Impact of Environmental Changes and Global Warming on Temperature in Pakistan

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ABSTRACT

Environmental changes and global warming have direct impact on human life. Estimation of these changes in various parameters of hydrologic cycle is necessary for future planning and development of a country. In this paper the impact of environmental changes and global warming on temperatures of Pakistan has been studied. The temperature changes in Pakistan have been extracted from simulations made using EdGCM model developed at Columbia University. Simulation study to the end of 21st century is executed using the model for GHG (Greenhouse Gases) scenario with doubled_CO_2 and scenario of Modern_Predicted SST (Sea Surface Temperature). The model analysis has been carried out for seasonal and annual changes for an average of last 5 years period from 2096-2100. Maps are generated to depict global temperature variations. The study divides Pakistan into five (05) main areas for twenty six (26) stations. A part-plan of globe focusing Pakistan is generated showing the five divisions for twenty six (26) data stations of Pakistan. This part plan is made compatible with grid-box resolution of EdGCM. Eagle-Point Engineering software has been used to generate isohyets of interval (0.5^{o}C) for downscaling GCM (Global Climate Model) grid data to data stations.

The station values of different seasons and annual changes are then compared with the values of base period data to determine changes in temperature. It is observed that impact of global environmental changes on temperature are higher (i.e. there is an increase in annual temperature for double_CO_2 experiment) at places near the Arabian Sea than areas located away from this sea. It is also observed that the temperature increase will be more in winter than that in other seasons for Pakistan.

Key Words: **EdGCM, Downscaling, Eagle-Point, Surface Modeling, Isohyets, GHG**

1. INTRODUCTION

Pakistan is a developing country. Its economy is wholly dependent on its water resources. It has a large snow-fed river system. There with environmental changes on hydrologic cycle and its components, especially temperature and precipitation, at times bear a serious shortfall in the water resources of Pakistan as may be in other regions worldwide. Environmental changes are occurring in many ways like increase in concentration of tropospheric aerosols, stratospheric aerosol, solar intensity and concentration of Greenhouse Gases. Carbon dioxide (CO_2) has increased by 35% over pre-industrial levels (CO_2 grew from 280 ppm

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in 1750-379 ppm in 2005); methane concentration has risen by 148% (ethane grew from 715 ppb in 1750-1774 ppb 2005) and nitrous oxide by 18% (N_2O grew from 270 ppb in 1750-319 ppb in 2005) [16]. Hence, study of impact of environmental changes on temperature and precipitation is important for future planning and development of water resources of the country. Temperature changes in Pakistan sharply stand opposite from region to region. In some regions of Sind and Southern Punjab, temperature values cross 50°C in summer whereas in Northern and Western parts of the country, temperature values go far below zero degree in winter.

Concerns about climate change arise from two basic admitted facts [8]: (a) GHG are retarding the rate of radiation in the atmosphere, and this causes the global warming; (b) the retardation in (a) above is due to human activities like vehicle pollution, trimming of jungles and coal burning, etc.

The study of impact of environmental changes is a complex affair because non-linear relations exist between the forces responsible for climatic change and regional or local area characteristics [10]. Hence, researchers in both the physical and social sciences have turned preferably to mathematical modeling for exploring complex phenomena. For example, Hengveled [8] ran three GHG+A scenarios to project global trends to the year 2100 by performing simulation with the CGCM (Canadian Global Climate Model). Hengveled [8] study was based on a reference period from 1975-1995 and model projections were calculated on it keeping in view the fact that climate fluctuates considerably from year to year due to internal climate system variability.

GCMs are efficient tools for estimation of seasonal variations. GCMs are state-of-the-art representation of the coupled atmosphere-land-ocean-ice systems and their interactions are used in modern research. To quote examples, we may refer to Carpenter, et. al. [3], Dettinger [4], Dettinger, et. al. [5], Georgakakos, et. al. [6], Hayhoe, et. al. [7], Kim [11], Knowles, et. al. [12], Leung, et. al. [13], Maurer, et. al. [14], Miller, et. al. [15], Stewart, et. al. [18], Vicuna, et. al. [21], Van Rheenen, et. al. [22]. Several factors distinguish these studies - the most important being the choice of GCM used, the downscaling methodology and the method used to characterize uncertainty.

Models being used worldwide include HadCM3 developed at the Hadley Center, Bracknell, UK; CGCM1 developed at the Canadian Center for Climate Modeling and Analysis; ECHAM4 developed in cooperation between the Max-Planck-Institute for Meteorology MPI and the Deutsches Klimarechenzentrum DKRZ in Hamburg, Germany and EdGCM developed at Columbia University © 2003-2007. All these models excluding EdGCM are not meant for direct public use. They require super computers useable only at their respective centers of production. However, their results are available for study. EdGCM is a powerful window-based GCM-II which is available in the public domain. This paper is based on the results reproduced by running EdGCM software for the years 1958-2100.

GCM grids present a defined spatial network of locations on the globe for which relevant GCM software produces the results. Difference between GCM grid averages and local series is the result of spatial resolution (grid spacing) of GCMs (about 200-700 km). It is too coarse [21] to forecast changes for locations that fall away from GCM grids. Hence, there is always need to transform the GCM results with their downscaling to predict local changes. Many techniques are available for such downscaling. Previous researchers applied statistical techniques for this purpose. These techniques include Random-Cascade and Kernel-based (k-nn) nonparametric models developed for stream-flow simulation [19] and for multivariate weather generation [17] and stream-flow dis-aggregation [20]. Another fairly simple, flexible and computationally economical but again a statistical technique involves use of stochastic weather models called "weather-generators". These models give an output that resembles real-weather data [23]. In this study, a new software-based approach has been introduced for the purpose of downscaling. Here, Eagle-Point software has been used to downscale GCM grid data to stations of interest. Eagle-point is a surface modeling software that might help environmental researchers and engineers to model a surface with reference to any regularly or randomly placed 3-D (Three-Dimensional) reference point data. As indicated in Fig. 1, sixteen (16) grid points have been used to generate isohyets by applying Eagle-point surface modeling. This software has flexibility to generate isohyets of any close interval e.g. 0.5^{o}C interval has been adopted in this study. Generation of close-interval isohyets helps to reduce coarseness of data-prediction and to obtain more close station values.

