8	1.2	0.7	1.2
14	Chahar Mahaal and Bakhtiari	15-11-1-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1992-1998	1999-2001	0.78	2.43	0.76	2.02
15	Yazd	10-9-1-1	1,5,7,20,21,22,23,24,25,26	1994- Feb.1998	Mar.1998-1999	0.7	0.68	0.7	1.55
16	Fars	15-5-1-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1982-1995	1996-2001	0.73	3.4	0.67	2.97
17	Kohgiluyeh and Boyer-Ahmad	15-13-1-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1992-1998	1999-2001	0.86	4.69	0.77	6.83
18	Ilam	15-18-2-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1987- Jan. 1997	Jul. 1997-2001	0.7	4.8	0.7	3.8
19	Bushehr	10-18-1-1	1,5,7,20,21,22,23,24,25,26	1990-1994	1995-1996	0.92	1.5	0.77	4.3
20	South Khorasan	15-6-1-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1982-1995	1996-2001	0.7	1.63	0.67	12.1
21	Razavi Khorasan	10-10-2-1	1,5,7,20,21,22,23,24,25,26	1992-1998	1999-2001	0.74	2.12	0.71	1.58
22	North Khorasan	10-15-2-1	1,5,7,20,21,22,23,24,25,26	1989-1993	1994-1995	0.64	1.94	065	1.61
23	Khuzestan	15-15-1-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1992-1998	1999-2001	0.8	2.91	0.7	2.55
24	Semnan	15-15-2-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1992-1998	1999-2001	0.79	1.48	0.68	1.41
25	Sistan and Baluchestan	10-3-1	1,5,7,20,21,22,23,24,25,26	May 1988-Jun. 1992	Jul. 1992-Apr. 1994	0.74	1.08	072	1.03
26	Kurdistan	15-6-1-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1982-1988	1989-1991	0.71	3.28	0.66	3.93
27	Kerman	15-11-2-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1993- Apr. 1999	May 1999-2001	0.79	1.37	067	1.57
28	Golestan	10-17-1-1	1,5,7,20,21,22,23,24,25,26	1984-Feb.1988	Mar.1988-1989	0.68	3.2	0.7	3.1
29	Lorestan	15-8-1-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1982-1995	1996-2001	0.8	2.99	076	3.3
30	Hormozgan	15-5-2-1	1,3,4,7,9,13,15,19,20,21,22,23,24,25,26	1992-1998	1999-2001	0.91	1.9	091	098

Table 4. Results of the selected neural network models for the downscaling of mean wind speed in all provinces of Iran