2. MODEL DESCRIPTION

An efficient 3D (Three Dimensional) global model for climatic studies is based upon four fundamental equations: (a) Conservation of momentum (Newton's second law of motion), (b) Mass continuity equation, (c) Conservation of energy (first law of thermodynamics) and (d) Ideal gas law (approximate equation of state). Differentiation schemes of Arakawa are used to solve the scheme. Other details of numerical solution of these equations can be seen from the manual developed by Hansen, et. al. [9]. The model produces on-line diagnostics including global maps, zonal means of surface and atmospheric quantities [9]. The simulation took about 36 hours non-stop run of PC (1.8GHz) to complete the process for each scenario.

This study is based on EdGCM resolution of 8^o latitude x10^o longitude x10 mb Vertical. The model has a grid-box structure. Each grid-box encloses land and ocean fractions based on 1^o resolution of topography. The model represents ocean ice cover and surface temperature climatologically on the basis of monthly-mean values. These values are applied for the mid of each month and interpolated linearly once per day. Surface and atmosphere interaction is computed separately in the model.

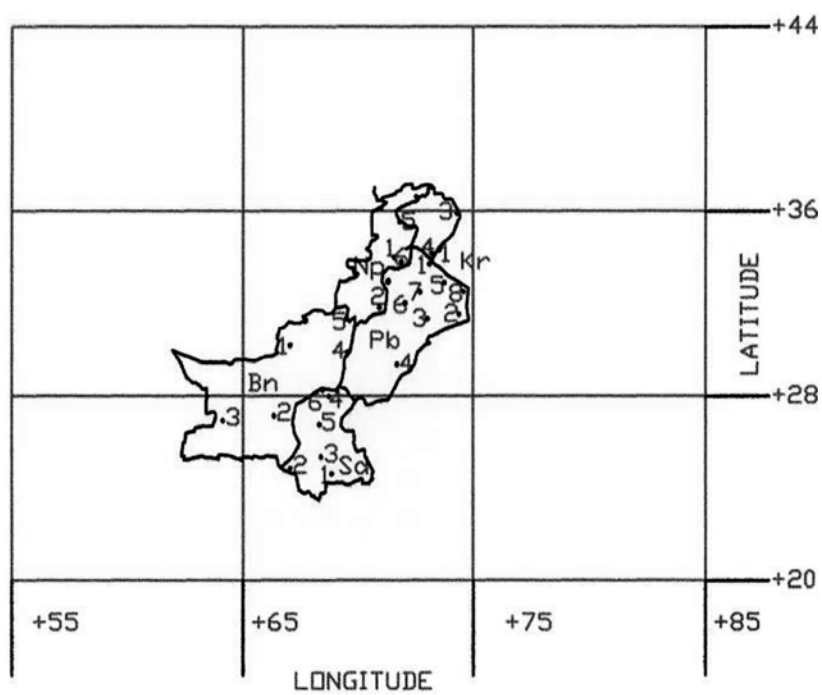

FIG. 1. PART-PLAN OF 8OX10O EDGCM MODEL GRID WITH SUPERIMPOSED MAP OF PAKISTAN SHOWING 26 STATIONS AND 05 AREAS

In this study, Double_CO2 experiment is based only on increases in Greenhouse Gas concentration of carbon dioxide. EdGCM CO2 trend has a linear increase of 0.50 ppm per year up to the year 2000 and then an exponential change of 1% per year for the years from 2000-2100.

In Modern_PredictedSST, effects of Greenhouse Gases and Sulphate aerosols are studied. GHG concentration is kept fixed at the year 1958 stage and SSTs (Sea Surface Temperatures) are allowed to vary in response to energy fluxes in the atmosphere.

As a matter of fact, the climate system is complex and global climate models are limited due to three factors. Firstly, scientists have limitations to understand perfectly all the processes that make global climate. Secondly, world's best supercomputer does not have sufficient power to simulate all the key factors that drive climate over every part of the planet. Solution of four differential equations for three dimensional conditions over the globe is really a challenge. Thirdly, there will always be a limit of accuracy to which climate can be predicted. Due to complexity of the global climate system, there always come about discrepancies between the simulated and actual i.e. measured climatic data. It is challenging issue for present research to overcome these problems. However, none of these discrepancies can invalidate the findings that rising Greenhouse Gas concentrations will lead to global warming. Climate model simulations typically have shown a warming for the period 1979-1998 which is slightly larger in the lower and mid-troposphere than at the surface in contrast with the trends observed by satellite instruments. The difference may be partly due to reductions in stratospheric ozone, and the stratospheric aerosols released by the 1991 Mt Pinatubo eruption. However, other observations which extend back further from 1979 show that the troposphere has warmed only slightly less than the surface in general agreement with modeled findings (CSIRO; Australia 1997-2008).

3. STUDY AREA

Temperature data collected from Meteorological Department, Islamabad, Pakistan for twenty six (26) stations is given in Table 1. The stations have been taken spread over four provinces Punjab (Pb), Sind (Sd), NWFP (Np) and Baluchistan (Bn)) and in addition Kashmir (Kr) as well. Names of twenty six (26) Stations of these provinces with their elevation from mean sea level, latitude and longitude are given in Table 2. Pakistan has four seasons. So, the analysis has been carried out for four (04) standard climatological seasons [23]: the winter DJF (December, January, February); the spring MAM (March, April, May.); the summer JJA (June, July, August); and the autumn SON (September, October, November). Annual average has also been worked out to study trend of annual changes.

Fig. 1 shows Pakistan superimposed within sixteen (16) grids of EdGCM. The whole country occupies space within +65 to +75 longitude and+28 to +36 latitude.

4. EdGCM MODEL SIMULATIONS:

Climate simulations are always compared to a "control run" which establishes a base for comparison of all other simulations. EdGCM has in-built "control run" that is representative of 1951-1980. The period of 1958 has been taken as first year when regular and continuous record of measurements of Greenhouse Gases began [1]. The concept of equilibrium-climate is applicable in simulations because of the fact that analysis is most preferably possible for no-climate-change phase. Out of many options available in Simulation Library of EdGCM, the following two have been run to check the two scenario-cases. The model has in-built input files which take into account solutions for the four differential equations.

4.1 Simulations Using Double_CO2 Experiments

For Doubled_CO_2 simulation, the run started from December 01, 1957 (one month earlier than actual time January 01, 1958) and ended on December 31, 2100. An EdGCM in-built solar correction value of 0.964467471038735 is used for ocean model. Monthly average data is generated by diagnostic output. Solar luminosity is 1366.6198 W/m^2, Greenhouse Gas forcing includes CO_2 as 629.80 ppm (which is double of 314.90 ppm observed in 1958), N_2O as 0.2908 ppm, CH_4 as1.224 ppm, CFC_{11}as 0.0076 ppt and CFC_{12} as 0.02966 ppt.

4.2 Simulations Using Modern_Predicted SST Experiments

EdGCM run for Modern_PredictedSST simulation also started from December 01, 1957 and ended on December 31, 2100. It uses a mixed ocean model that allows SSTs to vary in response to energy fluxes from the atmosphere and to collect deep ocean diffusion data. Monthly average data is generated in similar way as stated above by diagnostic output. The other data used is same as that used in simulations using double_CO_2 experiment.

5. ANALYSIS OF EdGCM MODEL/ SIMULATIONS

This is the most important feature of a climate model. It is also known as "post-processing" and involves several steps. EdGCM allows creation of global maps, zonal averages, time series plots, and diagnostic tables for 80 climate variables. There is option to analyse data for a number of climate variables. In the first analysis step, average for the last five years (2096-2100) is calculated. In the second analysis step monthly, seasonal and annual averages are extracted.

TABLE 1. 30 YEAR AVERAGE TEMPERATURE RECORD FOR 26 CITIES OF PAKISTAN

Station	Location Name	Average Temperature (°C)				
		DJF	MAM	JJA	SON	Annual
1.	Islamabad	11.47	22.26	29.05	21.93	21.18
2.	Lahore	14.58	26.40	31.84	25.19	24.50
3.	Faisalabad	13.09	25.03	31.90	24.28	23.58
4.	Bahawalpur	14.96	27.26	33.85	25.08	25.29
5.	Jhelum	13.79	24.89	31.18	24.21	23.52
6.	Multan	14.38	27.17	33.88	25.75	25.29
7.	Sargodha	13.28	25.86	32.76	24.03	23.98
8.	Sialkot	12.87	24.43	30.30	23.21	22.70
1.	Badin	18.24	28.27	30.03	26.34	25.72
2.	Karachi	19.54	28.00	30.36	27.20	26.28
3.	Hyderabad	19.51	30.11	32.63	28.19	27.61
4.	Khanpur (PBO)	13.99	26.63	31.92	22.38	23.73
5.	Padidan	12.55	25.45	28.44	19.86	21.58
6.	Jaccobabad	16.50	29.64	34.88	27.06	27.02
1.	Peshawar	12.42	23.24	31.99	23.52	22.79
2.	D.I. Khan	13.70	25.57	32.60	24.88	24.19
3.	Gilgit	4.94	16.15	25.87	16.00	15.74
4.	Kakul	7.70	16.74	24.33	17.59	16.59
5.	Drosh	5.87	16.20	28.47	19.00	17.38
6.	Cherat	6.96	16.19	23.72	16.70	15.89
1.	Quetta	5.40	16.55	26.90	15.53	16.10
2.	Khuzdar	10.69	20.59	27.96	20.24	19.87
3.	Panjgur	11.92	23.17	31.46	22.19	22.19
4.	Barkhan	10.69	21.38	28.89	21.92	20.72
5.	Zhob	6.81	18.44	26.47	17.71	17.36
1.	Muzaffarabad	10.73	20.99	28.71	21.32	20.44

Fig. 2 (a-e) is output of temperature averages in map form for simulation run for Double_CO_2. Fig. 3 (a-e) is output of temperature averages for simulation run for Modern_PredictedSST. In both cases analysis has been done separately for four seasons DJF, MAM, JJA, SON and for annual temperature changes as well, at the end of year 2100.

Figs. 2(a)-3(a) are global maps for DJF which show temperature isohyets of low intensity in Northern part of Pakistan and of moderate values in South-Western regions. Figs. 2(b)-2(b) are global maps for MAM and give an indication of almost similar to DJF temperature variation trend. Figs, 2(c)-3(c) are global maps for JJA which depict moderate to high temperature values trend as one moves from North to South of Pakistan. Figs. 2(d)-2(d) are global maps for SON and these display low to slight-intense temperature variation from North to South of Pakistan. Fig. 2(e)-3(e) are global maps for annual temperature changes which demonstrate that average annual surface air temperature change takes place uniformly across Pakistan from North to South.

6. TRANSFORMING OF EdGCM MODEL DATA TO STATIONS

In the study of impacts of environmental changes on the local climate of an area, the most important step is to transform global data down to an area of study. This is

TABLE 2. 26 STATIONS OF PAKISTAN

Station	Location Name	Abbreviation	Elevation (m)	Latitude	Longitude
1.	Islamabad	ID	569.34	33.72	73.06
2.	Lahore	LE	211.52	31.55	74.34
3.	Faisalabad	FD	178.91	31.36	72.99
4.	Bahawalpur	BR	118.26	29.39	71.66
5.	Jhelum	JM	283.45	32.92	73.71
6.	Multan	MN	315.15	32.04	72.02
7.	Sargodha	SA	182.26	32.52	72.67
8.	Sialkot	ST	242.91	32.52	74.55
1.	Badin	BN	10.67	24.66	68.84
2.	Karachi	KI	38.40	24.89	67.03
3.	Hyderabad	HD	37.49	25.38	68.37
4.	Khanpur (PBO)	KP	63.09	28.01	68.72
5.	Padidan	PN	44.19	26.78	68.29
6.	Jaccobabad	JD	56.39	28.28	68.43
1.	Peshawar	PR	351.11	34.00	71.54
2.	DI khan	DN	173.42	31.83	70.90
3.	Gilgit	GT	1736.36	35.91	74.26
4.	Kakul	KL	1196.89	34.16	73.21
5.	Drosh	DH	2181.35	35.55	71.79
6.	Cherat	CT	611.13	33.82	71.86
1.	Quetta	QA	1801.58	30.21	67.02
2.	Khuzdar	KR	1183.18	27.17	66.33
3.	Panjgur	PG	1002.44	26.96	64.12
4.	Barkhan	BN	1258.46	29.91	69.51
5.	Zhob	ZB	1568.12	31.36	69.46
1.	Muzaffarabad	MZ	881.13	34.34	73.50

also known as downscaling as discussed earlier. Longitude (x), Latitude (y) and Temperature (z) values from EdGCM data separately for DJF, MAM, JJA, SON and annual outputs have been used to generate isohyets (contours). These (x,y,z) values for grids relevant to sixteen (16) points as shown in Fig. 1 are used as input to Eagle-Point to