No.	Province	Model structure	Inputs' No.	Period		Training		Testing	
				Testing	Training	R	RMSE	R	RMSE
1	East Azerbaijan	16-19-1	1,2,3,4,5,6,7,8,13,14,19,20,21,24,25,26	1982-1988	1989-1991	0.77	2.3	0.77	2.22
2	West Azerbaijan	16-10-2-1	1,2,3,4,5,6,7,8,13,14,19,20,21,22,23,24,25,26	1994-1998	1999-2000	0.77	1.45	0.68	2.9
3	Ardabil	16-13-1-1	1,2,3,4,5,6,7,8,13,14,19,20,21,22,23,24,25,26	1992-1998	1999-2001	0.8	1.83	0.72	2.32
4	Gilan	16-7-2-1	1,2,3,4,5,6,7,8,13,14,19,20,21,24,25,26	1996-1999	2000-2001	0.74	1.73	0.72	1.73
5	Zanjan	14-13-2-1	1,2,3,4,5,6,7,8,13, 14,19,20,21,26	1989-1993	1994-1995	0.62	1.64	0.6	1.77
6	Qazvin	18-6-1	1,2,3,4,5,6,7,8,13,14,19,20,21,22,23,24,25,26	1984-Apr. 1990	May1990-1992	0.64	2.08	0.7	1.77
7	Kermanshah	17-6-1	1,2,3,4,5,6,7,8,13,14,19,20,21,22,23,24,25	1992-1998	1999-2001	0.72	1.77	0.74	1.74
8	Markazi	14-5-2-1	1,2,3,4,5,6,7,8,13, 14,19,20,21,26	1995-Jan.1999	Jul.1999-2001	0.7	2.73	0.67	2.74
9	Hamadan	16-8-1-1	1,2,3,4,5,6,7,8,13,14,19,20,21,24,25,26	1992-1998	1999-2001	0.74	1.77	0.73	2.31
10	Tehran	17-16-1	1,2,3,4,5,6,7,8,13,14,19,20,21,22,23,24,25	1982-1995	1996-2001	0.73	2.2	0.73	2.2
11	Qom	15-10-1	1,2,3,4,5,6,7,8,13,14,19,20,21,22,23,24,25,26	1987-Jun.1997	Jul.1997-2001	0.73	2.15	0.79	2.1
12	Mazandaran								
13	Isfahan	16-12-1-1	1,2,3,4,5,6,7,8,13,14,19,20,21,24,25,26	1994-May 1999	Jun.1999-2001	0.78	1.55	0.74	1.74
14	Chahar Mahaal and Bakhtiari	16-13-1-1	1,2,3,4,5,6,7,8,13,14,19,20,21,24,25,26	1982-1988	1989-1991	0.76	1.51	0.72	1.47
15	Yazd	16-13-1-1	1,2,3,4,5,6,7,8,13,14,19,20,21,22,23,24,25,26	1992-1998	1999-2001	0.55	2.2	0.67	2.08
16	Fars	16-13-2-1	1,2,3,4,5,6,7,8,13,14,19,20,21,22,23,24,25,26	Jan.1985-1996	1997-2001	0.7	1.53	0.7	1.76
17	Kohgiluyeh and Boyer-Ahmad	16-13-2-1	1,2,3,4,5,6,7,8,13,14,19,20,21,22,23,24,25,26	1989-Jul. 1998	Aug.1994-1996	0.65	1.31	0.61	1.6
18	Ilam	18-6-2-1	1,2,3,4,5,6,7,8,13,14,19,20,21,22,23,24,25,26	1995-Jun.1999	Jul.1999-2001	0.71	1.88	0.73	1.94
19	Bushehr	18-8-1	1,2,3,5,6,7,8,13, 14, 19,20,21,22,23,24,25,26	1982-1995	1996-2001	0.79	2.33	0.79	2.19
20	South Khorasan	17-2-1	1,2,3,5,6,7,8,14,20,21,24,25,26	1992-1998	1999-2001	0.71	2.1	0.76	2.4
21	Razavi Khorasan	14-14-1	1,2,3,5,6,7,8,14,19,20,21,24,25,26	Aug. 1994-Aug. 1998	Sep. 1999-2001	0.75	1.65	0.71	1.9
22	North Khorasan	16-12-2-1	1,3,4,5,6,7,8,14,19,20,21,22,23,24,25,26	1992-1998	1999-2001	0.8	2.83	0.73	3.07
23	Khuzestan	16-14-2-1	1,2,3,4,5,6,7,8,13,14,19,20,21,24,25,26	1996-1999	2000-2001	0.8	1.8	0.8	1.86
24	Semnan	16-13-1-1	1,2,3,4,5,6,7,8,13,14,19,20,21,24,25,26	1996-1999	2000-2001	0.77	1.41	0.75	2.06
25	Sistan and Baluchestan	15-14-1-1	1,2,3,4,5,6,7,8,13,14,19,20,21,24,25	1982-1988	1989-1991	0.83	2.16	0.8	2.2
26	Kurdistan	16-19-1-1	1,2,3,4,5,6,7,8,13,14,19,20,21,24,25,26	1994-May 1999	Jun. 1999-2001	0.74	2.2	0.72	27
27	Kerman	18-11-1-1	1,2,3,4,5,6,7,8,13,14,19,20,21,22,23,24,25,26	1992-1998	1999-2001	0.8	2.27	0.78	1.68
28	Golestan	15-14-1-1	1,2,3,4,5,6,7,8,14,20,21,22,23,24,25	1988-Feb. 1992	Mar. 1992-1993	0.7	0.93	0.63	1.04
29	Lorestan	14-20-1	1,2,3,4,5,6,7,8,13, 14,19,20,21,26	1991-Jul. 1996	Aug. 1996-1998	0.72	1.4	0.65	3.3
30	Hormozgan	18-18-1-1	1,2,3,4,5,6,7,8,13,14,19,20,21,22,23,24,25,26	1995-Jun.1999	Jul. 1999-2001	0.81	1.05	0.7	1.33

Conclusions:

2m平均温度，近地面气压，近地面比湿，500和850hPa地势高度以及风速是输入进网络中最重要的大尺度气候变量；可以看出日气温(0.98)相较于日降水(0.73)和风速(0.72)的相关性要高得多。