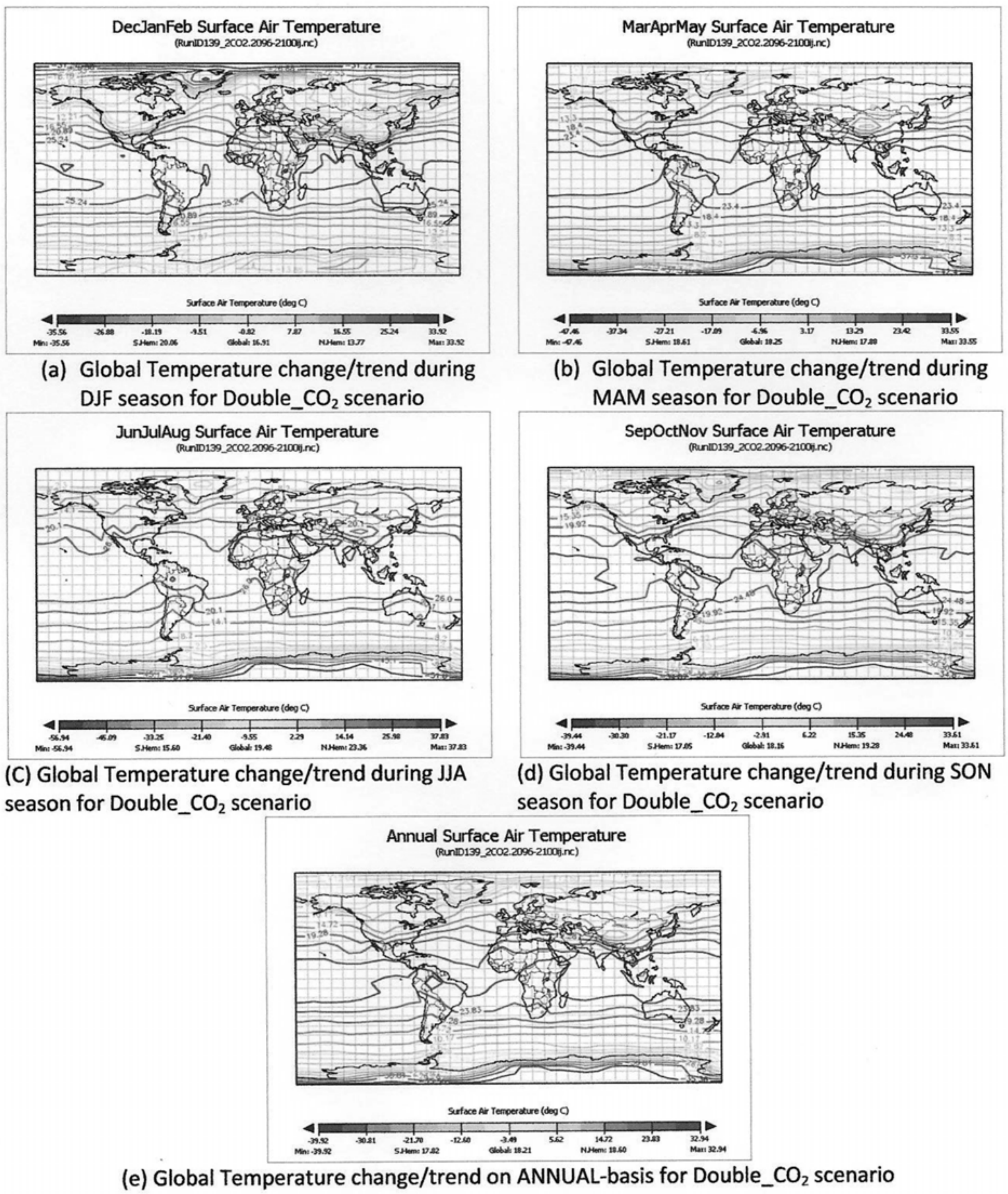

FIG. 2(A-E). GLOBAL TEMPERATURE CHANGE/TREND - MAPS FOR DJF, MAM, JJA, SON, AND ANNUAL RUNS, GENERATED BY PERFORMING EDGCM SIMULATION USING DOUBLE CO_2 EXPERIMENT generate isohyets at 0.5°C interval. Generated graphical outputs of Eagle Point surface modeling are shown in Fig. 4 (annual $2CO_2$) and Fig. 5 (annual MPSST). The Figs. 4-5 (maps) have been used to work out temperature values at 26 stations and those numeric values have been tabulated in Tables 3-4.

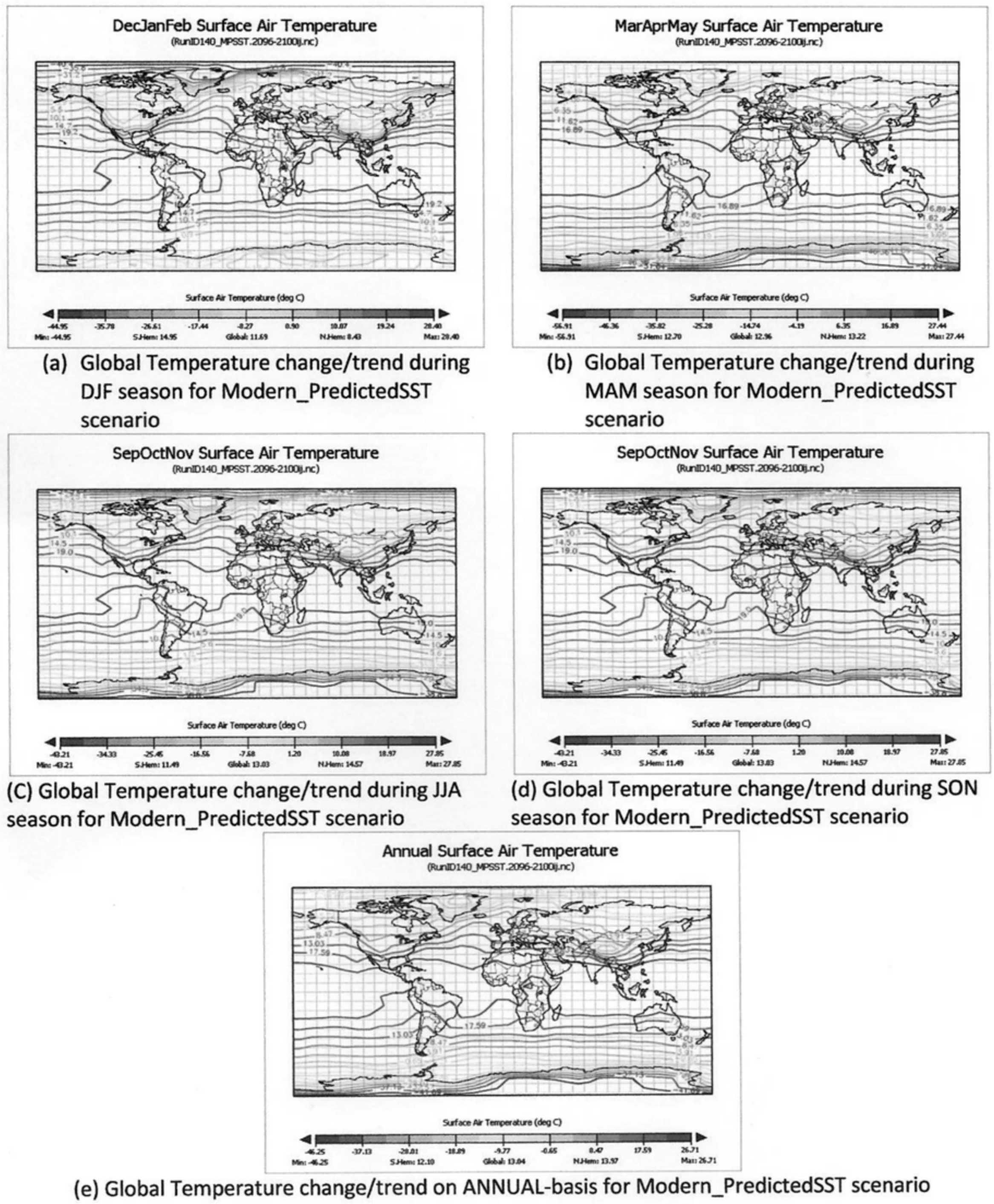

FIG. 3(A-E). GLOBAL TEMPERATURE CHANGE/TREND-MAPS FOR DJF, MAM, JJA, SON, AND ANNUAL RUNS, GENERATED BY PERFORMING EDGCM SIMULATION USING MODERN_PREDICTEDSST (MPSST) EXPERIMENT

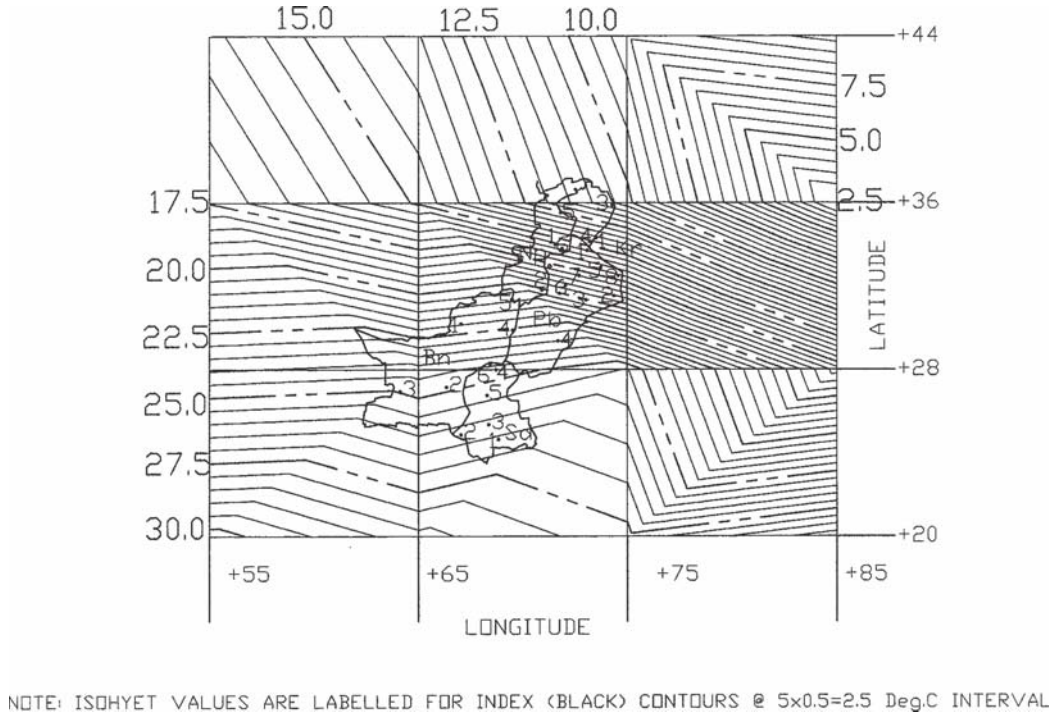

FIG. 4. TEMPERATURE ISOHYETS GENERATED USING EAGLE-POINT TO SEE CHANGE FOR 2CO2 EXPERIMENT ON ANNUAL BASIS

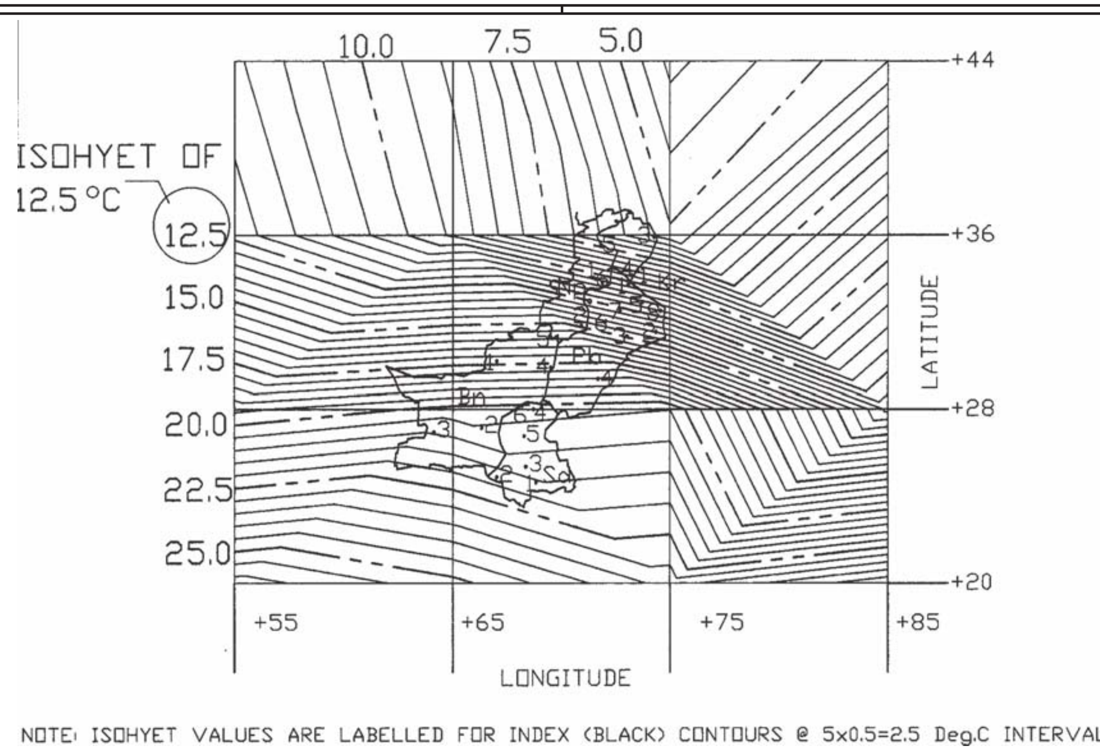

FIG. 5.TEMPERATURE ISOHYETS GENERATED USING EAGLE-POINT TO SEE CHANGE FOR MPSST EXPERIMENT ON ANNUAL BASIS

TABLE 3.COMPARISON OF RESULTS DOWNSCALED FOR DOUBLE_CO_2 EXPERIMENT FOR THE YEARS UP TO 2100 WITH 30 YEARS AVAILABLE RECORD (1971-2000)

Area	Station	Average Temperature (°C)								
		(1971-2000) DJF	(2096-2100) DJF	Change (°C)	(1971-2000) MAM	(2096-2100) MAM	Change (°C)	(1971-2000) JJA	(2096-2100) JJA	Change (°C)
Punjab (Pb)	1	11.47	5.75	-5.72	22.26	13.00	-9.26	29.05	24.40	-4.65
	2	14.58	10.00	-4.58	26.40	16.65	-9.75	31.84	28.40	-3.44
	3	13.09	10.80	-2.29	25.03	16.90	-8.13	31.90	28.50	-3.40
	4	14.96	14.00	-0.96	27.26	20.00	-7.26	33.85	31.90	-1.95
	5	13.79	7.35	-6.44	24.89	14.45	-10.44	31.18	25.90	-5.28
	6	14.38	8.90	-5.48	27.17	15.65	-11.52	33.88	27.10	-6.78
	7	13.28	8.00	-5.28	25.86	15.00	-10.86	32.76	26.40	-6.36
	8	12.87	8.10	-4.77	24.43	15.10	-9.33	30.30	26.50	-3.80
Sindh (Sd)	1	18.24	21.00	2.76	28.27	25.10	-3.17	30.03	31.75	1.72
	2	19.54	20.60	1.06	28.00	24.70	-3.30	30.36	32.05	1.69
	3	19.51	20.00	0.49	30.11	24.40	-5.71	32.63	32.05	-0.58
	4	13.99	16.50	2.51	26.63	22.00	-4.63	31.92	34.00	2.08
	5	12.55	18.15	5.60	25.45	23.10	-2.35	28.44	33.10	4.66
	6	16.50	15.95	-0.55	29.64	21.50	-8.14	34.88	33.50	-1.38
NWFP (Np)	1	12.42	5.50	-6.92	23.24	13.05	-10.19	31.99	24.10	-7.89
	2	13.70	9.25	-4.45	25.57	15.90	-9.67	32.60	27.50	-5.10
	3	4.94	1.95	-2.99	16.15	10.00	-6.15	25.87	20.85	-5.02
	4	7.70	5.00	-2.70	16.74	12.30	-4.44	24.33	23.50	-0.83
	5	5.87	3.50	-2.37	16.20	11.60	-4.60	28.47	22.10	-6.37
	6	6.96	5.75	-1.21	16.19	13.00	-3.19	23.72	24.25	0.53
Baluchistan (b)	1	5.40	12.50	7.10	16.55	18.75	2.20	26.90	30.25	3.35
	2	10.69	17.50	6.81	20.59	22.55	1.96	27.96	33.10	5.14
	3	11.92	17.65	5.73	23.17	22.90	-0.27	31.46	33.50	2.04
	4	10.69	12.90	2.21	21.38	19.00	-2.38	28.89	30.75	1.86
	5	6.81	10.10	3.29	18.44	16.50	-1.94	26.47	28.00	1.53
Kashmir (Kr)	1	10.73	4.50	0.42	20.99	12.00	-8.99	28.71	23.75	-4.96

Area	Station	(1971-2000) SON	(2096-2100) SON	Change (°C)	(1971-2000) Annual	(2096-2100) Annual	Change (°C)
Punjab (Pb)	1	21.93	15.50	-6.43	21.18	15.50	-5.68
	2	25.19	20.00	-5.19	24.50	19.00	-5.50
	3	24.28	21.00	-3.28	23.58	20.00	-3.58
	4	25.08	25.00	-0.08	25.29	23.45	-1.84
	5	24.21	17.00	-7.21	23.52	16.65	-6.87
	6	25.75	19.90	-5.85	25.29	19.20	-6.09
	7	24.03	18.45	-5.58	23.98	18.00	-5.98
	8	23.21	17.50	-5.71	22.70	17.00	-5.70
Sindh (Sd)	1	26.34	26.05	-0.29	25.72	26.60	0.88
	2	27.20	26.10	-1.10	26.28	26.25	-0.02
	3	28.19	25.90	-2.29	27.61	26.10	-1.51
	4	22.38	26.05	3.67	23.73	24.65	0.92
	5	19.86	26.00	6.14	21.58	25.40	3.82
	6	27.06	25.70	-1.36	27.02	24.40	-2.62
NWFP (Np)	1	23.52	15.50	-8.02	22.79	15.55	-7.24
	2	24.88	20.90	-3.98	24.19	20.00	-4.19
	3	16.00	9.75	-6.25	15.74	10.60	-5.14
	4	17.59	14.40	-3.19	16.59	14.50	-2.09
	5	19.00	11.75	-7.25	17.38	12.50	-4.88
	6	16.70	15.75	-0.95	15.89	15.90	0.01
Baluchistan (Bn)	1	15.53	22.55	7.02	16.10	22.00	5.90
	2	20.24	25.50	5.26	19.87	24.90	5.03
	3	22.19	25.65	3.46	22.19	25.00	2.81
	4	21.92	23.75	1.83	20.72	22.50	1.78
	5	17.71	24.10	6.39	17.36	20.90	3.54
Kashmir (Kr)	1	21.32	13.75	-7.57	20.44	14.00	-6.44

TABLE 4. COMPARISON OF RESULTS DOWNSCALED FOR MODERN_PREDICTEDSST EXPERIMENT FOR THE YEARS UP TO 2100 WITH 30 YEARS AVAILABLE RECORD (1971-2000)

Area	Station	Average Temperature (°C)								
		(1971-2000) DJF	(2096-2100) DJF	Change (°C)	(1971-2000) MAM	(2096-2100) MAM	Change (°C)	(1971-2000) JJA	(2096-2100) JJA	Change (°C)
Punjab (Pb)	1	11.469	2.50	-8.97	22.258	8.50	-13.76	29.051	20.25	-8.80
	2	14.579	4.10	-10.48	26.404	12.25	-14.15	31.842	23.50	-8.34
	3	13.093	5.90	-7.19	25.030	12.50	-12.53	31.897	24.00	-7.90
	4	14.960	10.40	-4.56	27.258	15.65	-11.61	33.847	27.10	-6.75
	5	13.786	2.50	-11.29	24.892	10.00	-14.89	31.177	21.40	-9.78
	6	14.380	5.00	-9.38	27.171	11.80	-15.37	33.876	23.00	-10.88
	7	13.280	3.25	-10.03	25.861	10.55	-15.31	32.763	22.10	-10.66
	8	12.868	2.50	-10.37	24.429	10.70	-13.73	30.298	21.90	-8.40
Sind (Sd)	1	18.242	16.50	-1.74	28.266	21.00	-7.27	30.030	28.50	-1.53
	2	19.541	16.00	-3.54	28.004	20.70	-7.30	30.359	28.85	-1.51
	3	19.510	15.50	-4.01	30.110	20.30	-9.81	32.633	28.80	-3.83
	4	13.986	11.60	-2.39	26.633	17.70	-8.93	31.919	29.60	-2.32
	5	12.550	13.40	0.85	25.454	18.95	-6.50	28.441	29.40	0.96
	6	16.502	11.25	-5.25	29.640	17.15	-12.49	34.883	29.50	-5.38
NWFP (Np)	1	12.420	2.25	-10.17	23.240	8.60	-14.64	31.986	20.00	-11.99
	2	13.704	6.50	-7.20	25.572	11.50	-14.07	32.603	23.50	-9.10
	3	4.943	-4.00	-8.94	16.150	5.50	-10.65	25.871	16.50	-9.37
	4	7.702	2.00	-5.70	16.737	7.90	-8.84	24.328	19.50	-4.83
	5	5.867	0.00	-5.87	16.202	7.05	-9.15	28.472	17.25	-11.22
	6	6.962	2.25	-4.71	16.186	8.55	-7.64	23.718	20.25	-3.47
Baluchistan (Bn)	1	5.401	8.70	3.30	16.548	14.40	-2.15	26.903	26.50	-0.40
	2	10.690	12.50	1.81	20.588	18.40	-2.19	27.960	29.80	1.84
	3	11.917	12.50	0.58	23.172	18.60	-4.57	31.460	30.40	-1.06
	4	10.689	9.45	-1.24	21.380	14.60	-6.78	28.888	26.25	-2.64
	5	6.809	7.70	0.89	18.439	12.25	-6.19	26.471	24.50	-1.97
Kashmir (Kr)	1	10.732	1.75	-8.98	20.986	7.50	-13.49	28.709	19.10	-9.61

Area	Station	(1971-2000) SON	(2096-2100) SON	Change (°C)	(1971-2000) Annual	(2096-2100) Annual	Change (°C)
Punjab (Pb)	1	21.926	10.00	-11.93	21.176	10.30	-10.88
	2	25.190	14.40	-10.79	24.504	14.00	-10.50
	3	24.280	15.50	-8.78	23.575	14.90	-8.68
	4	25.080	19.75	-5.33	25.286	18.50	-6.79
	5	24.209	11.50	-12.71	23.516	11.50	-12.02
	6	25.746	14.50	-11.25	25.293	14.00	-11.29
	7	24.028	13.00	-11.03	23.983	12.80	-11.18
	8	23.210	12.00	-11.21	22.701	12.00	-10.70
Sindh (Sd)	1	26.339	22.00	-4.34	25.719	21.60	-4.12
	2	27.196	22.40	-4.80	26.275	21.80	-4.48
	3	28.193	21.90	-6.29	27.612	21.30	-6.31
	4	22.382	21.55	-0.83	23.730	20.20	-3.53
	5	19.858	21.75	1.89	21.576	20.75	-0.83
	6	27.061	21.40	-5.66	27.022	20.00	-7.02
NWFP (Np)	1	23.519	10.20	-13.32	22.791	10.40	-12.39
	2	24.882	15.50	-9.38	24.191	14.90	-9.29
	3	16.004	4.50	-11.50	15.742	5.50	-10.24
	4	17.593	9.00	-8.59	16.590	9.40	-7.19
	5	18.998	6.50	-12.50	17.385	7.50	-9.88
	6	16.704	10.50	-6.20	15.893	10.40	-5.49
Baluchistan (Bn)	1	15.529	18.25	2.72	16.095	17.25	1.15
	2	20.242	21.75	1.51	19.870	20.60	0.73
	3	22.194	22.10	-0.09	22.186	20.90	-1.29
	4	21.921	18.90	-3.02	20.719	17.75	-2.97
	5	17.712	16.50	-1.21	17.358	15.80	-1.56
Kashmir (Kr)	1	21.323	8.50	-12.82	20.438	9.00	-11.44

7. COMPARISON BETWEEN SIMULATED AND REAL CLIMATE

A comparison of average of real data of 30 years period (1971-2000) with average of model-simulated last 5 years (1996-2000) is made as validation of the model. The results of validation are given:

(a) For Double_CO_2 model run, the model simulated overall 11.38% lower values of temperature than the real ones. Simulated values for Punjab and NWFP are found close to each other and are 24.61and 23.91% lower than observed values, respectively. For Kashmir, the difference between simulated and observed temperature is found 34.68%. Trend of change for entire Kashmir region can not to be determined because of non-availability of record for more stations. The model simulated 17.13% higher than the observed temperature averages for Baluchistan. It is interesting to note that model simulations are very close (1.09% less) to the observed temperature values for Sind.

(b) For Modern_PredictedSST model run, simulation values are 30.34% less overall 43.61% less for Punjab, 48.36% less for NWFP, 56.45% less for Kashmir, 1.40% less for Baluchistan and 14.39% less for Sind in comparison with the observed data.

8. RESULTS

Table 3 shows results of downscaled temperature values obtained for Double_CO_2 run (results based on average of last five years 2096-2100 [1]). Change for these projected values, from available [23] 30 years (1971-2000), has been worked out to examine projected variation in temperature over different areas and stations for the four seasons and finally for annual temperature by the end of year 2100. There is decrease in temperature for Punjab, NWFP and Kashmir and increase for Sind and Baluchistan. Overall decrease in annual temperature by the end of year 2100 over Pakistan is approximately 2^{o}C (Table 5) in the case of Double_CO_2 scenario.

Table 4 shows results of downscaled temperature values obtained for Modern_PredictedSST run (results based on average of last five years 2096-2100). Here too, there is decrease in temperature for Punjab, NWFP, Kashmir, while increase for Sind and Baluchistan. Overall decrease in annual temperature by the end of year 2100 over Pakistan is approximately 7^{o}C (Table 5) in case of Modern_PredictedSST run.

Table 5 summarizes the simulated changes in seasonal and annual temperature by the end of year 2100 for the five areas of study. Highest changes in annual temperature have been predicted for Baluchistan whereas the next highest are for Sind - both being near the ocean (the Arabian Sea). Decrease is encountered for both Punjab and NWFP provinces. The Kashmir region is expected to experience more decrease because of its more relative distance from a massive water body (Sea) and the higher altitude from sea-level. It is interesting to note that MAM season is predicted to undergo maximum decrease in temperature for all areas of Pakistan. MPSST (Modern_PredictedSST) run predicted approximately 3 times (i.e. 300%) more decrease in temperature as compared to Double_CO2 (2CO2) run.

9. CONCLUSIONS

New downscaling approach has been applied in this study which would be much helpful for the future research especially in the field of water resources engineering. Surface Modeling in Eagle point software created Isohyetal maps of desirable close interval (here 0.5^{o}C). Following conclusions may be inferred from the above analysis of downscaled EdGCM data:

(i) Maximum seasonal change in temperature, for all areas of Pakistan except Baluchistan, occurs during the months of MAM (March-April-May).

(ii) Regarding regional changes in annual temperature at the end of 21st century, it is observed that Baluchistan has a change of +3.81^{o}C for 2CO_2 and -0.79^{o}C for MPSST; Sind has a change of +0.24^{o}C for 2CO_2 and -4.38^{o}C for MPSST; NWFP shows a change of -3.92^{o}C for 2CO_2 and -9.08^{o}C for MPSST; Punjab would experience an change of -5.15^{o}C for 2CO_2 and

-10.25°C for MPSST; and Kashmir is predicted to undergo a change of -6.44°C for $2CO_2$ and -11.44°C for MPSST-all in descending order. $2CO_2$ stands for Double_CO_2 and MPSST stands for Modern_PredictedSST runs.

(iii) Station-wise temperature change, at the end of 21st century, ranges from 11.52°C decrease (change from 27.17-15.65°C for station 6 of Punjab during MAM) to 7.10°C increase (change from 5.40-12.50°C for Station 1 of Baluchistan during DJF) for Double_CO_2 run.

(iv) Station-wise temperature change, at the end of 21st century, ranges from 15.37°C decrease (change from 27.17-11.80°C for station 6 of Punjab during MAM) to 3.30°C increase (change from 5.40-8.70°C for Station 1 of Baluchistan during DJF) for Modern_PredictedSST run.

(v) The above predictions conclude that temperature changes, at the end of 21st century, are mostly positive (increase) for areas (Baluchistan and Sindh) located nearer the Arabian Sea (water body) and negative (decrease) for areas (Punjab, NWFP and Kr) located away from the Arabian Sea.

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TABLE 5. TEMPERATURE CHANGE IN °C - COMPARISON OF CHANGES WORKED OUT FOR DOUBLE_CO_2 AND MODERN_PREDICTEDSST RUN FOR THE YEARS UP TO 2100

Area	Season	Change (°C)	
		Double_CO_2	MPSST
Punjab (Pb)	December, January, February	-4.44	-9.03
	March, April, May	-9.57	-13.92
	June, July, August	-4.46	-8.94
	September, October, November	-4.91	-10.38
	Annual	-5.15	-10.25
Sind (Sd)	December, January, February	1.98	-2.68
	March, April, May	-4.55	-8.72
	June, July, August	1.36	-2.27
	September, October, November	0.80	-3.34
	Annual	0.24	-4.38
NWFP (Np)	December, January, February	-3.44	-7.10
	March, April, May	-6.37	-10.83
	June, July, August	-4.11	-8.33
	September, October, November	-4.94	-3.34
	Annual	-3.92	-9.08
Baluchistan (Bn)	December, January, February	5.03	1.07
	March, April, May	-0.09	-4.38
	June, July, August	2.78	-0.85
	September, October, November	4.79	-0.02
	Annual	3.81	-0.79
Kashmir (Kr)	December, January, February	0.42	-8.98
	March, April, May	-8.99	-13.49
	June, July, August	-4.96	-9.61
	September, October, November	-7.57	-12.82
	Annual	-6.44	-11.44
OVERALL:		-1.95	-6.85

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